Australia Group
Common Control List Handbook

Volume II: Biological Weapons-Related Common Control Lists

Revision 6, January 2021

On the cover:

Top left: Complete reusable fermenter system (Figure 2.A)

Top centre left: Potatoes infected with *Synchytrium endobioticum* (Figure PF9.A)

Top centre right: Seeds containing abrin (Figure T1.A)

Top right: Wheat with *Puccinia striiformis* infection (Figure PF5.A)

Middle centre: Hollow fibre cross flow filters (Figure 4.D)

Bottom left: Spray drying system (Figure 6.B)

Bottom centre left: Class III biological safety cabinet (Figure 7.C)

Bottom centre right: Centrifugal separator packed for shipment (Figure 3.E)

Bottom right: Full suits with tethered air supplies (Figure 7.A)

Please note: The *Australia Group Common Control List Handbook* is produced by the United States Government for the purpose of facilitating effective export controls on AG-listed items. Unlike the AG Guidelines and Common Control Lists, the AG Handbook is not an official Australia Group publication of record.

Table of Contents

Volume II: Biological Weapons-Related Common Control Lists

Pathogens and Toxins

Human and Animal Pathogens and Toxins

Plant Pathogens

Dual-Use Biological Equipment and Related Technology and Software

Appendices

This page intentionally left blank.

Foreword

The Australia Group (AG) is an informal arrangement of countries which, through the harmonisation of export control measures, seeks to ensure that exports of materials, equipment, and technology do not contribute to the development of chemical or biological weapons.[1] Founded in 1985 in response to chemical weapons use in the Iran-Iraq War and the lack of uniformity in different countries' export controls, the AG since has grown to encompass 42 participating countries and the European Commission. From an initial focus on chemical weapons precursors, it has expanded its scope to include not only dual-use chemicals, but also biological materials, chemical and biological equipment, and related technology and software.

Since its founding, the AG has played an important role in hindering the spread of chemical and biological weapons. The AG Common Control Lists of dual-use materials, equipment, technology, and software – and guidelines for their responsible transfer – provide a framework for effective chemical and biological trade controls. While the AG has established sound lists of strategic chemical and biological goods, there remains a need for commodity-oriented training materials to enhance the capabilities of enforcement officers to identify dual-use materials and equipment in cargo shipments. Such resources also can assist other trade control officials in evaluating the legitimacy of transfers of these items.

The *Australia Group Common Control List Handbook* aims to serve as such a resource. The Handbook covers commodities found on each Common Control List and is divided into two volumes according to the threat posed by items on a particular list:

- Volume I: Chemical Weapons–Related Common Control Lists
  - Chemical Weapons Precursors
  - Dual-Use Chemical Manufacturing Facilities and Equipment and Related Technology and Software
- Volume II: Biological Weapons-Related Common Control Lists
  - Human and Animal Pathogens and Toxins
  - Plant Pathogens
  - Dual-Use Biological Equipment and Related Technology and Software

Chapters within each section provide an overview of the appearance, key features, uses, and global producers of each item on each control list. Brief introductions to dual-use technology are also included to provide context for the chemicals, pathogens, and equipment discussed, and additional supporting information can be found in the appendices to both volumes. We intend and hope that this Handbook will be a practical resource for personnel engaged in chemical- and biological-related trade controls – from enforcement officials working in the field and license analysts desiring a better understanding of controlled items to those responsible for training such personnel on dual-use commodities.

Please note: The AG Handbook is produced by the United States Government for the purpose of facilitating effective export controls on AG-controlled items. Unlike the AG Guidelines and the AG Common Control Lists, the AG Handbook itself is not an official Australia Group publication of record.

The images, websites, and other references included in this Handbook are intended to give examples of materials and equipment with features similar to those that the AG Common Control Lists describe. It is important to note that presence of certain items or equipment in a photograph, on a website, or in a reference does not necessarily mean that the pictured or referenced item meets AG control specifications. Decisions on the control status of an item are made by considering the technical specifications of a specific product on a case-by-case basis.

January 2021

[1] See the AG website at https://www.dfat.gov.au/publications/minisite/theaustraliagroupnet/site/en/index.html and the Introduction – the Australia Group in both volumes of the Handbook.

This page intentionally left blank.

Introduction – The Australia Group (AG)

The Australia Group: Origins, Objectives, and Activities[1]

The Australia Group (AG) is an informal arrangement that aims to minimise the risk of assisting chemical and biological weapons (CBW) proliferation through the harmonisation of export control measures. The AG meets annually to discuss ways to increase the effectiveness of participating countries' national export licensing systems in an effort to prevent proliferators from obtaining materials, equipment, and technology for CBW programs. AG participants do not undertake any legally binding obligations; the effectiveness of their collaboration depends solely on a shared commitment to CBW nonproliferation goals and the strength of their respective national measures.

When formulating control lists and guidelines for adoption by participants, the AG considers the following key characteristics of effective export licensing measures:

- they should be effective in impeding the production of CBW;
- they should be practical and reasonably easy to implement; and
- they should not impede the normal trade of materials and equipment used for legitimate purposes.

All countries participating in the AG are States Parties to the Chemical Weapons Convention (CWC) and the Biological and Toxin Weapons Convention (BTWC), and they strongly support efforts under those treaties to rid the world of CBW. As of January 2021, the AG includes 42 participating countries plus the European Commission.

AG Participants (as of January 2021)

- Argentina
- Australia
- Austria
- Belgium
- Bulgaria
- Canada
- Croatia
- Republic of Cyprus
- Czech Republic
- Denmark
- Estonia
- European Commission
- Finland
- France
- Germany
- Greece
- Hungary
- Iceland
- Indiat
- Ireland
- Italy
- Japan
- Republic of Korea
- Latvia
- Lithuania
- Luxembourg
- Malta
- Mexico
- The Netherlands
- New Zealand
- Norway
- Poland
- Portugal
- Romania
- Slovak Republic
- Slovenia
- Spain
- Sweden
- Switzerland
- Republic of Turkey
- Ukraine
- United Kingdom
- United States

AG Adherents (as of January 2021)

- Kazakhstan

The AG encourages all countries to adhere to the AG Guidelines and Common Control Lists. In order to increase synergies with nonparticipants using Australia Group control lists and Guidelines, the AG decided in 2014 to offer a broader range of information to non-participating countries that adhere to the AG by making a unilateral political commitment to control the export of all items on the AG Common Control Lists in accordance with the AG Guidelines, including future changes. The Adherent status formally acknowledges the growing role of the AG control lists and Guidelines as the benchmark for international best practice chemical and biological export controls and helps reduce loopholes.[2] Kazakhstan became an AG Adherent in 2015.

[1] The text of this section is taken largely from the AG website: https://www.dfat.gov.au/publications/minisite/theaustraliagroupnet/site/en/index.html.

[2] AG, Statement by the Chair of the 2014 Australia Group Plenary, https://www.dfat.gov.au/publications/minisite/theaustraliagroupnet/site/en/media_june2014.html.

This section provides an overview of the AG's history, its objectives, and the activities it undertakes to strengthen nonproliferation export controls on CBW-related goods and technologies.

Origins of the Australia Group

As noted on the AG website,[3] a United Nations investigation team found in 1984 that Iraq had used chemical weapons (CW) in the Iran-Iraq war in violation of the 1925 Geneva Protocol, and that at least some of the precursor chemicals and materials for its CW program had been sourced through legitimate trade channels. In response, several countries introduced export controls on certain chemicals that could be used to manufacture CW.

However, these controls suffered from a lack of uniformity, and it soon became apparent that attempts were being made to circumvent them. This led Australia to propose a meeting of countries with export controls with the aim of harmonising their national licensing measures and enhancing cooperation. The first meeting of what subsequently became known as the AG took place in Brussels in June 1985. At that meeting, 15 participating countries and the European Commission agreed that there was value in exploring how existing export controls might be made more effective to prevent the spread of CW.[4]

The AG has met regularly since then, with plenary meetings currently held annually in Paris and intersessional meetings held on an as-needed basis. The scope of the controls discussed by the AG has evolved to address emerging threats and challenges. Evidence of the diversion of dual-use materials to biological weapons (BW) programs in the early 1990s led to development of control lists on specific pathogens and toxins. Over time, the control lists have expanded to include certain equipment, technology, and software that can be used in the manufacturing or disposal of CBW.

Australia Group Objectives

The primary objective of AG participants is to use licensing measures to ensure that transfers of certain chemicals, pathogens, toxins, dual-use chemical and biological facilities and equipment, and related technologies do not contribute to the proliferation of CBW. The AG achieves this by harmonising participating countries' national export licensing measures. The AG's activities are especially important because chemical and biotechnology sectors worldwide are targeted by proliferators as sources of materials, equipment, and technology that can be used to support CBW programs.

Participants have recognised from the beginning of the AG that export licensing measures are not a substitute for the strict and universal observance of the Geneva Protocol, the BTWC, and the CWC. All participants in the AG are States Parties to both the BTWC and the CWC. Support for these treaties and their objectives remains the overriding aim of AG participants. Export licensing measures instituted by individual member countries assist in implementing key obligations under the CWC (Article I, 1 [a] and [d]) and the BTWC (Articles I and III).

Export licensing measures also demonstrate participants' resolve to avoid not only direct but also inadvertent involvement in the proliferation of CBW, and to express their opposition to the use of these weapons. It is also in the interests of commercial firms and research institutes and of their governments to ensure that they do not inadvertently supply dual-use materials, equipment, technology, or software for use in the manufacture of CBW. Chemical and biological industries worldwide have firmly supported this principle.

Australia Group Activities

As previously mentioned, the AG is an informal arrangement. The purpose of AG meetings is to explore ways to increase the effectiveness of existing controls through exchange of information, harmonisation of national control measures, and, where necessary, changes to the scope of controls. All AG decisions are made by consensus.

[3] AG, The Origins of the Australia Group, https://www.dfat.gov.au/publications/minisite/theaustraliagroupnet/site/en/origins.html.

[4] AG, The Origins of the Australia Group; Ibid.

All AG participants agree to require licenses for the export of specific:

- Chemical weapons precursors;
- Dual-use chemical manufacturing facilities and equipment and related technology and software;
- Human and animal pathogens and toxins;
- Plant pathogens; and
- Dual-use biological equipment and related technology and software.

The above items form the basis for the AG's "Common Control Lists," which have been developed through AG consultations and are adjusted periodically to ensure their continued effectiveness in the face of technological advancements. Measures agreed upon by AG participants are applied on a national basis. Under these measures, exports are denied only if there is a well-founded concern about potential diversion for CBW purposes.

AG participants encourage all countries to take the necessary steps to ensure that they and their industries are not contributing to the proliferation of CBW. Controls will be more effective if similar measures are introduced by all potential exporters of listed items, as well as by potential transshipment countries. Export licensing measures demonstrate the determination of AG countries to avoid involvement in the proliferation of these weapons, which would be a violation of international law and norms. In addition to being consistent with the nonproliferation provisions of the CWC and BTWC, such measures are required of all states to ensure compliance with UN Security Council Resolution 1540 and its extensions.

The Australia Group Common Control List Handbook

This Handbook is designed to assist officials in implementing controls on AG Common Control List (CCL) items. It provides basic descriptions of and information on the notable features, packaging, and typical applications of AG-listed CW precursors, pathogens, toxins, and dual-use chemical manufacturing and biological processing equipment. In addition, it discusses CCL entries on related technology and software. The Handbook is based on the AG CCLs as of October 2020. The most current version of the AG CCLs can be accessed via the AG website at https://www.dfat.gov.au/publications/minisite/theaustraliagroupnet/site/en/index.html.

The AG Handbook is produced by the United States Government for the purpose of facilitating effective export controls on AG-controlled items. Unlike the AG Guidelines and the AG CCLs, the AG Handbook itself is not an official AG publication of record.

The Handbook is organised like the AG CCLs, with additional sections providing background information pertinent to understanding the controls. Each section on materials and equipment follows the same format: the AG control language is reproduced in a highlighted text box, followed by a basic description of the item, its notable features, packaging, and typical applications, as well as illustrative images. The images, websites, and other references included in this Handbook are intended to give examples of materials and equipment with features similar to those that the AG CCLs describe. It is important to note that the presence of certain items or equipment in a photograph, on a website, or in a reference does not necessarily mean that the pictured or referenced item meets AG control specifications. Decisions on the control status of an item are made by considering the technical specifications of a specific product on a case-by-case basis.

Any AG control "Notes" relevant to a particular item have been included with the actual control text. Each listed item is discussed separately. Where applicable, side boxes identifying the headquarters locations of companies that can produce particular items accompany the text. These lists of countries that might produce specific items are representative and not necessarily exhaustive, since subsidiaries or trading companies in other countries may be capable of supplying such items.

This page intentionally left blank.

Australia Group Guidelines

Guidelines for Transfers of Sensitive Chemical or Biological Items[5]

June 2015

The Government of xxx has, after careful consideration and consistent with its obligations under the BTWC and the CWC, decided that, when considering the transfer of equipment, materials, technology and software that could contribute to chemical and biological weapons activities, it will act in accordance with the following Guidelines.

1. The purpose of these Guidelines is to limit the risks of proliferation and terrorism involving chemical and biological weapons (CBW) by controlling tangible and intangible transfers that could contribute to CBW activities by states or non-state actors, consistent with Article III of the Biological Weapons Convention, Article I of the Chemical Weapons Convention, and all relevant United Nations Security Council Resolutions. In accordance with Article X of the Biological Weapons Convention and Article XI of the Chemical Weapons Convention, these Guidelines are not intended to impede chemical or biological trade or international cooperation that could not contribute to CBW activities or terrorism. These Guidelines, including the attached Australia Group (AG) control lists and subsequent amendments thereto, form the basis for controlling transfers to any destination beyond the Government's national jurisdiction or control of materials, equipment, technology and software that could contribute to CBW activities. The Government will implement these Guidelines in accordance with its national legislation.

2. These Guidelines will be applied to each transfer of any item in the AG control lists. However, it is a matter for the Government's discretion to determine whether and to what extent to apply expedited licensing measures in the case of transfers to destinations it judges possess consistently excellent non-proliferation credentials. Vigilance will be exercised in the consideration of all transfers of items on the AG control lists. Transfers will be denied if the Government judges, on the basis of all available, persuasive information, evaluated according to factors including those in paragraph 4, that the controlled items are intended to be used in a chemical weapons or biological weapons program, or for CBW terrorism, or that a significant risk of diversion exists. It is understood that the decision to transfer remains the sole and sovereign judgment of the Government.

3. In fulfilling the purposes of these Guidelines, national export control legislation, including enforcement and sanctions for violations, plays an important role.

4. To fulfil the purposes of these Guidelines, the evaluation of export applications will take into account the following non-exhaustive list of factors:

    a. Information about proliferation and terrorism involving CBW, including any proliferation or terrorism-related activity, or about involvement in clandestine or illegal procurement activities, of the parties to the transaction;

    b. The capabilities and objectives of the chemical and biological activities of the recipient state;

    c. The significance of the transfer in terms of (1) the appropriateness of the stated end-use, including any relevant assurances submitted by the recipient state or end-user, and (2) the potential development of CBW;

    d. The role of distributors, brokers or other intermediaries in the transfer, including, where appropriate, their ability to provide an authenticated end-user certificate specifying both the importer and ultimate end-user of the item to be transferred, as well as the credibility of assurances that the item will reach the stated end-user;

[5] Text of the Guidelines is reproduced from https://www.dfat.gov.au/publications/minisite/theaustraliagroupnet/site/en/guidelines.html.

e. The assessment of the end-use of the transfer, including whether a transfer has been previously denied to the end-user, whether the end-user has diverted for unauthorised purposes any transfer previously authorised, and, to the extent possible, whether the end-user is capable of securely handling and storing the item transferred;

f. The extent and effectiveness of the export control system in the recipient state as well as any intermediary states;

g. The applicability of relevant multilateral agreements, including the BTWC and CWC.

h. The risk of controlled items falling into the hands of terrorist groups and individuals.

5. In a manner consistent with its national legislation and practices, the Government should, before authorising a transfer of an AG-controlled item, either (a) satisfy itself that goods are not intended for re-export; (b) satisfy itself that, if re-exported, the goods would be controlled by the recipient government pursuant to these guidelines; or (c) obtain satisfactory assurances that its consent will be secured prior to any retransfer to a third country.

6. The objective of these Guidelines should not be defeated by the transfer of any non-controlled item containing one or more controlled components where the controlled component(s) are the principal element of the item and can feasibly be removed or used for other purposes. (In judging whether the controlled component(s) are to be considered the principal element, the Government will weigh the factors of quantity, value, and technological know-how involved and other special circumstances that might establish the controlled component or components as the principal element of the item being procured.) The objective of these Guidelines also should not be defeated by the transfer of a whole plant, on any scale, that has been designed to produce any CBW agent or AG-controlled precursor chemical.

7. The Government will ensure that its regulations require the following:

   a. an authorisation for the transfer of non-listed items where the exporter is informed by the competent authorities of the Government in which it is established that the items in question may be intended, in their entirety or part, for use in connection with chemical or biological weapons activities;

   b. that if the exporter is aware that non-listed items are intended to contribute to such activities it must notify the authorities referred to above, which will decide whether or not it is expedient to make the export concerned subject to authorisation.

8. The Government reserves the discretion to: (a) apply additional conditions for transfer that it may consider necessary; (b) apply these guidelines to items not on the AG control lists; and (c) apply measure to restrict exports for other reasons of public policy consistent with its treaty obligations.

9. In furtherance of the effective operation of the Guidelines, the Government will, as necessary and appropriate, exchange relevant information with other governments applying the same Guidelines.

10. The Government encourages the adherence of all states to these Guidelines in the interest of international peace and security.

(Latest versions of Control Lists to be attached)[6]

[6] This parenthetical remark is reproduced from the Guidelines on the AG website. The complete Common Control Lists can be found at https://www.dfat.gov.au/publications/minisite/theaustraliagroupnet/site/en/controllists.html.

Further Provisions Applicable to Australia Group Participants

In addition, participants in the Australia Group, consistent with their obligations under the BTWC and CWC and in accordance with their national legislation have, after careful consideration, decided also to give equal respect to the following provisions.

Catch-All

Participant states are encouraged to share information on these measures on a regular basis, and to exchange information on catch-all denials relevant for the purpose of the AG.

No Undercut Policy

In accordance with the Group's agreed procedures, a license for an export that is essentially identical to one denied by another AG participant will only be granted after consultations with that participant, provided it has not expired or been rescinded. Essentially identical is defined as being the same biological agent or chemical or, in the case of dual-use equipment, equipment which has the same or similar specifications and performance being sold to the same consignee. The terms of the Group's 'no undercut policy' do not apply to denials of items under national catch-all provisions.

Common Approaches

AG participants implement these Guidelines in accordance with the Group's agreed common approaches on end-user undertakings and chemical mixtures.

Intra EU Trade

So far as trade within the European Union is concerned, each member State of the European Union will implement the Guidelines in the light of its commitments as a member of the Union.

Brokering Services

AG members should have in place or establish measures against illicit activities that allow them to act upon brokering services related to items mentioned in the AG control lists which could contribute to CBW activities. AG members will make every effort to implement those measures in accordance with their domestic legal framework and practices.

This page intentionally left blank.

Introduction to Biological Weapons and Dual-Use Biotechnology

The processes and equipment involved in the development of biological weapons (BW) are inherently dual-use. Methods for manipulating, growing, recovering, concentrating, stabilising, and testing biological materials of weapons concern employ many of the same materials and equipment used to produce vaccines, pharmaceuticals, and a wide variety of food products. This introductory section discusses dual-use processes involved in the production of BW to provide context for the controlled commodities discussed later in this Handbook.

Figure 1 gives a schematic representation of the overall process of developing BW. BW production begins by obtaining and growing an inoculum of a specific agent and ends with delivery of the isolated (and possibly processed) biological material to a target population. It is important to note that although Figure 1 shows a linear and even process, research and development activities needed for various steps may influence the time and resources devoted to each. For example: inoculum selection may involve experiments to genetically modify a microorganism, and production may involve research on optimal growth conditions. In addition, stabilisation may involve experiments to find suitable excipients, and animal testing may occur at any stage of the process. These research and development activities may be carried out on a smaller scale compared to BW production, but they will all require safety measures to protect workers from dangerous pathogens and toxins. The vast majority of controlled commodities used in this process, including most pathogenic agents used as inocula, are also used in legitimate research and commercial activities, and are inherently dual-use.

Subsequent sections in this Handbook will discuss the materials and equipment associated with each step of this process in more detail, particularly with regard to the specific technical characteristics that qualify the materials and equipment for export control.

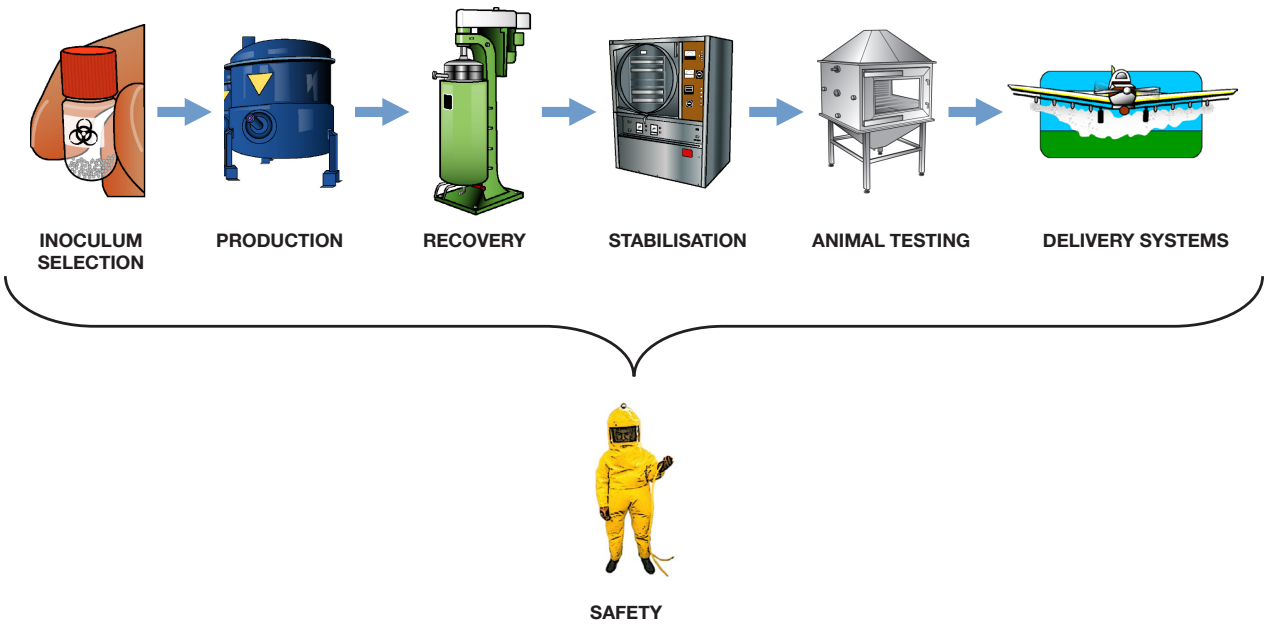

Figure 1. *Schematic of the BW development process.*

The Inoculum

Microorganisms are ubiquitous in our environment and reside in human, insect, and other animal bodies, as well as in soil, water, and plant matter. Most microorganisms are not harmful or pathogenic to healthy living beings. Humans coexist with them and are, in many cases, dependent upon them. For example, the production of pharmaceuticals (e.g., antibiotics and vaccines), as well as food and beverages (e.g., yogurt, cheese, beer, and wine) uses naturally occurring microorganisms. Although most microorganisms in the environment are not harmful, some are extremely dangerous, causing lethal or severely debilitating diseases in humans, animals, or plants. Some of these diseases can be treated, but for others there are no preventative or treatment measures available. Many disease-causing microorganisms can pose a BW threat.

In the context of this Handbook, the term "agent" describes a living microorganism that is pathogenic to humans, plants, or animals. Some biological agents cause harm to animals or humans by producing chemical toxins, which are poisonous in very small quantities. Toxins themselves can pose a BW threat and they present several dual-use considerations. For example, legitimate neuroscience and pharmacology research uses small amounts of many deadly toxins obtained from venomous spiders, snakes, and snails to study the electrical activity of the nervous system. In addition, some toxins that are harmful to humans in large quantities can be medically helpful substances in minute amounts. Botulinum toxin, one of the most deadly toxins on earth, is now approved for use in medical treatments that correct skin wrinkles and muscle contraction disorders.

The key ingredient for production of BW is biological material referred to as the inoculum. The inoculum is a relatively small sample of a specific agent that is used to produce a larger quantity of that agent or the toxin produced by it. That inoculum may be in a naturally occurring form or genetically modified, with components of the latter obtained from an organism or chemically synthesized by a nucleic acid assembler or synthesizer. The process begins by placing the inoculum into a small quantity of nutritional media and allowing the microorganism to grow to a predetermined concentration. Those microorganisms are then used to inoculate a larger quantity of media in the production phase.

Agents and toxins can be obtained from a variety of sources and are dual-use materials. These materials appear on two lists promulgated by the Australia Group, according to whether they cause disease in humans and animals, or in plants. The List of Human and Animal Pathogens and Toxins for Export Control and List of Plant Pathogens for Export Control encompass a substantial number of agents and toxins and are described in detail in subsequent sections.

Production

Both small-scale and industrial-scale processes and equipment can be used to grow biological agents. Each agent has specific nutritional requirements and environmental conditions that are optimal for its growth. The production of any agent therefore involves the growth of the microorganism in defined media under carefully controlled conditions. Bacteria and fungi are typically grown in fermenters or bioreactors where the environmental conditions can be precisely controlled to optimise their growth. Viruses can be produced in cell culture bioreactors that provide conditions optimal for the culture of the host cells necessary for viral reproduction. Viruses can also be produced in large quantities using certified "pathogen-free" embryonated eggs, each of which must be inoculated with virus. Fermenters and bioreactors, sometimes called chemostats or cell culture devices, often feature computer controls and can have multiple growth vessels connected to one central control unit. They may also possess a continuous-flow capability to enhance their efficiency.

The production of microorganisms in bioreactors and fermenters is essential for the pharmaceutical industry's manufacture of vaccines, antibiotics, and other products. The food industry also employs fermenters in the production of food and beverages such as yogurt, beer, and wine. These devices therefore are highly dual-use. Fermenters that have a total internal volume of 20 litres or greater and can be operated without the propagation of aerosols are subject to control according to the AG recommendations. The AG includes smaller fermenters in awareness-raising guidelines for industry, especially when they are ordered in aggregate or designed to be connected for use as a combined system.

Product Recovery

After growing agents to substantial quantities, the agent or the toxin it produces must be separated from the growth media and concentrated for further processing. This product recovery phase can use equipment such as centrifugal separators (which differentiate materials by density) or specialised filters (which discriminate particles by size).

Centrifugal Separators

A centrifugal separator (also known as a centrifuge) is a machine that uses the centrifugal force produced by high-speed rotation to separate materials of different densities. To separate biological materials, the liquid culture from the production step is moved from the fermenter or cell culture vessel into the centrifugal separator. The liquid culture enters the centrifuge bowl where it experiences high-speed rotation and centrifugal force that separates components by density. If the centrifuge is a continuous-flow device, the retained material (e.g., the agent or the toxin) and the discarded material (e.g., spent media or unneeded cells) are segregated into different streams. Each exits the centrifuge through a different outlet port. The retained material is pooled and may be further purified by filtration.

These devices can be used in BW programs, but they also have legitimate commercial, industrial, and pharmaceutical applications. Centrifugal separators have similar uses in the pharmaceutical industry, where microorganisms must be grown and harvested to produce vaccines. A wide variety of other industry sectors, such as the dairy industry and water purification, also use them. Centrifugal separators capable of continuous separation of pathogenic microorganisms without the propagation of aerosols which have one or more sealing joints within the steam containment area; possess a flow rate greater than 100 litres per hour; have components of polished stainless steel or titanium; and are capable of *in situ* steam sterilisation in a closed state meet the specifications of the AG biological equipment control list. Conceptually similar devices known as decanters are also subject to the centrifugal separator control list entry.

Filtration Equipment

Filtration is a separation technique that uses a porous membrane to separate particles in a certain size range from particles outside that range. In the traditional ("dead-end") process of filtration, liquid flows perpendicular to the surface of the filter membrane. The membrane traps large particles, while particles small enough to fit through the pores pass through it. Large-scale production of biological products employs a special type of filtration – called cross-flow or tangential flow filtration – to purify the material of interest. In this method, the liquid flows parallel (i.e., tangentially) to the surface of the membrane. At high flow rates, this minimises fouling and clogging of the filter surface and results in significant product yield. This type of filtration provides unique purification capabilities and it is particularly effective at reducing the content of small, dissolved impurities or particles less than 0.2 micrometres in size.

Cross-flow filtration equipment is dual-use, since it has legitimate applications in the pharmaceutical industry as well as in food and beverage production. Cross (tangential) flow filtration equipment capable of separation of microorganisms, viruses, toxins, or cell cultures, which possess a total filtration area equal to or greater than 1 square metre and are either capable of being sterilised or disinfected *in situ* or use disposable or single-use filtration components meets the criteria of the AG biological equipment control list. In addition, the AG identifies individual filtration components with at least 0.2 square metre filtration area for control if suitable for use in AG-controlled equipment. The AG specifically excludes reverse osmosis equipment and haemodialysis equipment from control.

Stabilisation

When exposed to environmental stresses and prolonged storage, biological agents and toxins can gradually degrade and lose their potency. Several methods are available to stabilise agents against environmental degradation during storage or dissemination. These include freeze-drying, spray-drying, deep freezing, or other types of processing. The AG includes freeze-drying and spray-drying equipment in its biological equipment control list.

Freeze Dryers

Freeze-drying, or "lyophilisation," converts materials into a dry powder form. To accomplish this, the material is first suspended in a liquid (such as water). The liquid material is placed into the lyophilisation chamber, where a refrigeration system lowers the temperature so that the material freezes. Then a vacuum is applied, changing the ice directly into water vapour through a process called sublimation. The vacuum removes the water vapour from the chamber as it forms. When removal of the ice is complete, all that remains is a dry powder of the material. This powder can be rehydrated easily at a later time to reactivate microorganisms or reconstitute a toxin.

Lyophilisers are dual-use items and are routinely used in the food industry to create freeze-dried food products. They also are used to preserve pharmaceuticals, flowers, and animals (i.e., taxidermy). Lyophilisers are available in a variety of sizes – from small benchtop models to large commercial machines. Only steam, gas, or vapour sterilisable freeze-drying equipment with a condenser capacity of between 10 and 1,000 kilograms of ice in 24 hours meets AG control specifications.

Spray Dryers

Spray-drying also converts liquid solutions into dry powders. However, spray-drying has several key differences from freeze-drying. First, the liquid feedstock is atomised and then immediately contacted with a drying gas of higher temperature. Evaporative cooling removes the liquid and the resulting powder is collected. Unlike freeze-drying, which must operate as a batch process, spray-drying can produce powders continuously.

Spray-drying technology is over 100 years old, but recent improvements in its technology have made this equipment decidedly dual-use. These advances include the ability to generate respirable particles without damaging the structure and viability of biological materials. The fastest growing area of application is in the pharmaceutical industry. Spray-drying equipment that has a water evaporation capacity of between 0.4 and 400 kilograms per hour (inclusive); that has the ability to generate product particle sizes of 10 microns or less; and that can be sterilised or disinfected *in situ* meets AG control specifications.

Animal Testing

Following production, purification, and processing of a biological agent or toxin, aerosol testing may be used to assess its effectiveness as a weapon. Microorganisms and toxins in the form of dry powders or wet mists can be tested by exposing animals to the aerosolised material. Aerosol tests can occur in large open-air testing grounds or in the laboratory under strict conditions of biological safety. In both situations, animals are typically used to assess the infectivity, pathogenicity, or toxicity of the agent. These tests can be carried out early in the discovery phase of research and development or in the efficacy and viability testing of biological product lots during later phases. In the laboratory, aerosol inhalation equipment can be used to deliver biological agents to research animals under controlled conditions. This equipment permits entire animal ("whole-body") or inhalation only ("nose-only") exposure to the agent.

Aerosol inhalation equipment is also a dual-use commodity. The pharmaceutical industry uses it to test the effectiveness of vaccines and pharmaceuticals on experimental animals, as well as in toxicology studies. Whole-body exposure chambers designed for aerosol challenge testing with pathogenic microorganisms, viruses, or toxins with a capacity of 1 cubic metre or greater are subject to control according to AG recommendations. Further, nose-only exposure apparati designed for aerosol challenge testing with pathogenic microorganisms, viruses, or toxins; utilizing directed aerosol flow; and having an exposure capacity of 12 or more rodents in closed animal restraint tubes are listed for control by the AG.

Delivery Systems

Dissemination of BW agents or toxins could occur in multiple ways using commonly available equipment. For example, agricultural sprayers used to spread pesticides on crops in the form of a dense mist of very small droplets could be used to spread biological agents. In particular, pesticide sprayers mounted on airplanes, helicopters, or unmanned aerial vehicles (UAVs) could disperse biological agents over a large area. A 10-micron-diameter droplet is considered an ideal size for intake into human lungs. However, spraying equipment that can generate larger droplets is of dual-use concern because evaporation during settling may reduce droplets to respirable sizes.

Spraying or fogging equipment listed by the AG for control encompasses systems used with aircraft that can generate droplets less than 50 microns in diameter at a flow rate greater than two litres per minute. The control entry includes spray booms or arrays of aerosol generating units that both fulfill the above criteria and are designed or modified to fit to aircraft, lighter than air vehicles, or UAVs. The control entry also includes individual aerosol generating units designed for fitting to larger systems that fulfill the above criteria.

Safety Considerations

Protection from dangerous pathogens and toxins is of paramount importance to individuals researching, transporting, producing, storing, or disseminating these materials. Human pathogens usable as BW agents are, by their very nature, exceptionally hazardous to human health. Some biological agents of concern have no vaccine or treatment. While other agents have available vaccines and treatments, these medical interventions generally are not 100% reliable for disease prevention and treatment. Consequently, anyone working with a biological agent typically adheres to the prudent practices and principles of biological safety appropriate for each agent. When combined with appropriate containment facilities and personal protective equipment, biological safety procedures can protect workers from the dangerous materials they manipulate. Such procedures and facilities can also protect the environment from agents hazardous to animals or plants.

Although an abundance of biological safety equipment is available, the items included on the AG biological equipment control list are those conferring the highest levels of protection: protective full suits, half suits, or hoods dependent upon a tethered external air supply and operating under positive pressure; Class III biological safety cabinets or isolation chambers with similar performance standards; complete Biosafety Level 3 and Biosafety Level 4 containment facilities; and related equipment for these facilities, including: double door pass through autoclaves, breathing air suit decontamination showers, and mechanical seal and inflatable seal doors. In addition, the AG includes fan-HEPA filter units, which filter pathogens from the air in containment and other facilities such as hospitals, in its awareness-raising guidelines for industry. Awareness-raising guidelines also include certain clean-air rooms that may be used for controlled containment facilities.

Summary

The production of BW bears numerous similarities to industrial biological processing. Therefore, biological equipment manufactured and sold for use in legitimate applications can pose BW proliferation concerns, and effective trade controls on such items is important. The following sections discuss AG-listed dual-use human and animal pathogens and toxins, plant pathogens, and biological equipment to familiarise trade control officials with these dual-use items, facilitate their identification in the field, and aid assessments of the proliferation risk associated with their trade.

This page intentionally left blank.

Introduction to Pathogens and Toxins

The AG organises pathogens into two distinct control lists by the types of species in which they manifest disease: humans and/or animals (Human and Animal Pathogens and Toxins) and plants (Plant Pathogens). AG-listed pathogens include viruses, bacteria, and fungi. Each pathogen has a different profile with respect to how it causes infection, how it can be transmitted, and the extent of the damage it inflicts on the infected organisms (e.g., the mortality rate of the disease it causes). These different characteristics can make a particular pathogen or the toxin it produces a potential proliferation concern. The paragraphs below describe these characteristics and common terminology associated with them, as well as details on the containment and handling of dangerous pathogens. These descriptions are followed by information on the biological pathogen types found in the Common Control Lists: viruses, bacteria, fungi, and toxins, as background for the individual pathogen and toxin descriptions in the Human and Animal Pathogens and Toxins and Plant Pathogens sections. Detailed information on pathogen taxonomy and similarities between pathogens on the Common Control Lists are located in Appendix E. A discussion of typical packaging of and transportation for pathogens and toxins is provided at the end of this section.

Characteristics of Infectious Diseases

Means of Infection and Exposure

Every infectious substance has a reservoir. A reservoir is the habitat in which an infectious agent normally lives, grows, and multiplies (e.g., humans, animals, or the environment). In addition to having a reservoir, pathogens that manifest (i.e., cause) disease in other species have a susceptible host. A host is a person or other living organism that is susceptible to or harbours an infectious agent under natural conditions. For example, all pathogens on the Plant Pathogens Control List have varying plant species for hosts as these microorganisms are capable of manifesting disease in plants. In certain cases, the reservoir and the host for a pathogen will be the same species, although this is not always the case. *However, for the purposes of this Handbook, individual commodity entries provide a combined list of hosts and reservoirs indicating the organism(s) in which each pathogen is most likely to be found and/or manifest disease.*

There are several means of infection that a human or animal pathogen can use to infect its host. In simplest terms, routes of transmission can be either direct or indirect. Direct transmission describes the spread of pathogens from one host to another without the presence of an intermediary. Types of direct transmission include physical contact, ingestion, or droplet spread. Indirect transmission describes pathogens that require an intermediary to spread from one host to another. Possible routes of indirect transmission include airborne exposure, vehicle-borne transmission, and vector-borne transmission.

In addition to defining pathogen transmission as either direct or indirect, there are other ways to categorise pathways that a pathogen uses to enter the host. *For the purposes of this Handbook, exposure routes for human and animal pathogens are listed under four possible entry pathways: cutaneous, inhalation, gastrointestinal, and injection.* Cutaneous exposure encompasses entry through the skin, cornea, or mucous membranes. Inhalation exposure includes aerosol, respiratory, or airborne transmission. Gastrointestional exposure describes ingestion because absorption into the body occurs in the gastrointestinal system. Injection describes exposures when an insect bites a host or when a pathogen or toxin has been shown to be capable of transmission directly into the bloodstream or other tissues. For example, injection is a common exposure route for toxins produced by biting or stinging animals such as cone snails, which inject conotoxin into the nervous system of the host. Transmission by injection also includes plant pathogens that can infect their host through the bite of an insect vector.

Not all routes of transmission are possible for every pathogen. *Natural* transmission routes are noted in the individual pathogen sections in this Handbook.

Certain pathogens can be transmitted from human to human without the second individual coming in contact with the initial reservoir. These pathogens are considered contagious and have the ability to spread when individuals come in close contact with each other. Pathogens that are transmitted between humans without the presence of a reservoir can pass via physical contact, droplet spread, or airborne (respiratory)

exposure. Pathogens that do not require a living intermediary to pass from one individual to another are said to be human-to-human transmissible. *For the purposes of this Handbook, human transmissibility is categorised as either direct or respiratory*.[7]

Several pathogens on the list of Human and Animal Pathogens and Toxins are zoonotic. A pathogen is zoonotic if it is naturally transmissible from vertebrate animals to humans and vice-versa.[8] Due to variability and high mutation rate within genomes of certain pathogens, many that may have been historically limited to one host have evolved to be capable of manifesting disease in multiple hosts; certain strains of *Avian influenza virus* are examples of this.

Morbidity Rate

The patterns associated with disease outbreak are unique to each particular pathogen. The morbidity rate describes the average percentage of diseased individuals given the total number of individuals exposed. When a given population is exposed to a pathogen, the morbidity rate describes the percentage of individuals that actually get sick. If a pathogen has a morbidity rate of 50%, then 1 in every 2 individuals that are exposed to a pathogen present with symptoms. Pathogens can have a high morbidity rate without causing a large number of deaths.

Mortality Rate

The mortality rate describes the average percentage of deaths given the total number of individuals infected. If a pathogen has a mortality rate of 20%, then 1 person in every 5 individuals infected are likely to die as a result of the infection.

Containment and Handling

The World Health Organization's (WHO's) *Laboratory Biosafety Manual* provides criteria for working at various levels of containment, depending on the risk posed by a particular pathogen.[9] The WHO classifies infectious agents into four Risk Groups and specifies the respective facilities appropriate for safely working with them. Assignment of a specific pathogen to a Risk Group depends on a variety of factors, and this Risk Group combined with other considerations (e.g., the need to work with aerosolised pathogens) will lead to a determination of the necessary Biosafety Level and appropriate facility requirements. In other words, the Biosafety Level required will depend on a full risk assessment on the work to be done. For example, the United States' Centers for Disease Control and Prevention (CDC) recommends Biosafety Level 2 containment and facilities for working with the *Bacillus anthracis* if the work involves using clinical materials and diagnostic quantities of infectious cultures. In contrast, the CDC recommends operating at Biosafety Level 3 if the work involves production quantities or concentrations of cultures, or a high potential for the production of aerosols.[10]

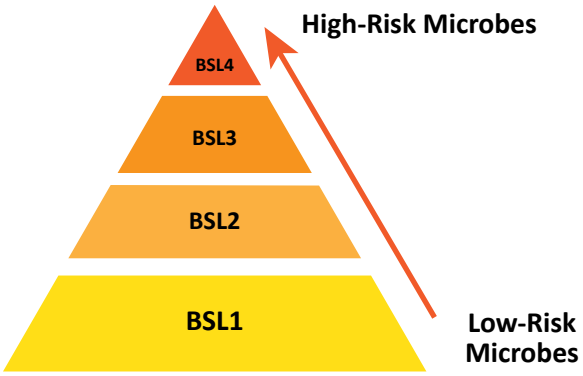

Figure 1. *Pictorial representation of the number of microorganisms handled at varying biosafety levels*[5]

[7] It can be difficult to differentiate when a pathogen spreads via respiratory transmission or droplet spread. Therefore, for the purposes of this Handbook, individual commodity entries annotate a pathogen as transmissible via respiratory transmission regardless of whether the pathogen spread occurs via droplet spread or true airborne transmission.

[8] World Health Organization; More information on Zoonosis, http://www.who.int/zoonoses/en/.

[9] *Laboratory Biosafety Manual*, 3rd Edition, World Health Organization, https://www.who.int/csr/resources/publications/biosafety/WHO_CDS_CSR_LYO_2004_11/en/.

[10] BMBL5 Section VIII-A: Bacterial Agents, http://www.cdc.gov/biosafety/publications/bmbl5/index.htm.

[11] Recognising the Biosafety Levels, http://www.cdc.gov/training/QuickLearns/biosafety/.

Biosafety levels range from Biosafety Level 1 (L1, P1, BL1, CL1, BSL1) to Biosafety Level 4 (L4, P4, BL4, CL4, BSL4), with the level of containment and protective measures increasing from Level 1 to Level 4. Biosafety Level designations for individual pathogens are not assigned by any international governing body. Therefore, each country is responsible for determining the appropriate biosafety level when conducting research on a pathogen.

Laboratory safety practices and standards differ for human, animal, and plant pathogens to account for the varying threats posed to the researcher by each pathogen. For example, Risk Group 3 and Risk Group 4 infectious plant pathogens will not require full or half suits dependent on a tethered external air supply as required for work with Risk Group 3 and Risk Group 4 human pathogens because plant pathogens are not capable of manifesting disease in humans. However, the same Risk Group 3 and Risk Group 4 plant pathogens will require containment facilities with most of the features of a standard P3 or P4 containment facility to ensure plant pathogens and relevant insect vectors are not released to the environment. As another example, animal research facilities have most of the same baseline facility biosafety requirements as human pathogen research facilities; however, certain construction requirements differ based on threats posed to the researcher. Restraining devices and necropsy rooms are required in agricultural containment facilities to accommodate research with large animals. Therefore, due to the unique characteristics of plant and non-zoonotic animal pathogens, national authorities regulate the containment of these pathogens by modifying containment and handling practices for human pathogens. The modified containment levels are denoted as Plant Biosafety Levels (e.g., BSL1-P through BSL4-P) and Agricultural Biosafety Levels (e.g., BSL1-Ag through BSL4-Ag). Biosafety Levels included in the AG Common Control List Handbook for human pathogens represent the biosafety level used for containment and handling by most AG member counties. However, biosafety levels may vary among member states due to the lack of international standards. Further information, including physical descriptions of containment facilities for human pathogens and protective and containment equipment may be found in the AG control list entries on Containment Facilities and Related Equipment and Protective and Containment Equipment, respectively.

Viruses

A virus is an infectious pathogen composed of genetic material packaged within a protein coat. The AG includes a total of 60 different viruses on its control lists: 58 under Human and Animal Pathogens and Toxins and two under Plant Pathogens. In addition, there is one virus in the Plant Pathogens Awareness Raising Guidelines. Viruses are unique in that they need to infect a host cell to replicate and produce new viral particles.

Virus genetic material (the viral genome) can be comprised of either RNA or DNA. Most of the viruses in the AG Human and Animal Pathogens and Toxins List are RNA viruses. Viruses with a RNA genome are subject to much higher rates of mutation than DNA viruses, increasing the likelihood that new strains and/or new hosts will emerge – because of this, RNA viruses are more prone to becoming zoonotic.

Viruses on the AG Human and Animal Pathogens and Toxins Control List can be grouped in general terms as causing four distinct types of disease symptoms: viral hemorrhagic fever (VHF), encephalitis, pulmonary syndrome, and arthralgia.

VHF describes the disease progression of a broad range of viruses on the AG Human and Animal Pathogens and Toxins Control List. These are of proliferation concern due to the high mortality rate and lack of preventative and post-exposure treatment generally associated with VHF. Typically, symptoms of VHF include but are not limited to fever, unregulated inflammation, and internal bleeding (e.g., *Ebolavirus* and *Marburgvirus*).

Encephalitis-causing viruses are a proliferation concern due to their ability to cause irritation and swelling of the brain and death. It is uncommon for pathogens to cross the blood-brain barrier, with the exception of this class of viruses (e.g., *Lyssaviruses*, *Eastern equine encephalitis virus*, and *St. Louis encephalitis virus*). Encephalitis can be especially dangerous because options for prevention and treatment of brain swelling are extremely limited, correlating with high mortality rates. In addition to generic flu-like symptoms, persons with encephalitis may experience severe headache, personality changes, seizures, and a wide range of neurologic symptoms.

Pulmonary syndrome predominately impacts the respiratory system. Viruses that cause pulmonary syndrome are of proliferation concern because they are associated with rapid onset of symptoms that, once diagnosed, have extremely limited treatment options (e.g., *Sin Nombre virus* and *Andes virus*).

Arthralgia is the medical term for joint pain. Viruses causing arthralgia are of proliferation concern because they are extremely debilitating (e.g., *Chikungunya virus*) and can include severe complications such as haemorrhagic fever.

Bacteria

A bacterium (plural: bacteria) is a unicellular microorganism. Unlike a virus, a bacterium is an independent living organism that generally does not need to infect another organism for replication. Notable exceptions to this rule are known as obligate intracellular pathogens because they can only reproduce inside another living cell. Bacteria of the genera *Rickettsia* and *Brucella* are obligate intracellular pathogens. Similar to multicellular organisms, genetic material (the genome) in a bacterium will always be DNA. Although most bacteria in this world are beneficial or commensal to other organisms, many bacteria also cause disease in animals, plants, and humans. The AG Common Control Lists include 27 species of bacteria: 22 under the Human and Animal Pathogens and Toxins Control List and five under the Plant Pathogens Control List. In addition, there are five bacteria on the Human and Animal Pathogens and Toxins Warning List and one bacterium in the Plant Pathogens Awareness Raising Guidelines.

At the highest level of taxonomy and classification, bacteria are categorised as either Gram stain negative or Gram stain positive. Gram staining is usually the first experimental procedure performed when identifying bacteria. Gram staining determines whether the bacteria has a cell wall composed of a carbohydrate (known as peptidoglycan) as is seen in Gram stain positive bacteria or a mixture of protein and fat-carbohydrate complexes (known as lipopolysaccharides) as is seen in Gram stain negative bacteria. Although both Gram stain negative and Gram stain positive bacteria can be pathogenic, Gram stain negative bacteria tend to be more adept at avoiding host defence immune systems. Of those agents controlled by the AG, 20 are Gram stain negative, and seven are Gram stain positive.

Spores

Bacteria can replicate through binary fission or sporulation. Binary fission is essentially normal cell division; however, sporulation is unique to bacteria and *fungi* and a property of potential proliferation concern. Spores are highly resistant to environmental pressures, often surviving extremes of temperature, humidity, and acidity. In certain cases, spores can survive and remain dormant in the environment for decades until they are provided favorable living conditions and nutrition for germination as outlined in *Figure 2*.

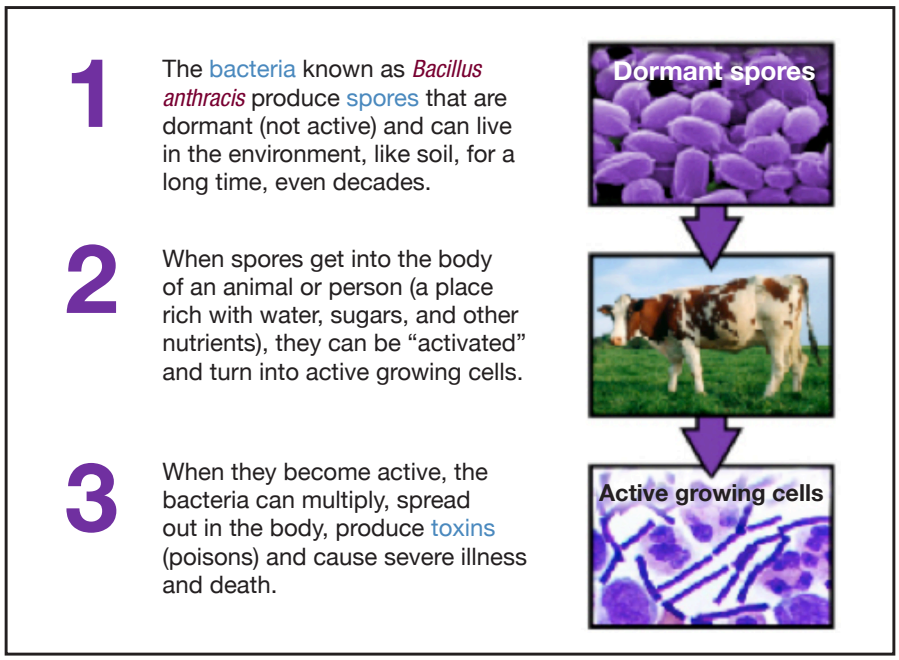

Figure 2. *Bacteria replication through sporulation*[6]

Fungi

Fungi (singular: fungus) are a group of mostly multicellular organisms that are similar in their internal cell structure. Historically, certain fungal species were incorrectly categorised as bacteria or plants based on appearance. However, scientists later discovered that fungi are distinct in many ways, thus warranting their own unique kingdom. Although most fungi are multicellular, they tend not to be overly large organisms, and they live primarily in the soil. During periods of reproduction, fungi can sprout large blooms (e.g., mushrooms). Though many are benign and even eaten as food, many fungi create hazardous toxins or have the ability to colonise and reproduce inside an organism, causing illness. There are a total of 13 fungi species controlled by the AG: 2 Human and Animal Pathogens and Toxins and 11 Plant Pathogens. In addition, there are two fungi species on the Human and Animal Pathogens and Toxins Warning List, and two fungi species in the Plant Pathogens Awareness Raising Guidelines.

The taxonomy of fungi is constantly in flux due to increasing knowledge from genetic research. Currently, there are seven major divisions in the fungi kingdom based on differences in sexual reproduction. For the purposes of the AG, most fungi fall in the subkingdom *Dikarya,* which includes the phyla *Ascomycota* and *Basidiomycota*. Of the 15 fungi included in the AG Common Control Lists, 12 are either *Ascomycota* or *Basidiomycota*. In addition, two organisms listed as fungi in the Plant Pathogens Control List belong to the genus of protists known as *Oomycota*.

Toxins

A toxin is a substance, often a macromolecule or protein, produced by a living organism (bacteria, fungi, and plants) that is poisonous to another living organism. Like other chemicals, toxins are not transmissible from organism to organism unless an exposed organism is externally contaminated with the toxin. Due to the nature and stability of toxins, nefarious exposure through inhalation, ingestion, or injection are possible routes of transmission. Most toxins are not dermally active; they will not cause harm through simple contact with unbroken skin. Two exceptions are T-2 toxin, which can severely irritate unbroken skin, and aflatoxins, which can be absorbed through unbroken skin.

[12] United States Centers for Disease Control and Prevention, "Anthrax," http://www.cdc.gov/anthrax/basics/.

The lethality of a toxin is commonly quantified[13] as the amount of toxin causing death in 50% of an exposed population, known as the LD_{50}.[14] LD_{50} values are expressed as the mass of a toxin (micrograms, µg) required per mass of exposed organism (kilograms, kg). Typically, the latter is a body weight. Table 1 provides LD_{50} values for AG-listed toxins; they were derived from multiple sources[15,16,17,18] and are reported as ranges because of the variability introduced by comparing different species of experimental animal (commonly rat, rabbit, or mouse) and different routes of exposure (usually inhalation, ingestion, or injection). Still, the values reported illustrate several common characteristics of AG-controlled toxins. First, the botulinum toxins are the most potent of all AG-controlled toxins (LD_{50} of 0.001 µg/kg). Second, most AG-controlled toxins are very potent, having LD_{50} values of approximately 10 µg/kg or lower. Because an average human weighs about 70 kilograms, this corresponds to only 0.7 milligrams of toxin. In short, very little toxin is required to produce deleterious effects – even less than many chemical weapons agents (see Volume I, Introduction to Chemical Weapons and Dual-Use Chemical Technology).

Table 1. LD_{50} information for AG-listed toxins

Toxin	LD_{50}, µg/kg
Abrin	0.7–20
Aflatoxins	1,750–2,000
Botulinum toxins	0.001
Cholera toxin	250
Clostridium perfringens alpha, beta 1, beta 2, epsilon and iota toxins	0.1–0.4
Conotoxin	11.0–30
Diacetoxyscirpenol	7,800
HT-2 toxin	1.2–3,000
Microcystins (Cyanoginosins)	0.05
Modeccin	1–10
Ricin	2.7–22
Saxitoxin	8.0–10
Shiga toxins	0.2–20
Staphylococcus aureus entertoxins, hemolysin alpha toxin, and toxic shock syndrome toxin (formerly known as Staphylococcus enterotoxin F)	2–1,000
T-2 toxin	1.2–3,000
Tetrodotoxin	8.0–300
Volkensin	1.4
Viscumin (Viscum album lectin 1)	2.4–80

[13] The lethality of pathogens can also be quantified; however, data assessing the minimum number of pathogen particles or cells required for a lethal infection is less readily available and more subjective than available data assessing the amount of a toxin required for a lethal exposure.

[14] Canadian Centre for Occupational Health and Safety, "What is a LD_{50}?," http://www.ccohs.ca/oshanswers/chemicals/ld50.html.

[15] Gill, D.M. 1982. "Bacterial Toxins: A Table of Lethal Amounts," *Microbiological Reviews* 46:86–94, https://mmbr.asm.org/content/mmbr/46/1/86.full.pdf.

[16] Stirpe, F., et al. 1992. "Ribosome-Inactivating Proteins from Plants: Present Status and Future Prospects," *Biotechnology* 10:405–412

[17] Sweet, Doris V. ed. 1997. *Registry of Toxic Effects of Chemical Substances (RTECS): A Comprehensive Guide to the RTECS*. U.S. Dept. of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health. Cincinnati, Ohio, https://www.cdc.gov/niosh/docs/97-119/pdfs/97-119.pdf.

[18] Paddle, B.M. 2003. "Therapy and Prophylaxis of Inhaled Biological Toxins," *Journal of Applied Toxicology* 23:139–170.

Packaging and Transportation of Agents and Toxins

Similar to the packaging and transport of chemical weapons precursors (see Volume I, Chemical Packaging and Transportation), the safe storage and transport of biological pathogens relies on using proper containers and effective warning labels for any hazard posed by their release. Unlike chemicals, most biological pathogens can be transported in similar materials as they are not generally reactive with the containers that hold them. Most agents and toxins are transported in liquid or solid growth media, either in test tubes or petri dishes.

The risk of pathogen release from even the most suitable containers requires measures to warn people of the hazards posed by the pathogen in transit. International standards for the transport of hazardous materials dictate that containers bear specific labels and codes to identify the dangers associated with the shipped pathogens. These markings assist hazardous materials personnel in properly responding to a biological agent or toxin release.

The United Nations Economic Commission for Europe maintains Recommendations on the Transport of Dangerous Goods, commonly known as the "Model Regulations."[19] These recommendations maintain consistency in the categorisation of pathogens and overlap in the recommendations on packaging and shipment of goods and are discussed in more detail in the Volume I section on Chemical Packaging and Transportation. Toxic and infectious substances are both considered Class 6 goods. There are two divisions within Class 6: Division 6.1 and Division 6.2. Division 6.1 is Toxic Substances, which are liable either to cause death or serious injury or to harm human health if swallowed or inhaled or by skin contact. Toxins fall into this division; they are assigned UN 3172 if in liquid form or UN 3462 if in solid form. Division 6.2 is Infectious Substances, which are known to or reasonably expected to contain pathogens. Under Division 6.2, pathogens are defined as "microorganisms (including bacteria, viruses, parasites, and fungi) and other agents such as prions, which can cause disease in humans or animals."[20] All microorganisms on the AG Human and Animal Pathogens and Toxins Control List would be regulated under Division 6.2.

Within Division 6.2, Infectious Substances can be classified as either Category A or Category B. Category A pathogens are defined as follows: "an infectious substance which is transported in a form that, when exposure to it occurs, is capable of causing permanent disability, life-threatening or fatal disease in otherwise healthy humans or animals." Those pathogens capable of causing disease in humans or both humans and animals are assigned UN 2814. Those pathogens that only cause disease in animals are assigned UN 2900. Pathogens fall into Category B when they do not meet the criteria defined by Category A. All Category B pathogens are assigned UN 3373 regardless of whether they manifest disease in humans or animals. Category A and Category B infectious substances that are also genetically modified organisms are further assigned UN 3245.

Due to the high perishability of infectious substances, they are frequently shipped in containers with dry ice. In addition to categorisation under Class 6, infectious substances may also be assigned a second shipping class (Class 9) if shipped with dry ice. Any infectious substances packaged with dry ice will include both a Class 9 and UN 1845 designation in addition to the applicable Class 6 UN designation. The applicable pictograms from Class 6 and 9 are included in Table 2.

[19] United Nations Economic Commission for Europe, *United Nations (UN) Model Regulations including UN Recommendations on the Transport of Dangerous Goods*, https://www.unece.org/trans/danger/publi/unrec/rev21/21files_e.html.

[20] United Nations Economic Commission for Europe, Volume I, Chapter 2 of *United Nations (UN) Model Regulations including UN Recommendations on the Transport of Dangerous Goods*, https://www.unece.org/trans/danger/publi/unrec/rev21/21files_e.html.

Table 2. UN Hazard Classes, Divisions, and Pictograms Applicable to AG-listed Pathogens and Toxins

Class/Division	Name	UN Pictogram
Class 6	Toxic and infectious substances	
Division 6.1	Toxic substances	
Division 6.2	Infectious substances	
Class 9	Miscellaneous dangerous substances and articles, including environmentally hazardous substances	

Infectious pathogens are subject to both country-specific and international regulations. Air shipments are regulated by International Air Transport Association (IATA), an international trade association whose membership comprises nearly 84% of total air traffic. IATA is responsible for the publication and maintenance of the Dangerous Goods Regulations (DGR); though not identical to the UN Model Regulations, this publication outlines all packaging and air shipment requirements for hazardous material including infectious pathogens.[21] It is likely that goods will be shipped in compliance with IATA regulations due to the predominance of transnational goods movement by air and the high perishability of many living pathogens.

International shipments are generally assigned a commodity classification code according to the Harmonized Commodity Description and Coding System, more commonly referred to as the "Harmonized System" or HS, developed by the World Customs Organization. Six-digit HS codes are harmonised internationally, providing a standardized system for classifying traded products. Cultures of microorganisms (including pathogens) and toxins are commonly classified under HS code 3002.90. However, because this code is not specific to AG-controlled pathogens and toxins, additional information should be sought to identify materials shipped using this HS code.

The shipping practices for plant pathogens are not addressed in current international guidelines. This is due to the exclusion of plant pathogens from the definition of infectious substances or microorganisms as defined by the UN Model Regulations and IATA. Packaging and shipment of plant pathogens falls to bilateral arrangements between countries; in the absence of harmonised international guidelines for these materials, shipping and labeling will be dictated by the requirements and practices of the importing and exporting countries.

[21] International Air Transport Association. More information on the organisation and its tenets: http://www.iata.org/about/Pages/index.aspx.

List of Human and Animal Pathogens and Toxins for Export Control

The following sections provide basic descriptions of and information on the notable features, packaging, and typical applications of items on the AG List of Human and Animal Pathogens and Toxins.[22] In addition to Core List pathogens and toxins, this section also includes pathogens on the Warning List and a section on Genetic Elements and Genetically-modified Organisms. Explanations of terms used in the opening table for each agent or toxin are provided in Appendix D. See the Glossary for technical terms used in this Handbook.

The complete AG control language as of its February 2020 revision is found in Appendix A. Entries in this chapter are numbered to match the respective AG control list entry numbers.

It should be noted that all Core List items are subject to a footnote clarifying the forms of material covered by each entry:

- An agent/pathogen is covered by this list except when it is in the form of a vaccine. A vaccine is a medicinal product in a pharmaceutical formulation licensed by, or having marketing or clinical trial authorisation from, the regulatory authorities of either the country of manufacture or of use, which is intended to stimulate a protective immunological response in humans or animals in order to prevent disease in those to whom or to which it is administered.
- Biological agents and pathogens are controlled when they are an isolated live culture of a pathogen agent, or a preparation of a toxin agent that has been isolated or extracted from any source, or material including living material which has been deliberately inoculated or contaminated with the agent. Isolated live cultures of a pathogen agent include live cultures in dormant form or in dried preparations, whether the agent is natural, enhanced, or modified.

Other footnotes apply to a subset of listed items. The footnote numbers, with links to the respective text, are noted in the Basic Description table for each pathogen and toxin.

[22] The current AG control language may be found online at https://www.dfat.gov.au/publications/minisite/theaustraliagroupnet/site/en/human_animal_pathogens.html.

This page intentionally left blank.

Core List[1]

Viruses

V1. *African horse sickness virus*

V1.1. Basic Description

Identifier/Property	Description
Type	Virus: RNA
Associated Disease	African horse sickness
Other Names	AHS
Key WMD Characteristic(s)	▸ Mortality rate 50–90% (horses) ▸ Potential aerosol ▸ Potential for socioeconomic harm ▸ Vaccine available ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 3; subject to enhanced containment for countries with vulnerable agriculture
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Not a known route of exposure ▸ Inhalation (lungs): Not a known route of exposure ▸ Gastrointestinal (intestine): Not a known route of exposure ▸ Injection (bloodstream): Midge bite **Host/Reservoir:** Horses, mules, donkeys, zebras, camels, dogs **Vector:** Midges
Geographic Distribution	Africa, Middle East, Central Asia, Western Europe (Spain and Portugal)
Zoonotic	No
Human Transmissibility	Not transmissible
EU Control List Entry	1C351.a.1
Applicable AG Footnote(s)	[1]

V1.2. Notable Features

African horse sickness virus causes African horse sickness (AHS), a disease endemic to sub-Saharan Africa. Sporadic cases of AHS have been reported outside of Africa in the Middle East, India, Pakistan, Spain, and Portugal. AHS primarily affects horses and mules, though the disease also can manifest in donkeys, zebras, camels, and dogs. Virus transmission is only known to occur through a midge vector. There are nine different viral serotypes of *African horse sickness virus*; each is most commonly found in a distinct geographic region. All serotypes are capable of manifesting four distinct forms of AHS: peracute (pulmonary), subacute edematous (cardiac), acute (mixed), and horsesickness fever. Symptoms of pulmonary AHS include fever and respiratory distress that eventually result in death. Cardiac AHS presents with fever and swelling of the eyes, cheeks, lips, lungs, and chest, resulting in death from heart failure. Mixed AHS presents with symptoms of both pulmonary and cardiac forms of AHS. Horsesickness fever is rarely fatal and presents with fever, runny nose, and increased heart rate. Vaccines are available for AHS but are only used in endemic regions due to side effects.

V1.3. Packaging

African horse sickness virus is a Category B infectious substance with the shipping code UN 3373 because it is infectious but does not meet the criteria for Category A.

V1.4. Typical Applications

Basic medical research and medical countermeasure development (e.g., vaccine research), epidemiology, and global surveillance.

V2. *African swine fever virus*

V2.1. Basic Description

Identifier/Property	Description
Type	Virus: DNA
Associated Disease	African swine fever, warthog disease
Other Names	ASF
Key WMD Characteristic(s)	▸ Potential aerosol ▸ Environmentally stable ▸ No vaccine ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 3; subject to enhanced containment for countries with vulnerable agriculture
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wound ▸ Inhalation (lungs): Not a known route of exposure ▸ Gastrointestinal (intestine): Not a known route of exposure ▸ Injection (bloodstream): Tick bite **Host/Reservoir:** Hogs, pigs, boars **Vector:** Ticks
Geographic Distribution	Africa, Europe, South America, Caribbean
Zoonotic	No
Human Transmissibility	Not transmissible
EU Control List Entry	1C351.a.2
Applicable AG Footnote(s)	[1]

V2.2. Notable Features

African swine fever virus is the causative pathogen of African swine fever. The disease is endemic to Africa, and the first incidence of African swine fever in Europe occurred in 2007. The virus is unique in that it is the only DNA virus known to transmit via an arthropod vector, the tick. The virus also can spread through direct contact with feces, urine, and other bodily fluids. All species of swine, boar, and hog are known to be susceptible to viral infection, though symptoms are known to manifest in domestic pigs and wild boar only. Therefore, other swine species are thought to be effective reservoirs for the virus. Disease manifestation varies greatly between viral strains from asymptomatic to 100% mortality in both domestic and wild pigs. Animals suffering from milder infections will often lose weight and develop pneumonia, skin ulcers, and swollen joints. More virulent strains will result in bluish-purple colouration on the ears and abdomen that eventually progress to coma and death. *African swine fever virus* stays viable in the environment and infected bodily fluids and tissues long after the death of an infected animal. Therefore, disease control generally includes culling of domestic swine species in endemic areas to avoid spread of the virus and contamination of food supplies.

V2.3. Packaging

African swine fever virus is a Category A infectious substance with the shipping code UN 2900 because it is capable of causing permanent disability or life-threatening or fatal disease in otherwise healthy animals when exposure to it occurs.

V2.4. Typical Applications

Basic medical research and medical countermeasure development (e.g., vaccine research), epidemiology, and global surveillance.

V3. *Andes virus*

V3.1. Basic Description

Identifier/Property	Description
Type	Virus: RNA
Associated Disease	Hantavirus cardiopulmonary syndrome (HCPS or HPS)
Other Names	ANDV
Key WMD Characteristic(s)	▸ Mortality rate 35–50% ▸ Effective aerosol ▸ No vaccine ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 3
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wound ▸ Inhalation (lungs): Aerosols ▸ Gastrointestinal (intestine): Not a known route of exposure ▸ Injection (bloodstream): Not a known route of exposure **Host/Reservoir:** Rodents, humans **Vector:** Not applicable
Geographic Distribution	South America
Zoonotic	Yes
Human Transmissibility	Yes – direct and respiratory
EU Control List Entry	1C351.a.3
Applicable AG Footnote(s)	[1]

V3.2. Notable Features

First discovered in 1993, Andes virus (ANDV) is a New World *Hantavirus*. ANDV is contracted by humans through direct contact with infected rodent urine or feces. It is the only *Hantavirus* for which person-to-person transmission is suspected based on case history. All confirmed cases of ANDV infection in humans have been restricted to Chile and Argentina. There are two forms of ANDV; the southern form causes the most severe forms of HCPS, and the northern form causes a slightly milder form of the disease. Symptoms during the early stages of illness include fever, headaches, muscle aches, upset stomach, and dizziness. The later stages are marked by shortness of breath due to the lungs filling with fluid.

V3.3. Packaging

ANDV does not have a category designation but meets the qualifications for handling as a Category A infectious substance because it is capable of causing permanent disability or life-threatening or fatal disease in otherwise healthy humans when exposure to it occurs. Therefore, ANDV should be handled with shipping code UN 2814.[23]

[23] The UN Model Regulations state that the Category A listing of infectious substances "…is not exhaustive. Infectious substances, including new or emerging pathogens, which do not appear in the table but which meet the same criteria shall be assigned to Category A. In addition, if there is doubt as to whether or not a substance meets the criteria it shall be included in Category A." See Volume I, Chapter 2 https://www.unece.org/trans/danger/publi/unrec/rev21/21files_e.html.

V3.4. Typical Applications

Basic medical research and medical countermeasure development (e.g., vaccine research), epidemiology, and global surveillance.

V4. *Avian influenza virus*[2]

V4.1. Basic Description

Identifier/Property	Description
Type	Virus: RNA
Associated Disease	Avian flu, bird flu
Scientific Name	Influenza A virus
Other Names	Highly pathogenic avian influenza (HPAI)
Key WMD Characteristic(s)	▸ Mortality rate 60% (poultry) ▸ Effective aerosol ▸ Potential for socioeconomic harm ▸ Vacine available for certain strains (poultry and humans) ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 3; subject to enhanced containment for countries with vulnerable agriculture
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wound ▸ Inhalation (lungs): Aerosols ▸ Gastrointestinal (intestine): Not a known route of exposure ▸ Injection (bloodstream): Not a known route of exposure **Host/Reservoir:** Chickens, turkeys **Vector:** Not applicable
Geographic Distribution	Asia, Europe, Middle East, Africa
Zoonotic	Yes
Human Transmissibility	Yes (rare) – direct and respiratory
EU Control List Entry	1C351.a.4
Applicable AG Footnote(s)	[1] [2]

V4.2. Notable Features

Avian influenza virus is a name that usually refers to strains of *Influenza A virus* that predominately cause disease in birds and aquatic mammals. Certain strains are capable of manifesting disease in other mammals, including humans. In addition, the virus is particularly well adapted for rapid mutation, which means that the total number of unique infectious viral strains is steadily increasing. Most strains are adapted to preferentially affect domesticated birds and aquatic mammals; however, certain strains are better adapted to other host species (e.g., humans, dogs, or pigs).

Only those strains that are considered highly pathogenic for birds are controlled by the AG, according to Footnote [2] of this list. It states:

> This includes only those *Avian influenza viruses* of high pathogenicity as defined by the World Organisation for Animal Health (OIE), the European Union (EU), or competent national regulatory bodies.

The World Organisation for Animal Health (OIE) defines highly pathogenic avian influenza (HPAI) as a strain that causes "more than 75% mortality within 10 days."[24,25] To date, all strains meeting the definition of HPAI have been either H5 or N7 strains.[26] Most strains of *Avian influenza virus* cause low pathogenic avian influenza (LPAI) meaning they are less virulent and have lower mortality rates than HPAI.

Virus transmission most commonly occurs manually through direct contact with infected birds or their bodily fluids. Certain strains are suspected of aerosol transmission for those birds who share a close living area. Similarly, strains adapted for a human host are most commonly transmitted through direct contact with dead birds or contaminated bodily fluids. Human-to-human transmission has been documented in a small number of cases; however, this is not a common route of exposure for most human contracted cases of HPAI.[27] Symptoms of avian influenza in humans include fever, joint and muscle pain, sore throat, and cough.

V4.3. Packaging

Avian influenza virus is a Category B infectious substance with the shipping code UN 3373 because it is infectious but does not meet the criteria for Category A.

V4.4. Typical Applications

Basic medical research and medical countermeasure development (e.g., vaccine research), epidemiology, and global surveillance.

[24] The OIE also defines a strain as highly pathogenic when "inoculation of 10 susceptible 4 to 8-week-old chickens results in an intravenous pathogenicity index of greater than 1.2." This definition is most applicable to laboratory experiments. More information from the OIE can be found at: https://www.oie.int/fileadmin/Home/eng/Health_standards/tahm/3.03.04_AI.pdf.

[25] The European Union (EU) defines avian influenza as "an infection of poultry caused by any influenza A virus which has an IVPI in six-week-old chickens greater than 1.2 or any infection with influenza A viruses of H5 or H7 subtype for which nucleotide sequencing has demonstrated the presence of multiple basic amino acids at the cleavage site of the hemagglutinin," https://ec.europa.eu/food/sites/food/files/safety/docs/sci-com_scah_out45-final_en.pdf. In addition, please see https://www.ecdc.europa.eu/en/avian-influenza-humans/surveillance-and-disease-data/avian-influenza-overview or https://ec.europa.eu/food/animals/animal-diseases/control-measures/avian-influenza_en.

[26] Please see https://ec.europa.eu/food/animals/animal-diseases/control-measures/avian-influenza_en.

[27] Further discussion on human transmissibility of HPAI can be found through the CDC: http://www.cdc.gov/flu/avian/gen-info/facts.htm.

V5. *Bluetongue virus*

V5.1. Basic Description

Identifier/Property	Description
Type	Virus: RNA
Associated Disease	Bluetongue disease, catarrhal fever, dancing disease, sore muzzle, muzzle disease, pseudo foot-and-mouth disease
Other Names	BTV
Key WMD Characteristic(s)	▸ Mortality rate varies: 30–70% (sheep); 80–90% (deer and antelope) ▸ Potential aerosol ▸ Potential for socioeconomic harm ▸ Vaccine available ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 3; subject to enhanced containment for countries with vulnerable agriculture
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Not a known route of exposure ▸ Inhalation (lungs): Not a known route of exposure ▸ Gastrointestinal (intestine): Not a known route of exposure ▸ Injection (bloodstream): Midge bite **Host/Reservoir:** Sheep, cattle, goats, buffalo, deer, bighorn sheep, elk, antelope **Vector:** Midges
Geographic Distribution	North and South America, Africa, Middle East, Asia, Europe, South Pacific
Zoonotic	No
Human Transmissibility	Not transmissible
EU Control List Entry	1C351.a.5
Applicable AG Footnote(s)	[1]

V5.2. Notable Features

Bluetongue virus is a member of the *Reoviridae* family causing bluetongue disease primarily in sheep and other large mammals. Outbreaks of bluetongue have occurred in Africa, Europe, the Middle East, North and South America, the South Pacific, and parts of Asia. *Bluetongue virus* is spread via a midge vector. Disease outbreaks are notoriously seasonal, subsiding during the winter when vector populations naturally decrease. Severity of the disease varies greatly by virus serotype and affected host species. Mortality rates can be as high as 90% in certain species of susceptible deer and antelope. Disease symptoms include fever, excessive saliva production, malaise, shortness of breath, ulcer formation in the mouth, and fluid retention in the head and ears. In addition, it is common for infected pregnant animals to have an increased incidence of abortion. Vaccines are available in countries where *Bluetongue virus* is endemic.

V5.3. Packaging

Bluetongue virus is a Category B infectious substance with the shipping code UN 3373 because it is infectious but does not meet the criteria for Category A.

V5.4. Typical Applications

Basic medical research and medical countermeasure development (e.g., vaccine research), epidemiology, and global surveillance.

V6. *Chapare virus*

V6.1. Basic Description

Identifier/Property	Description
Type	Virus: RNA
Associated Disease	Chapare hemorrhagic fever (CHHF)
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Mortality rate 15–30%[7] ▸ Effective aerosol ▸ No vaccine ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 4
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wound ▸ Inhalation (lungs): Aerosols ▸ Gastrointestinal (intestine): Not a known route of exposure ▸ Injection (bloodstream): Not a known route of exposure **Host/Reservoir:** Rodents, humans **Vector:** Not applicable
Geographic Distribution	Bolivia
Zoonotic	Yes
Human Transmissibility	Yes – direct and respiratory
EU Control List Entry	1C351.a.6
Applicable AG Footnote(s)	[1]

V6.2. Notable Features

Only a single documented outbreak of *Chapare virus* exists; it occurred in a village of Samuzabeti, Chapare Province, Bolivia in 2003. Due to the fact that all *Arenaviridae* are transmitted to humans via the same route and the case history of the 2003 incident, it is believed that humans contract the virus through direct contact with an infected rodent or inhalation of aerosolised rodent urine or feces. In addition, human-to-human transfer is likely possible through direct contact with contaminated blood, serum, or tissue. Symptoms of CHHF include fever, headache, muscle pain, and vomiting followed by haemorrhaging at multiple locations in the body in the late stages of the disease. Patients suffering from other species of *Arenaviridae* may continue to excrete the virus through bodily fluids weeks after recovery, suggesting that the same is true for patients infected by *Chapare virus*.

[28] *Chapare virus* has only been isolated from a single patient from the 2003 outbreak in Bolivia. As such, it is very difficult to determine an overall mortality rate; 15–30% reflects the mortality rate for genetically similar *Arenavirus* species endemic to Bolivia.

V6.3. Packaging

Chapare virus does not have a category designation but meets the qualifications for handling as a Category A infectious substance because it is capable of causing permanent disability or life-threatening or fatal disease in otherwise healthy humans when exposure to it occurs. Therefore, *Chapare virus* should be handled with shipping code UN 2814.[29]

V6.4. Typical Applications

Basic medical research and medical countermeasure development (e.g., vaccine research), epidemiology, and global surveillance.

[29] The UN Model Regulations state that the Category A listing of infectious substances "…is not exhaustive. Infectious substances, including new or emerging pathogens, which do not appear in the table but which meet the same criteria shall be assigned to Category A. In addition, if there is doubt as to whether or not a substance meets the criteria it shall be included in Category A." See Volume I, Chapter 2 https://www.unece.org/trans/danger/publi/unrec/rev21/21files_e.html.

V7. *Chikungunya virus*

V7.1. Basic Description

Identifier/Property	Description
Type	Virus: RNA
Associated Disease	Chikungunya fever
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Mortality rate <2% ▸ Potential aerosol ▸ No vaccine ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 3
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Not a known route of exposure ▸ Inhalation (lungs): Not a known route of exposure ▸ Gastrointestinal (intestine): Not a known route of exposure ▸ Injection (bloodstream): Mosquito bite **Host/Reservoir:** Primates, humans **Vector:** Mosquitoes
Geographic Distribution	Caribbean, Africa, Asia (especially India)
Zoonotic	Yes
Human Transmissibility	Not transmissible
EU Control List Entry	1C351.a.7
Applicable AG Footnote(s)	[1]

V7.2. Notable Features

Chikungunya fever was first identified in Tanzania in 1952. Since then it has been responsible for numerous human epidemics in many parts of Asia, Africa, Australia, and limited areas of Europe. Historically, most cases have been primarily limited to Asia, Africa, and the Indian subcontinent. In January 2014, cases of Chikungunya fever were documented in the Caribbean for the first time. This is the first incidence of locally acquired Chikungunya fever in the New World. The species of mosquito that acts as a vector for the virus is indigenous to warm climates throughout parts of North and South America; therefore, experts suspect incidence of the disease could spread beyond the Caribbean islands. The name chikungunya comes from the Kimakonde language meaning “to become contorted” describing the stooped appearance of those who suffer joint pain from the disease. Symptoms of chikungunya fever can be severe and debilitating, though rarely fatal; symptoms include high fever, severe joint paint, headache, muscle pain, and rash.

V7.3. Packaging

Chikungunya virus is a Category B infectious substance with the shipping code UN 3373 because it is infectious but does not meet the criteria for Category A.

V7.4. Typical Applications

Basic medical research and medical countermeasure development (e.g., vaccine research), epidemiology, and global surveillance.

V8. *Choclo virus*

V8.1. Basic Description

Identifier/Property	Description
Type	Virus: RNA
Associated Disease	Hantavirus cardiopulmonary syndrome (HCPS or HPS)
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Mortality rate 10–30% ▸ Effective aerosol ▸ No vaccine ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 3
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wound ▸ Inhalation (lungs): Aerosols ▸ Gastrointestinal (intestine): Not a known route of exposure ▸ Injection (bloodstream): Not a known route of exposure **Host/Reservoir:** Rodents, humans **Vector:** Not applicable
Geographic Distribution	Central and South America
Zoonotic	Yes
Human Transmissibility	Not transmissible
EU Control List Entry	1C351.a.8
Applicable AG Footnote(s)	[1]

V8.2. Notable Features

First discovered in Panama in 1999, *Choclo virus* is a New World *Hantavirus* linked to the mildest form of HCPS. Infection with the *Choclo virus* is thought to cause only mild to asymptomatic infections. This suggests that the mortality rate of 10–30% is only indicative of those cases severe enough for patients to seek medical treatment and diagnosis. Transmission to humans occurs from direct contact with an infected animal, bodily fluids or tissues, or from the aerosolisation of contaminated urine or feces.

V8.3. Packaging

Choclo virus does not have a category designation but meets the qualifications for handling as a Category A infectious substance because it is capable of causing permanent disability or life-threatening or fatal disease in otherwise healthy humans when exposure to it occurs. Therefore, *Choclo virus* should be handled with shipping code UN 2814.[30]

V8.4. Typical Applications

Basic medical research and medical countermeasure development (e.g., vaccine research), epidemiology, and global surveillance.

[30] The UN Model Regulations state that the Category A listing of infectious substances "…is not exhaustive. Infectious substances, including new or emerging pathogens, which do not appear in the table but which meet the same criteria shall be assigned to Category A. In addition, if there is doubt as to whether or not a substance meets the criteria it shall be included in Category A." See Volume I, Chapter 2 https://www.unece.org/trans/danger/publi/unrec/rev21/21files_e.html.

V9. *Classical swine fever virus* (*Hog cholera virus*)

V9.1. Basic Description

Identifier/Property	Description
Type	Virus: RNA
Associated Disease	Classical swine fever (CSF), hog cholera, pig plague
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Mortality rate varies 0–100% ▸ Effective aerosol ▸ Potential for socioeconomic harm ▸ Vaccine available ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 3; subject to enhanced containment for countries with vulnerable agriculture
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wound ▸ Inhalation (lungs): Aerosols ▸ Gastrointestinal (intestine): Consumption of contaminated food, milk, or raw meat ▸ Injection (bloodstream): Not a known route of exposure **Host/Reservoir:** Pigs **Vector:** Not applicable
Geographic Distribution	Asia, Caribbean, Africa (Madagascar and Mauritius), North and South America, Europe
Zoonotic	No
Human Transmissibility	Not transmissible
EU Control List Entry	1C351.a.20
Applicable AG Footnote(s)	[1]

V9.2. Notable Features

Classical swine fever virus is a virus species of the genus *Pestivirus* and family *Flaviviridae*. *Classical swine fever virus* causes classical swine fever (CSF) in pigs. The disease is widespread across Asia, the Caribbean, parts of Africa, and Central and South America. Eradication efforts have eliminated outbreaks in domestic pigs in much of North America, Europe, New Zealand, and Australia; however, the virus is still existent in wild pigs. Transmission occurs via direct contact with infectious bodily fluids, aerosolisation of virus particles, and consumption of contaminated food, milk, or garbage. It is common to feed domestic pigs feed and garbage that contains undercooked pig tissues or other infectious bodily fluids. Containment efforts include cooking feed before it is given to pigs as heat kills the virus. Like other viruses, CSFV is relatively fragile in the environment, though it can remain viable in refrigerated meats for months and frozen meats for years. The virus can manifest symptoms including abortion in pregnant pigs, coughing, sneezing, fever, constipation, weakness, drowsiness, and anorexia. Sick herds of pigs with CSF tend to huddle together. The severity of symptoms varies by virus strain and age of the pig. Piglets are most susceptible to severe outbreaks, while older pigs are more likely to develop mild forms of CSF; this causes a mortality range from 0 to 100%. Vaccines are available and used in many endemic countries.

V9.3. Packaging

Classical swine fever virus is a Category B infectious substance with the shipping code UN 3373 because it is infectious but does not meet the criteria for Category A.

V9.4. Typical Applications

Basic medical research and medical countermeasure development (e.g., vaccine research), epidemiology, and global surveillance.

V10. *Crimean-Congo hemorrhagic fever virus*

V10.1. Basic Description

Identifier/Property	Description
Type	Virus: RNA
Associated Disease	Crimean-Congo hemorrhagic fever (CCHF)
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Mortality rate 9–50% ▸ Potential aerosol ▸ No vaccine ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 4
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wounds ▸ Inhalation (lungs): Not a known route of exposure ▸ Gastrointestinal (intestine): Not a known route of exposure ▸ Injection (bloodstream): Tick bite **Host/Reservoir:** Cattle, goats, sheep, hares, ostrich, humans **Vector:** Ticks
Geographic Distribution	Africa, Eastern Europe, Middle East, Asia
Zoonotic	Yes
Human Transmissibility	Yes – direct
EU Control List Entry	1C351.a.9
Applicable AG Footnote(s)	[1]

V10.2. Notable Features

Crimean-Congo hemorrhagic fever (CCHF) is caused by a tick-borne virus. First identified in 1944 in Crimea, it was later recognised in the Congo in 1969. The geographic distribution of this disease is now expansive; it can be found in Eastern Europe, the Mediterranean, Asia, southern Europe, Africa, and the Middle East. Reservoirs of the disease include cattle, goats, sheep, and hares. Transmission to humans results from manual contact with the blood or other bodily fluids of an infected animal or bite of an infected tick. Symptoms include headache, high fever, back pain, joint pain, stomach pain, and vomiting. Red eyes, flushed face, red throat, and red spots on the palate are common. As the illness progresses, signs of VHF can be seen, including large areas of severe bruising, nosebleeds, or uncontrolled bleeding.

V10.3. Packaging

Crimean-Congo hemorrhagic fever virus is a Category A infectious substance with the shipping code UN 2814 because it is capable of causing permanent disability or life-threatening or fatal disease in otherwise healthy humans when exposure to it occurs.

V10.4. Typical Applications

Basic medical research and medical countermeasure development (e.g., vaccine research), epidemiology, and global surveillance.

V11. *Dobrava-Belgrade virus*

V11.1. Basic Description

Identifier/Property	Description
Type	Virus: RNA
Associated Disease	Hemorrhagic fever with renal syndrome (HFRS)
Other Names	DOBV
Key WMD Characteristic(s)	▸ Mortality rate 12% ▸ Effective aerosol ▸ No vaccine ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 3
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wound ▸ Inhalation (lungs): Aerosols ▸ Gastrointestinal (intestine): Not a known route of exposure ▸ Injection (bloodstream): Not a known route of exposure **Host/Reservoir:** Rodents, humans **Vector:** Not applicable
Geographic Distribution	Eastern Europe
Zoonotic	Yes
Human Transmissibility	Not transmissible
EU Control List Entry	1C351.a.11
Applicable AG Footnote(s)	[1]

V11.2. Notable Features

Dobrava-Belgrade virus is originally from the Balkan Peninsula. It causes hemorrhagic fever with renal syndrome (HFRS) and has the highest mortality rate of any *Hantavirus* found in Europe.

V11.3. Packaging

Dobrava-Belgrade virus does not have a category designation but meets the qualifications for handling as a Category A infectious substance because it is capable of causing permanent disability or life-threatening or fatal disease in otherwise healthy humans when exposure to it occurs. Therefore, *Dobrava-Belgrade virus* should be handled with shipping code UN 2814.[31]

V11.4. Typical Applications

Basic medical research and medical countermeasure development (e.g., vaccine research), epidemiology, and global surveillance.

[31] The UN Model Regulations state that the Category A listing of infectious substances "…is not exhaustive. Infectious substances, including new or emerging pathogens, which do not appear in the table but which meet the same criteria shall be assigned to Category A. In addition, if there is doubt as to whether or not a substance meets the criteria it shall be included in Category A." See Volume I, Chapter 2 https://www.unece.org/trans/danger/publi/unrec/rev21/21files_e.html.

V12. *Eastern equine encephalitis virus*

V12.1. Basic Description

Identifier/Property	Description
Type	Virus: RNA
Associated Disease	Triple E, sleeping sickness
Other Names	EEEV
Key WMD Characteristic(s)	▸ Mortality rate 33% ▸ Potential aerosol ▸ Vaccine available for use in livestock ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 3
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Not a known route of exposure ▸ Inhalation (lungs): Not a known route of exposure ▸ Gastrointestinal (intestine): Not a known route of exposure ▸ Injection (bloodstream): Mosquito bite[13] **Host/Reservoir:** Mammals, birds, reptiles, amphibians, humans **Vector:** Mosquitoes
Geographic Distribution	North, Central, and South America; Caribbean
Zoonotic	Yes
Human Transmissibility	Not transmissible
EU Control List Entry	1C351.a.12
Applicable AG Footnote(s)	[1]

V12.2. Notable Features

The *Eastern equine encephalitis virus* was first described in the United States in the late 1800s. Humans and horses are susceptible to infection by the virus, but disease is rare in both. The most common reservoirs for EEEV are birds though mammals, reptiles, and amphibians are also susceptible to the virus. Despite its rarity, EEEV is one of the most severe encephalitis viruses in the New World. As seen in other severe cases of encephalitis, patients that recover typically have significant brain damage. The virus is especially fatal in horses (equines) but can manifest symptoms in pheasants, quail, ostrich, emus, and puppies.

V12.3. Packaging

Eastern equine encephalitis virus is a Category A infectious substance with the shipping code UN 2814 because it is capable of causing permanent disability or life-threatening or fatal disease in otherwise healthy humans or animals when exposure to it occurs.

V12.4. Typical Applications

Basic medical research and medical countermeasure development (e.g., vaccine research), epidemiology, and global surveillance.

[32] More information on EEEV transmission can be found at http://www.cdc.gov/EasternEquineEncephalitis/tech/transmission.html.

V13. *Ebolavirus:* all members of the *Ebolavirus* genus

V13.1. Basic Description

Identifier/Property	Description
Type	Virus: RNA
Associated Disease	Ebola hemorrhagic fever
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Mortality rate >65% ▸ Effective aerosol ▸ No vaccine ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 4
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wound ▸ Inhalation (lungs): Aerosols ▸ Gastrointestinal (intestine): Not a known route of exposure ▸ Injection (bloodstream): Not a known route of exposure **Host/Reservoir:** Bats, primates, antelope, porcupine, humans **Vector:** Not applicable
Geographic Distribution	Africa
Zoonotic	Yes
Human Transmissibility	Yes – direct and respiratory
EU Control List Entry	1C351.a.13
Applicable AG Footnote(s)	[1]

V13.2. Notable Features

The genus *Ebolavirus* includes five distinct species known to cause ebola hemorrhagic fever: *Bundibugyo ebolavirus* (BDBV), *Zaire ebolavirus* (EBOV), *Sudan ebolavirus* (SUDV), *Taï Forest ebolavirus* (TAFV), and *Reston ebolavirus* (RESTV). When first discovered in 1977, the term *Ebolavirus* was used to describe what is now known as the *Zaire ebolavirus* species. As a result, the name *Ebolavirus* is often used to refer to either the entire *Ebolavirus* genus or just the *Zaire ebolavirus* species.

To date, only four species are known to cause disease in humans: BDBV, EBOV, SUDV, and TAFV. RESTV causes infection in in nonhuman primates. Fruit bats are presumed to be the natural reservoir for all *Ebolavirus* species, spreading the virus through partially eaten fruits and pulp that subsequently are consumed by nonhuman primates. Transmission to humans from primates is typically through direct contact with the carcass of an infected primate. Human-to-human transfer usually occurs through direct contact with bodily fluids from an infected individual, but aerosol transmission can occur between individuals in close proximity to one another. Cases outside of Africa have been limited to accidental laboratory infections. All *Ebolavirus* species cause ebola hemorrhagic fever, a type of VHF, at varying degrees of severity. The highest rates of mortality are seen in cases of *Zaire ebolavirus*. Initial symptoms include fever, headache, muscle pain, and weakness. Later symptoms can include vomiting, diarrhea, rash, impaired liver and kidney function, and internal and external bleeding.

V13.3. Packaging

Members of the *Ebolavirus* genus are Category A infectious substances with the shipping code UN 2814 because they are capable of causing permanent disability or life-threatening or fatal disease in otherwise healthy humans or animals when exposure to them occurs.

V13.4. Typical Applications

Basic medical research and medical countermeasure development (e.g., vaccine research), epidemiology, and global surveillance.

V14. *Foot-and-mouth disease virus*

V14.1. Basic Description

Identifier/Property	Description
Type	Virus: RNA
Associated Disease	Foot-and-mouth disease, hoof-and-mouth disease
Other Names	FMDV
Key WMD Characteristic(s)	▸ Mortality rate varies: 1–5% (adults); 20% (calves, lambs, and piglets) ▸ Effective aerosol ▸ Potential for socioeconomic harm ▸ Vaccine available ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 3; subject to enhanced containment for countries with vulnerable agriculture
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wound ▸ Inhalation (lungs): Aerosols ▸ Gastrointestinal (intestine): Consumption of contaminated food ▸ Injection (bloodstream): Not a known route of exposure **Host/Reservoir:** Numerous (over 70 species): cattle, water buffalo, sheep, goats, pigs, antelope, deer, bison **Vector:** Not applicable
Geographic Distribution	Asia, Africa, Middle East, South America
Zoonotic	No
Human Transmissibility	Not transmissible
EU Control List Entry	1C351.a.14
Applicable AG Footnote(s)	[1]

V14.2. Notable Features

Foot-and-mouth disease virus is a member of the *Picornaviridae* family and causes foot-and-mouth disease in a variety of hosts including livestock and other large mammals. There are seven different serotypes of FMDV with over 60 strains within these serotypes. Historically, disease outbreaks have occurred worldwide. Currently, the disease is endemic to Asia, Africa, the Middle East, and South America. In contrast, North America, New Zealand, Australia, Iceland, Greenland, and most of Europe are considered free of the disease. Transmission of the virus can occur through direct contact with contaminated bodily fluids, inhalation of aerosolised virus particles, or ingestion of contaminated feed. Symptoms of foot-and-mouth disease include fever and blisters on the feet and mammary glands. Although the disease is rarely fatal, animals can spread the disease long after symptoms no longer manifest. The disease is particularly devastating to the livestock industry as diseased animals cannot be used for food production. Vaccines are available for FMDV control and are used with varying frequency in endemic regions.

V14.3. Packaging

Foot-and-mouth disease virus is a Category A infectious substance with the shipping code UN 2900 because it is capable of causing permanent disability or life-threatening or fatal disease in otherwise healthy animals when exposure to it occurs.

V14.4. Typical Applications

Basic medical research and medical countermeasure development (e.g., vaccine research), epidemiology, and global surveillance.

V15. *Goatpox virus*

V15.1. Basic Description

Identifier/Property	Description
Type	Virus: DNA
Associated Disease	Goatpox
Other Names	Goat pox, GPV
Key WMD Characteristic(s)	▸ Mortality rate 10–100% ▸ Effective aerosol ▸ Vaccine available ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 3; subject to enhanced containment for countries with vulnerable agriculture
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wound ▸ Inhalation (lungs): Aerosols ▸ Gastrointestinal (intestine): Not a known route of exposure ▸ Injection (bloodstream): Not a known route of exposure **Host/Reservoir:** Goats, sheep **Vector:** Not applicable
Geographic Distribution	Africa, Middle East, Central Asia
Zoonotic	No
Human Transmissibility	Not transmissible
EU Control List Entry	1C351.a.15
Applicable AG Footnote(s)	[1]

V15.2. Notable Features

Goatpox virus belongs to the *Poxviridae* family. Although GPV generally manifests disease in goats, certain strains of GPV can manifest symptoms in sheep. Mortality rates are generally 5–10% in areas with endemic outbreaks, though mortality rates can reach <100% for imported animals. Transmission of the virus occurs through aerosolisation of virus particles by animals in close living spaces or direct contact with infectious bodily fluids. Goatpox manifests most commonly in two forms: papulovesicular (common) and nodular (uncommon). Symptoms include fever and pustule formation on the skin. During papulovesicular manifestation, dark scabs form over the pustule scars. In contrast, during nodular manifestation, also known as stonepox, pustules develop into nodules which eventually die and slough off the animal leaving hairless patches. Animals that do not recover from infection develop systemic inflammation and death similar to other VHF viruses. Highly susceptible goat species may also develop flat hemorrhagic goatpox, which results in one large pustule forming over the entire skin surface.[33]

V15.3. Packaging

Goatpox virus is a Category A infectious substance with the shipping code UN 2900 because it is capable of causing permanent disability or life-threatening or fatal disease in otherwise healthy animals when exposure to it occurs.

[33] Additional information on *Goatpox virus* can be found through the OIE: http://www.oie.int/fileadmin/Home/eng/Animal_Health_in_the_World/docs/pdf/Disease_cards/SHEEP_GOAT_POX.pdf.

V15.4. Typical Applications

Basic medical research and medical countermeasure development (e.g., vaccine research), epidemiology, and global surveillance.

V16. *Guanarito virus*

V16.1. Basic Description

Identifier/Property	Description
Type	Virus: RNA
Associated Disease	Venezuelan hemorrhagic fever
Other Names	GTOV
Key WMD Characteristic(s)	▸ Mortality rate 23% ▸ Effective aerosol ▸ No vaccine ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 4
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wound ▸ Inhalation (lungs): Aerosols ▸ Gastrointestinal (intestine): Not a known route of exposure ▸ Injection (bloodstream): Not a known route of exposure **Host/Reservoir:** Rodents, humans **Vector:** Not applicable
Geographic Distribution	Venezuela
Zoonotic	Yes
Human Transmissibility	Yes – direct and respiratory
EU Control List Entry	1C351.a.16
Applicable AG Footnote(s)	[1]

V16.2. Notable Features

Guanarito virus was first identified in Venezuela in 1989. The primary host for the virus is the short tailed cane mouse, which is native to western Venezuela, particularly in rural, tall grass, agricultural areas. Infection in humans occurs from inhalation of aerosolised urine or feces or through direct contact with other bodily fluids of an infected rodent. Symptoms of Venezuelan hemorrhagic fever are similar to that of other species of *Arenaviridae* that cause VHF.

V16.3. Packaging

Guanarito virus is a Category A infectious substance with the shipping code UN 2814 because it is capable of causing permanent disability or life-threatening or fatal disease in otherwise healthy humans or animals when exposure to it occurs.

V16.4. Typical Applications

Basic medical research and medical countermeasure development (e.g., vaccine research), epidemiology, and global surveillance.

V17. *Hantaan virus*

V17.1. Basic Description

Identifier/Property	Description
Type	Virus: RNA
Associated Disease	Hemorrhagic fever with renal syndrome (HFRS)
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Mortality rate 5–15% ▸ Effective aerosol ▸ No vaccine ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 3
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wound ▸ Inhalation (lungs): Aerosols ▸ Gastrointestinal (intestine): Not a known route of exposure ▸ Injection (bloodstream): Not a known route of exposure **Host/Reservoir:** Rodents, humans **Vector:** Not applicable
Geographic Distribution	Eastern Europe, Eastern Asia (especially Republic of Korea)
Zoonotic	Yes
Human Transmissibility	Yes – direct and respiratory
EU Control List Entry	1C351.a.17
Applicable AG Footnote(s)	[1]

V17.2. Notable Features

Hantaan virus causes hemorrhagic fever with renal syndrome (HFRS) similar to other Old World *Hantaviruses*. *Hantaan virus* outbreaks are mostly confined to East Asia, specifically in the Republic of Korea. In addition to symptoms of generic VHF, persons with HFRS can have acute kidney failure. Transmission to humans occurs by direct contact with an infected animal or from inhalation of aerosolised urine or feces.

V17.3. Packaging

Hantaan virus is a Category A infectious substance with the shipping code UN 2814 because it is capable of causing permanent disability or life-threatening or fatal disease in otherwise healthy humans or animals when exposure to it occurs.

V17.4. Typical Applications

Basic medical research and medical countermeasure development (e.g., vaccine research), epidemiology, and global surveillance.

V18. *Hendra virus (Equine morbillivirus)*

V18.1. Basic Description

Identifier/Property	Description
Type	Virus: RNA
Associated Disease	Hendra virus disease
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Mortality rate 60% ▸ Effective aerosol ▸ No vaccine ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 4
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wound ▸ Inhalation (lungs): Aerosols ▸ Gastrointestinal (intestine): Not a known route of exposure ▸ Injection (bloodstream): Not a known route of exposure **Host/Reservoir:** Domestic animals, humans **Vector:** Bats
Geographic Distribution	Australia and South East Asia
Zoonotic	Yes
Human Transmissibility	Suspected – direct and respiratory
EU Control List Entry	1C351.a.18
Applicable AG Footnote(s)	[1]

V18.2. Notable Features

Hendra virus was first isolated in 1994 following an outbreak of respiratory and neurological diseases in horses and humans in Australia. Transmission of the disease is via direct exposure to tissues or bodily fluids from infected animals or from the urine and feces of infected bats. Hendra is predominately a virus that infects horses and other large mammals, but it has a high mortality rate when seen in humans. Infection can appear flu-like or be associated with neurologic symptoms similar to encephalitis.

V18.3. Packaging

Hendra virus is a Category A infectious substance with the shipping code UN 2814 because it is capable of causing permanent disability or life-threatening or fatal disease in otherwise healthy humans or animals when exposure to it occurs.

V18.4. Typical Applications

Basic medical research and medical countermeasure development (e.g., vaccine research), epidemiology, and global surveillance.

V19. *Japanese encephalitis virus*

V19.1. Basic Description

Identifier/Property	Description
Type	Virus: RNA
Associated Disease	Japanese encephalitis (JE)
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Mortality rate 25% ▸ Vaccine available for humans ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 2
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Not a known route of exposure ▸ Inhalation (lungs): Not a known route of exposure ▸ Gastrointestinal (intestine): Not a known route of exposure ▸ Injection (bloodstream): Mosquito bite **Host/Reservoir:** Pigs, wading birds, humans **Vector:** Mosquitoes
Geographic Distribution	Asia, Western Pacific[15]
Zoonotic	Yes
Human Transmissibility	Not transmissible
EU Control List Entry	1C351.a.21
Applicable AG Footnote(s)	[1]

V19.2. Notable Features

Outbreaks of Japanese encephalitis have been documented since the mid-1500s and are the leading cause of vaccine-preventable encephalitis in Asia and the Western Pacific. The viral life cycle includes a mosquito vector and vertebrate hosts, namely pigs and wading birds. Human infections generally are asymptomatic or present only mild symptoms; however, encephalitis can develop. Although patients that are symptomatic can have mortality rates of up to 60%, it is suspected that less than 1% of persons who contract the virus are symptomatic.

V19.3. Packaging

Japanese encephalitis virus is a Category A infectious substance with the shipping code UN 2814 because it is capable of causing permanent disability or life-threatening or fatal disease in otherwise healthy humans or animals when exposure to it occurs.

V19.4. Typical Applications

Basic medical research and medical countermeasure development (e.g., vaccine research), epidemiology, and global surveillance.

[34] Map depicting geographic distribution of Japanese encephalitis outbreaks: http://wwwnc.cdc.gov/travel/yellowbook/2014/chapter-3-infectious-diseases-related-to-travel/japanese-encephalitis.

V20. *Junin virus*

V20.1. Basic Description

Identifier/Property	Description
Type	Virus: RNA
Associated Disease	Argentine hemorrhagic fever, O'Higgins disease
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Mortality rate 5–35% ▸ Effective aerosol ▸ Vaccine available ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 4
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wound ▸ Inhalation (lungs): Aerosols ▸ Gastrointestinal (intestine): Not a known route of exposure ▸ Injection (bloodstream): Not a known route of exposure **Host/Reservoir:** Rodents, humans **Vector:** Not applicable
Geographic Distribution	Argentina
Human Transmissibility	Yes – direct and respiratory
Zoonotic	Yes
EU Control List Entry	1C351.a.22
Applicable AG Footnote(s)	[1]

V20.2. Notable Features

First identified in the late 1950s, *Junin virus* is the causative agent of Argentine hemorrhagic fever. The natural host of the virus is the corn mouse; similar to other viruses in the *Arenaviridae* family, *Junin virus* is shed through urine, feces, and saliva from infected rodents. Human infection results from direct contact with an infected animal or direct exposure to urine, feces, or aerosolised bodily fluids. Exposure is often linked to contaminated food or water supplies. Similar to other VHFs, Argentine hemorrhagic fever has major effects on the vascular, neurological, and immune systems. A vaccine is available and used in populations within Argentina that are deemed to be at very high risk for contracting the disease. Mortality rate if left untreated is 10–30%; this can be as low as 1% if treated with convalescent plasma, but there are significant neurological side effects that can develop as a result of this therapy. Therefore, treatment options for Argentine hemorrhagic fever once a person develops symptoms are limited.

V20.3. Packaging

Junin virus is a Category A infectious substance with the shipping code UN 2814 because it is capable of causing permanent disability or life-threatening or fatal disease in otherwise healthy humans or animals when exposure to it occurs.

V20.4. Typical Applications

Basic medical research and medical countermeasure development (e.g., vaccine research), epidemiology, and global surveillance.

V21. *Kyasanur Forest disease virus*

V21.1. Basic Description

Identifier/Property	Description
Type	Virus: RNA
Associated Disease	Kyasanur forest disease, monkey fever, monkey disease
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Mortality rate 3–5% ▸ Potential aerosol ▸ No vaccine ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 4
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wound ▸ Inhalation (lungs): Not a known route of exposure ▸ Gastrointestinal (intestine): Not a known route of exposure ▸ Injection (bloodstream): Tick bite **Host/Reservoir:** Monkeys, humans, porcupine, rats, squirrels, shrews **Vector:** Ticks
Geographic Distribution	India
Zoonotic	Yes
Human Transmissibility	Not transmissible
EU Control List Entry	1C351.a.23
Applicable AG Footnote(s)	[1]

V21.2. Notable Features

First identified in 1957 from an infected monkey from the Kyasanur Forest in India, Kyasanur forest disease virus (KFDV) infects humans through the bite of an infected tick. The primary reservoir for KFDV includes rodents, shrews, bats, and monkeys. In addition to a tick bite, humans can contract the disease through contact with the bodily fluids or carcass of a diseased animal. Symptoms include fever, headache, severe muscle pain, cough, dehydration, low blood pressure, and possibly signs of encephalitis. In addition to humans, goats, cows, and sheep are also susceptible to the disease.

V21.3. Packaging

Kyasanur Forest disease virus is a Category A infectious substance with the shipping code UN 2814 because it is capable of causing permanent disability or life-threatening or fatal disease in otherwise healthy humans or animals when exposure to it occurs.

V21.4. Typical Applications

Basic medical research and medical countermeasure development (e.g., vaccine research), epidemiology, and global surveillance.

V22. *Laguna Negra virus*

V22.1. Basic Description

Identifier/Property	Description
Type	Virus: RNA
Associated Disease	Hantavirus pulmonary syndrome (HCPS or HPS)
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Mortality rate 10–30% ▸ Effective aerosol ▸ No vaccine ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 3
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wound ▸ Inhalation (lungs): Aerosols ▸ Gastrointestinal (intestine): Not a known route of exposure ▸ Injection (bloodstream): Not a known route of exposure **Host/Reservoir:** Rodents, humans **Vector:** Not applicable
Geographic Distribution	South America
Zoonotic	Yes
Human Transmissibility	Not transmissible
EU Control List Entry	1C351.a.24
Applicable AG Footnote(s)	[1]

V22.2. Notable Features

First seen in Paraguay in the 1990s, *Laguna Negra virus* is a New World species of *Hantavirus* that causes a fairly mild form of HCPS. The corn mouse is the reservoir for *Laguna Negra virus*, and current documented cases of HCPS that result from *Laguna Negra virus* are limited to South America. Human infection occurs from direct exposure to infected rodent urine, feces, or other bodily secretions.

V22.3. Packaging

Laguna Negra virus does not have a category designation but meets the qualifications for handling as a Category A infectious substance because it is capable of causing permanent disability or life-threatening or fatal disease in otherwise healthy humans when exposure to it occurs. Therefore, *Laguna Negra virus* should be handled with shipping code UN 2814.[35]

V22.4. Typical Applications

Basic medical research and medical countermeasure development (e.g., vaccine research), epidemiology, and global surveillance.

[35] The UN Model Regulations state that the Category A listing of infectious substances "…is not exhaustive. Infectious substances, including new or emerging pathogens, which do not appear in the table but which meet the same criteria shall be assigned to Category A. In addition, if there is doubt as to whether or not a substance meets the criteria it shall be included in Category A." See Volume I, Chapter 2 https://www.unece.org/trans/danger/publi/unrec/rev21/21files_e.html.

V23. *Lassa virus*

V23.1. Basic Description

Identifier/Property	Description
Type	Virus: RNA
Associated Disease	Lassa fever, Lassa hemorrhagic fever
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Mortality rate 5–50% ▸ Effective aerosol ▸ No vaccine ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 4
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wound ▸ Inhalation (lungs): Aerosols ▸ Gastrointestinal (intestine): Ingestion of contaminated food or water ▸ Injection (bloodstream): Not a known route of exposure **Host/Reservoir:** Rodents, humans **Vector:** Not applicable
Geographic Distribution	West Africa
Zoonotic	Yes
Human Transmissibility	Yes – direct and respiratory
EU Control List Entry	1C351.a.25
Applicable AG Footnote(s)	[1]

V23.2. Notable Features

Discovered in 1969 following the deaths of two missionary nurses in Nigeria, Lassa fever is a viral illness causing VHF. In parts of Africa where the disease is endemic, there are high rates of human infection and death. Signs and symptoms of exposure and infection range from mild to asymptomatic, but some cases cause multisystem disease and can have a mortality rate as high as 50% during an epidemic. The natural reservoir of the virus is a rodent rat species. Increased incidence of the disease has occurred when humans cohabitate with these rats. The virus is transmitted to humans by rodent urine, feces, or from direct contact with infectious bodily fluids. The virus can also spread through contaminated food or water. Symptoms include fever, chest pain, sore throat, back pain, cough, abdominal pain, vomiting, diarrhea, eye infection, facial swelling, and mucosal bleeding. The most common complication of Lassa fever is deafness.

V23.3. Packaging

Lassa virus is a Category A infectious substance with the shipping code UN 2814 because it is capable of causing permanent disability or life-threatening or fatal disease in otherwise healthy humans or animals when exposure to it occurs.

V23.4. Typical Applications

Basic medical research and medical countermeasure development (e.g., vaccine research), epidemiology, and global surveillance.

V24. *Louping ill virus*

V24.1. Basic Description

Identifier/Property	Description
Type	Virus: RNA
Associated Disease	Louping ill, ovine encephalomyelitis, infectious encephalomyelitis of sheep, Trembling ill
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Mortality rate <1% ▸ Potential aerosol ▸ Vaccine available ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 3
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wound ▸ Inhalation (lungs): Not a known route of exposure ▸ Gastrointestinal (intestine): Ingestion of infectious bodily fluids and undercooked meat ▸ Injection (bloodstream): Tick bite **Host/Reservoir:** Sheep, red grouse, goats, humans **Vector:** Ticks
Geographic Distribution	Western Europe
Zoonotic	Yes
Human Transmissibility	Not transmissible
EU Control List Entry	1C351.a.26
Applicable AG Footnote(s)	[1]

V24.2. Notable Features

Louping ill virus is a tick-transmitted viral disease primarily of sheep and red grouse. However, it also can manifest disease in humans, making sheep herders particularly susceptible to the illness. *Louping ill virus* is transmitted most commonly through a tick vector. However, transmission also occurs through direct contact and consumption of infectious bodily fluids or raw meat. There are four subtypes of the virus: British, Irish, Spanish, and Turkish. Infection causes neurological disease in sheep and birds, and the mortality rate can be as high as 80%. A vaccine for sheep is available and used in regions with endemic disease. Louping ill is rarely fatal in humans, but it can cause either flu-like or neurological complications.

V24.3. Packaging

Louping ill virus is a Category B infectious substance with the shipping code UN 3373 because it is infectious but does not meet the criteria for Category A.

V24.4. Typical Applications

Basic medical research and medical countermeasure development (e.g., vaccine research), epidemiology, and global surveillance.

V25. *Lujo virus*

V25.1. Basic Description

Identifier/Property	Description
Type	Virus: RNA
Associated Disease	Lujo hemorrhagic fever (LUHF)
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Mortality rate 80%[17] ▸ Effective aerosol ▸ No vaccine ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 4
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wound ▸ Inhalation (lungs): Aerosols ▸ Gastrointestinal (intestine): Not a known route of exposure ▸ Injection (bloodstream): Not a known route of exposure **Host/Reservoir:** Rodents, humans **Vector:** Not applicable
Geographic Distribution	Africa
Zoonotic	Yes
Human Transmissibility	Yes – direct and respiratory
EU Control List Entry	1C351.a.27
Applicable AG Footnote(s)	[1]

V25.2. Notable Features

Lujo virus was first discovered following a hospital outbreak in Johannesburg, South Africa, in 2008. The disease outbreak was limited to five individuals, and no cases have been seen since that time. Since *Lujo virus* is a species of *Arenaviridae* and presented with similar VHF disease manifestations, it is assumed that the virus is spread via aerosolised rodent urine, feces, or other bodily fluids.

V25.3. Packaging

Lujo virus does not have a category designation but meets the qualifications for handling as a Category A infectious substance because it is capable of causing permanent disability or life-threatening or fatal disease in otherwise healthy humans when exposure to it occurs. Therefore, *Lujo virus* should be handled with shipping code UN 2814.[37]

[36] Mortality rate is based on five documented cases of the disease. Four patients acquired the virus through exposure to the first infected patient once he/she was hospitalised. Therefore, the mortality rate in the event of future outbreaks is unknown. See http://www.cdc.gov/vhf/lujo/.

[37] The UN Model Regulations state that the Category A listing of infectious substances "…is not exhaustive. Infectious substances, including new or emerging pathogens, which do not appear in the table but which meet the same criteria shall be assigned to Category A. In addition, if there is doubt as to whether or not a substance meets the criteria it shall be included in Category A." See Volume I, Chapter 2 https://www.unece.org/trans/danger/publi/unrec/rev21/21files_e.html.

V25.4. Typical Applications

Basic medical research and medical countermeasure development (e.g., vaccine research), epidemiology, and global surveillance.

V26. *Lumpy skin disease virus*

V26.1. Basic Description

Identifier/Property	Description
Type	Virus: DNA
Associated Disease	Lumpy skin disease
Other Names	Neethling virus
Key WMD Characteristic(s)	▸ Mortality rate 1–3% ▸ Potential aerosol ▸ Potential for socioeconomic harm ▸ Vaccine available ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 3; subject to enhanced containment for countries with vulnerable agriculture
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wound ▸ Inhalation (lungs): Not a known route of exposure ▸ Gastrointestinal (intestine): Consumption of contaminated food, milk, and water ▸ Injection (bloodstream): Mosquito bite **Host/Reservoir:** Cattle **Vector:** Mosquito
Geographic Distribution	Sub-Saharan Africa, Egypt, Israel
Zoonotic	No
Human Transmissibility	Not transmissible
EU Control List Entry	1C351.a.28
Applicable AG Footnote(s)	[1]

V26.2. Notable Features

Lumpy skin disease virus is a viral species belonging to the *Poxviridae* family that causes disease in cattle. Lumpy skin disease outbreaks are mostly confined to sub-Saharan Africa, and Egypt. An outbreak was seen in Israel in the late 1980s, but the virus is currently considered eradicated due to containment and vaccination efforts. The mortality rate is usually 1–3% although acute outbreaks have mortality rates as high as 80%. Outbreaks in domestic herds can result in decreased milk production, infertility, abortion, damaged hides, and death. Disease symptoms include fever and nodules on the skin and mucous membranes. In severe forms of the disease, it is common for nodules to burst, leaving cattle susceptible to secondary bacterial infection. Outbreaks are controlled by quarantine of infected or exposed animals, insect control, vaccination, culling, and sanitisation of exposed areas and surfaces. Vaccines are available and used in some African countries.

V26.3. Packaging

Lumpy skin disease virus is a Category A infectious substance with the shipping code UN 2900 because it is capable of causing permanent disability or life-threatening or fatal disease in otherwise healthy animals when exposure to it occurs.

V26.4. Typical Applications

Basic medical research and medical countermeasure development (e.g., vaccine research), epidemiology, and global surveillance.

V27. *Lymphocytic choriomeningitis virus*

V27.1. Basic Description

Identifier/Property	Description
Type	Virus: RNA
Associated Disease	Lymphocytic choriomeningitis (LCM)
Other Names	LCMV
Key WMD Characteristic(s)	▸ Mortality rate <1% ▸ Effective aerosol ▸ No vaccine ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 3
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wound ▸ Inhalation (lungs): Aerosols ▸ Gastrointestinal (intestine): Not a known route of exposure ▸ Injection (bloodstream): Not a known route of exposure **Host/Reservoir:** Rodents, humans **Vector:** Not applicable
Geographic Distribution	Worldwide, except Antarctica
Zoonotic	Yes
Human Transmissibility	Not transmissible
EU Control List Entry	1C351.a.29
Applicable AG Footnote(s)	[1]

V27.2. Notable Features

Lymphocytic choriomeningitis virus (LCMV) is the one species of *Arenaviridae* currently found in both the Old World and New World. LCMV causes an infection of the membranes and cerebrospinal fluid surrounding the brain and spinal cord. The natural reservoir for LCMV is the common house mouse, which becomes chronically infected and constantly sheds the virus in saliva and excrement. Human infection occurs from direct contact or from feces, urine, other bodily fluids, or nesting materials from an infected mouse. Acute infections in humans often clear naturally with no long-term consequences. Despite its prevalence, infection with LCMV is not commonly reported in humans; generally, symptoms are mild and the disease is never diagnosed.

V27.3. Packaging

Lymphocytic choriomeningitis virus is a Category B infectious substance with the shipping code UN 3373 because it is infectious but does not meet the criteria for Category A.

V27.4. Typical Applications

Basic medical research and medical countermeasure development (e.g., vaccine research), epidemiology, and global surveillance.

V28. *Machupo virus*

V28.1. Basic Description

Identifier/Property	Description
Type	Virus: RNA
Associated Disease	Bolivian hemorrhagic fever (BHF), black typhus, ordog fever
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Mortality rate 15–30% ▸ Effective aerosol ▸ No vaccine ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 4
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wound ▸ Inhalation (lungs): Aerosols ▸ Gastrointestinal (intestine): Ingestion of contaminated food or water ▸ Injection (bloodstream): Not a known route of exposure **Host/Reservoir:** Rodents, humans **Vector:** Not applicable
Geographic Distribution	South America
Zoonotic	Yes
Human Transmissibility	Yes – direct and respiratory
EU Control List Entry	1C351.a.30
Applicable AG Footnote(s)	[1]

V28.2. Notable Features

First identified in 1959, *Machupo virus* is endemic to rural parts of Bolivia, and it is spreading because the rodent reservoir is found over most of South America. The primary reservoir of the virus is the vesper mouse, and the virus is shed through urine, feces, and saliva from infected rodents. Human infection occurs from direct contact with an infected animal; inhalation of aerosolised urine, feces, or other bodily fluids; or consumption of contaminated foods or water. Like other species of *Arenaviridae*, symptoms of Bolivian hemorrhagic fever are similar to other VHFs and include eye infection, bleeding gums and cavities, headache, joint pain, and small rash-like haemorrhages on the skin.

V28.3. Packaging

Machupo virus is a Category A infectious substance with the shipping code UN 2814 because it is capable of causing permanent disability or life-threatening or fatal disease in otherwise healthy humans or animals when exposure to it occurs.

V28.4. Typical Applications

Basic medical research and medical countermeasure development (e.g., vaccine research), epidemiology, and global surveillance.

V29. *Marburgvirus:* all members of the *Marburgvirus* genus

V29.1. Basic Description

Identifier/Property	Description
Type	Virus: RNA
Associated Disease	Marburg virus disease, Marburg hemorrhagic fever
Other Names	*Lake Victoria marburgvirus, Marburg marburgvirus*
Key WMD Characteristic(s)	▸ Mortality rate 23–90% ▸ Effective aerosol ▸ No vaccine ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 4
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wound ▸ Inhalation (lungs): Aerosols ▸ Gastrointestinal (intestine): Not a known route of exposure ▸ Injection (bloodstream): Not a known route of exposure **Host/Reservoir:** Primates, humans **Vector:** Bats
Geographic Distribution	Africa
Zoonotic	Yes
Human Transmissibility	Yes – direct
EU Control List Entry	1C351.a.31
Applicable AG Footnote(s)	[1]

V29.2. Notable Features

First described in a laboratory-confirmed outbreak in Germany in 1967, Marburg hemorrhagic fever is a rare disease in humans, and confirmed outbreaks throughout Africa have been sporadic, isolated events. The primary reservoir of the virus is the African fruit bat. Disease manifestations of severe VHF are similar in both humans and nonhuman primates. Direct contact with infected animals, tissues, and bodily fluids can transmit the virus to humans.

V29.3. Packaging

Members of the *Marburgvirus* genus are Category A infectious substances with the shipping code UN 2814 because they are capable of causing permanent disability or life-threatening or fatal disease in otherwise healthy humans or animals when exposure to them occurs.

V29.4. Typical Applications

Basic medical research and medical countermeasure development (e.g., vaccine research), epidemiology, and global surveillance.

V30. *Middle East respiratory syndrome-related coronavirus (MERS-CoV)*

V30.1. Basic Description

Identifier/Property	Description
Type	Virus: RNA
Associated Disease	Middle East Respiratory Syndrome (MERS)
Other Names	MERS-CoV, Camel Flu
Key WMD Characteristic(s)	▸ Mortality rate 30-40% ▸ Effective aerosol ▸ No vaccine ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 3
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wound ▸ Inhalation (lungs): Aerosols, droplets ▸ Gastrointestinal (intestine): Not a known route of exposure ▸ Injection (bloodstream): Not a known route of exposure **Host/Reservoir:** Humans, dromedary camel **Vector:** Not applicable
Geographic Distribution	Saudi Arabia and the Arabian Peninsula, worldwide via travel
Zoonotic	Yes
Human Transmissibility	Yes
EU Control List Entry	1C351.a.59
Applicable AG Footnote(s)	[1]

V30.2. Notable Features

All reported cases of *Middle East respiratory syndrome-related coronavirus* have been linked to countries in and near the Arabian Peninsula, with most either living in the Arabian Peninsula or recently traveled from the Arabian Peninsula before they became ill. A few cases are known to have gotten MERS after having close contact with an infected person who had recently traveled from the Arabian Peninsula. The largest known outbreak of MERS outside the Arabian Peninsula occurred in the Republic of Korea in 2015 and was associated with a traveler returning from the Arabian Peninsula. Initial symptoms of Middle East respiratory syndrome (MERS) include fever, cough, and shortness of breath that often manifest into more severe symptoms of pneumonia, kidney failure, and death. Most people who died of MERS had a pre-existing or underlying medical condition. There is no effective vaccine, and post-exposure treatment options are limited to supportive care.

V30.3. Packaging

A specimen infected with *Middle East respiratory syndrome-related coronavirus* is considered a Category B infectious substance with the shipping code UN 3373 because it is infectious but does not meet the criteria for Category A.

V30.4. Typical Applications

Basic medical research and medical countermeasure development (e.g. vaccine research), epidemiology, and global surveillance.

V31. *Monkeypox virus*

V31.1. Basic Description

Identifier/Property	Description
Type	Virus: DNA
Associated Disease	Monkeypox (MPV)
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Mortality rate 0–10% ▸ Effective aerosol ▸ *Variola virus* vaccine provides protection ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 3
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wound ▸ Inhalation (lungs): Aerosols ▸ Gastrointestinal (intestine): Not a known route of exposure ▸ Injection (bloodstream): Not a known route of exposure **Host/Reservoir:** Primates, rats, squirrels, rabbits, humans **Vector:** Not applicable
Geographic Distribution	Tropics of Central and West Africa
Zoonotic	Yes
Human Transmissibility	Yes – direct and respiratory
EU Control List Entry	1C351.a.32
Applicable AG Footnote(s)	[1]

V31.2. Notable Features

Monkeypox virus causes a disease similar to other *Poxviridae*. Although it is called monkeypox, the virus has been isolated from other small mammals like rats, mice, and rabbits. Symptoms are generally quite mild and the mortality rate relatively low. Transmission occurs through direct contact with bodily fluids or from the bite of an infected animal. Although the disease only occurs naturally in Africa, an outbreak occurred in the United States as the result of imported infected prairie dogs. Transmission occurs through direct contact with an infected human or animal or its bodily fluids by aerosolisation of respiratory droplets. Symptoms include fever, backache, headache, swollen lymph nodes, and a blister-like rash. Due to genetic similarities between different *Poxviridae*, the *Variola* vaccine is thought to provide cross-protection against the *Monkeypox virus* in humans. Vaccination against *Variola major virus* seems to prevent fatal cases of monkeypox.

V31.3. Packaging

Monkeypox virus is a Category A infectious substance with the shipping code UN 2814 because it is capable of causing permanent disability or life-threatening or fatal disease in otherwise healthy humans or animals when exposure to it occurs.

V31.4. Typical Applications

Basic medical research and medical countermeasure development (e.g., vaccine research), epidemiology, and global surveillance.

V32. *Murray Valley encephalitis virus*

V32.1. Basic Description

Identifier/Property	Description
Type	Virus: RNA
Associated Disease	Murray Valley encephalitis, Australian encephalitis
Other Names	MVEV
Key WMD Characteristic(s)	▸ Mortality rate 25% ▸ Potential aerosol ▸ No vaccine ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 3
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Not a known route of exposure ▸ Inhalation (lungs): Not a known route of exposure ▸ Gastrointestinal (intestine): Not a known route of exposure ▸ Injection (bloodstream): Mosquito bite **Host/Reservoir:** Aquatic birds, horses, humans **Vector:** Mosquitoes
Geographic Distribution	Northern Australia, Papua New Guinea, and Eastern Indonesia
Zoonotic	Yes
Human Transmissibility	Not transmissible
EU Control List Entry	1C351.a.33
Applicable AG Footnote(s)	[1]

V32.2. Notable Features

Murray Valley encephalitis was first described in an epidemic in 1917–1918 in Southeastern Australia. The virus can cause serious infections that result in permanent neurological disease or death. Transmission to humans occurs from the bite of an infected mosquito, not from manual transmission via direct contact with an infected animal or fluids. Migratory birds can be carriers of the virus to non-endemic areas. Confirmed clinical infection is quite rare as it is believed that most infections present mild symptoms or are asymptomatic. In a small number of patients, MVEV presents symptoms indicative of encephalitis caused by *Flaviviridae* encephalitis: nausea, vomiting, and macular rash, followed by neurologic symptoms. Outbreaks are common in Australia and are often associated with rainfall or flood-affected areas.[38]

V32.3. Packaging

Murray Valley encephalitis virus is a Category B infectious substance with the shipping code UN 3373 because it is infectious but does not meet the criteria for Category A.

V32.4. Typical Applications

Basic medical research and medical countermeasure development (e.g., vaccine research), epidemiology, and global surveillance.

[38] Additional information on Murray Valley encephalitis can be found at http://www.health.nsw.gov.au/Infectious/factsheets/Pages/Murray-Valley-Encephalitis.aspx.

V33. *Newcastle disease virus*

V33.1. Basic Description

Identifier/Property	Description
Type	Virus: RNA
Associated Disease	Newcastle disease
Other Names	NDV
Key WMD Characteristic(s)	▸ Mortality rate 10–90% ▸ Effective aerosol ▸ Potential for socioeconomic harm ▸ Potential to damage the environment ▸ Vaccine available ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 3; subject to enhanced containment for countries with vulnerable agriculture
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wound ▸ Inhalation (lungs): Aerosols ▸ Gastrointestinal (intestine): Consumption of contaminated food and water ▸ Injection (bloodstream): Not a known route of exposure **Host/Reservoir:** Birds, humans **Vector:** Not applicable
Geographic Distribution	Asia, Middle East, North and South America
Zoonotic	Yes
Human Transmissibility	Yes – direct and respiratory
EU Control List Entry	1C351.a.34
Applicable AG Footnote(s)	[1]

V33.2. Notable Features

Newcastle disease virus is a species belonging to the *Paramyxoviridae* family that manifests disease in hundreds of species of birds including poultry and aquatic birds. NDV is also capable of manifesting disease in humans. Strains of *Newcastle disease virus* are categorised into three types based on the virulence in chickens: lentogenic, mesogenic, and velogenic. The most virulent strains are endemic to Asia, the Middle East, and Central and South America. Less virulent strains are endemic to the United States and Canada. Transmission can occur through direct contact with infectious bodily fluids, inhalation of aerosolised virus particles, or ingestion of contaminated food and water. Mild (lentogenic or mesogenic) forms of Newcastle disease can manifest mild respiratory and neurologic disease with low mortality rates. Severe (velogenic) strains are often fatal and present with eye reddening, diarrhea, respiratory distress, swelling of the neck and head, and neurologic symptoms such as tremors, spasms, twisted neck, circling, and paralysis. In humans, NDV causes a mild infection with flu-like symptoms. NDV infection in humans also can cause conjunctivitis and laryngitis. Vaccines are widely available for domestic poultry and are used with varying frequency in endemic countries.

V33.3. Packaging

Newcastle disease virus is a Category A infectious substance with the shipping code UN 2900 because it is capable of causing permanent disability or life-threatening or fatal disease in otherwise healthy animals when exposure to it occurs.

V33.4. Typical Applications

Basic medical research and medical countermeasure development (e.g., vaccine research), epidemiology, and global surveillance.

V34. *Nipah virus*

V34.1. Basic Description

Identifier/Property	Description
Type	Virus: RNA
Associated Disease	Nipah virus encephalitis
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Mortality rate 40–74% ▸ Effective aerosol ▸ No vaccine ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 4
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wound ▸ Inhalation (lungs): Aerosols ▸ Gastrointestinal (intestine): Not a known route of exposure ▸ Injection (bloodstream): Not a likely route of exposure **Host/Reservoir:** Pigs, humans **Vector:** Bats
Geographic Distribution	Bangladesh, Singapore, Thailand, Malaysia
Zoonotic	Yes
Human Transmissibility	Yes – direct and respiratory
EU Control List Entry	1C351.a.35
Applicable AG Footnote(s)	[1]

V34.2. Notable Features

Nipah virus was first isolated in 1999 following an outbreak of encephalitis and respiratory illness among adult men in Malaysia and Singapore. Viral transmission can occur from bat to pig to human as seen in cases in Malaysia and Singapore, or it can be direct from infected bats to humans as seen in Bangladesh. Transmission to humans results from direct contact with infected animals or contaminated tissues and bodily fluids. Disease manifestation in humans includes fever and drowsiness followed by severe symptoms within 24 to 48 hours, including encephalitis or more severe central nervous system conditions (i.e., coma, seizures, and the inability to maintain breathing).

V34.3. Packaging

Nipah virus is a Category A infectious substance with the shipping code UN 2814 because it is capable of causing permanent disability or life-threatening or fatal disease in otherwise healthy humans or animals when exposure to it occurs.

V34.4. Typical Applications

Basic medical research and medical countermeasure development (e.g., vaccine research), epidemiology, and global surveillance.

V35. *Omsk hemorrhagic fever virus*

V35.1. Basic Description

Identifier/Property	Description
Type	Virus: RNA
Associated Disease	Omsk hemorrhagic fever
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Mortality rate 0.5–3% ▸ Potential aerosol ▸ Environmentally stable ▸ No vaccine ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 4
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wound ▸ Inhalation (lungs): Not a known route of exposure ▸ Gastrointestinal (intestine): Ingestion of contaminated water ▸ Injection (bloodstream): Tick bite **Host/Reservoir:** Muskrats, voles, humans **Vector:** Ticks
Geographic Distribution	Western Siberia
Zoonotic	Yes
Human Transmissibility	Not transmissible
EU Control List Entry	1C351.a.36
Applicable AG Footnote(s)	[1]

V35.2. Notable Features

First described in 1945 in Omsk, Russia, from patients experiencing VHF, *Omsk hemorrhagic fever virus* is a species in the *Flaviviridae* genus transmitted to its host via an infected tick. The virus mainly affects muskrats and voles but has the ability to infect to humans as well. The virus survives in water; this can be a possible route of transmission for humans and other small mammals in addition to direct contact with the bodily fluids, urine, and feces of small mammals infected with the virus. Patients initially experience symptoms typical of a VHF; however, the disease can be biphasic. Therefore, after initial recovery of symptoms, some individuals experience fever and encephalitis.

V35.3. Packaging

Omsk hemorrhagic fever virus is a Category A infectious substance with the shipping code UN 2814 because it is capable of causing permanent disability or life-threatening or fatal disease in otherwise healthy humans or animals when exposure to it occurs.

V35.4. Typical Applications

Basic medical research and medical countermeasure development (e.g., vaccine research), epidemiology, and global surveillance.

V36. *Oropouche virus*

V36.1. Basic Description

Identifier/Property	Description
Type	Virus: RNA
Associated Disease	Oropouche fever
Other Names	OROV
Key WMD Characteristic(s)	▸ Mortality rate <10–50% ▸ Potential aerosol ▸ No vaccine ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 3
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Not a known route of exposure ▸ Inhalation (lungs): Not a known route of exposure ▸ Gastrointestinal (intestine): Not a known route of exposure ▸ Injection (bloodstream): Mosquito or midge bite **Host/Reservoir:** Sloths, marsupials, primates, birds, humans **Vector:** Mosquitoes, midges
Geographic Distribution	Caribbean, Central America, South America
Zoonotic	Yes
Human Transmissibility	Not transmissible
EU Control List Entry	1C351.a.37
Applicable AG Footnote(s)	[1]

V36.2. Notable Features

First described in a laboratory in the mid 1950s, *Oropouche virus* is named for the Oropouche River in Trinidad and Tobago where outbreaks of the disease were first documented. *Oropouche virus* is found in tropical and subtropical areas of Central and South America. The virus is transmitted to humans from the bite of an infected midge or mosquito; however reservoirs of the virus include sloths, marsupials, primates, and birds. Direct contact with an infected carrier or its bodily fluids can result in transmission of the virus to humans. The disease is not known to be fatal but does cause symptoms including high fever, severe headache, severe pain behind the eyes, joint pain, muscle and bone pain, rash, and mild bleeding. Patients can also develop meningitis.

V36.3. Packaging

Oropouche virus is a Category B infectious substance with the shipping code UN 3373 because it is infectious but does not meet the criteria for Category A.

V36.4. Typical Applications

Basic medical research and medical countermeasure development (e.g., vaccine research), epidemiology, and global surveillance.

V37. *Peste-des-petits ruminants virus*

V37.1. Basic Description

Identifier/Property	Description
Type	Virus: RNA
Associated Disease	PPR, ovine rinderpest, goat plague, pseudorinderpest, pest of small ruminants, pest of sheep and goats, stomatitis-pneumoenteritis syndrome
Other Names	PPRV
Key WMD Characteristic(s)	▸ Mortality rate 20–96% ▸ Effective aerosol ▸ Potential for socioeconomic harm ▸ Potential to damage the environment ▸ Effective vaccine ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 3; subject to enhanced containment for countries with vulnerable agriculture
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wound ▸ Inhalation (lungs): Aerosols ▸ Gastrointestinal (intestine): Consumption of contaminated food or water ▸ Injection (bloodstream): Not a known route of exposure **Host/Reservoir:** Goats, sheep, buffalo, gazelles, ibex **Vector:** Not applicable
Geographic Distribution	Africa, Middle East, Asia (Indian subcontinent)
Zoonotic	No
Human Transmissibility	Not transmissible
EU Control List Entry	1C351.a.38
Applicable AG Footnote(s)	[1]

V37.2. Notable Features

Peste-des-petits ruminants virus is a species of the Paramyxoviridae family. Peste-des-petits ruminants is most commonly seen in goats and sheep, but isolated outbreaks have been documented in buffalos, gazelles, and ibex. Peste-des-petits ruminants outbreaks occur in Africa, the Middle East, and parts of Asia (Indian subcontinent). Transmission of the PPRV occurs through direct contact with infectious bodily fluids and inhalation of aerosolised virus particles. The virus is not very stable outside an animal host; however, transmission can occur through inhalation of aerosolised virus particles over short distances or ingestion of contaminated water and food. Symptoms of peste-des-petits ruminants vary in severity but can include fever, malaise, nasal and ocular discharge, oral and vaginal lesions, diarrhea, respiratory distress, dehydration, and death. Vaccines are available for *Peste-des-petits ruminants virus* and are used with varying frequency worldwide. Vaccination against *Rinderpest virus* provides some cross-protection against PPRV due to genetic similarities between PPRV and *Rinderpest virus*.

V37.3. Packaging

Peste-des-petits ruminants virus is a Category A infectious substance with the shipping code UN 2900 because it is capable of causing permanent disability or life-threatening or fatal disease in otherwise healthy animals when exposure to it occurs.

V37.4. Typical Applications

Basic medical research and medical countermeasure development (e.g., vaccine research), epidemiology, and global surveillance.

V38. *Porcine teschovirus*

V38.1. Basic Description

Identifier/Property	Description
Type	Virus: RNA
Associated Disease	Talfan disease, Teschen disease, porcine enteroviral encephalomyelitis disease, teschovirus encephalomyelitis, Klobouk's disease
Other Names	PTV
Key WMD Characteristic(s)	▸ Mortality rate <90% ▸ Potential aerosol ▸ Environmentally stable ▸ Vaccine exists, but not commercially available ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 3; subject to enhanced containment for countries with vulnerable agriculture
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wound ▸ Inhalation (lungs): Not a known route of exposure ▸ Gastrointestinal (intestine): Consumption of contaminated food ▸ Injection (bloodstream): Not a known route of exposure **Host/Reservoir:** Pigs **Vector:** Not applicable
Geographic Distribution	Europe, Madagascar, Japan
Zoonotic	No
Human Transmissibility	Not transmissible
EU Control List Entry	1C351.a.50
Applicable AG Footnote(s)	[1]

V38.2. Notable Features

Porcine teschovirus is a member of the *Picornaviridae* family and is the causative agent of Teschen disease. First named for its discovery in Teschen, Czechoslovakia, in 1929, Teschen disease is also known as teschovirus encephalomyelitis because it causes a virulent form of encephalomyelitis in pigs. *Porcine teschovirus* has also been known at various points in history as *Procine enterovirus 1*.[39]

Although mild and asymptomatic forms of the disease occur worldwide, teschovirus encephalomyelitis is limited to Europe, Madagascar, and Japan. Incidence of the disease in Western Europe has not occurred since the 1980s. Transmission of the virus can occur through direct contact with contaminated bodily fluids or ingestion of undercooked meat products. Clinical symptoms of teschovirus encephalomyelitis include fever, malaise, neurologic symptoms (hypersensitivity to pain, incoordination, paralysis), and death. Other strains are relatively asymptomatic in adult pigs but can cause neurological disease in piglets. A vaccine exists for *Porcine teschovirus*, but it is not commercially available due to successful eradication efforts in certain parts of the world.

[39] *Porcine teschovirus* was first officially referred to as *Porcine enterovirus* when the International Committee on Taxonomy of Viruses (ICTV) added the virus to its taxonomy list in 1975. In 1979, the ICTV split the *Porcine enterovirus* species into eight subtypes (Porcine enterovirus 1–8). In the late 1990s, *Porcine enterovirus 1* was renamed *Porcine teschovirus* and given its own genus (*Teschovirus*). Additional information on the taxonomy history of *Porcine teschovirus* can be found through the ICTV website: https://talk.ictvonline.org/taxonomy/.

V38.3. Packaging

Porcine teschovirus is a Category B infectious substance with the shipping code UN 3373 because it is infectious but does not meet the criteria for Category A.

V38.4. Typical Applications

Basic medical research and medical countermeasure development (e.g., vaccine research), epidemiology, and global surveillance.

V39. *Powassan virus*

V39.1. Basic Description

Identifier/Property	Description
Type	Virus: RNA
Associated Disease	Powassan encephalitis, POW
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Mortality rate 10% ▸ Potential aerosol ▸ No vaccine ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 3
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Not a known route of exposure ▸ Inhalation (lungs): Not a known route of exposure ▸ Gastrointestinal (intestine): Not a known route of exposure ▸ Injection (bloodstream): Tick bite **Host/Reservoir:** Small mammals (woodchucks, squirrels, chipmunks, voles, hares, skunks, and raccoons), humans **Vector:** Ticks
Geographic Distribution	North America; Russia
Zoonotic	Yes
Human Transmissibility	Not transmissible
EU Control List Entry	1C351.a.40
Applicable AG Footnote(s)	[1]

V39.2. Notable Features

Primarily found in the Northern United States and Canada, cases of POW also have been diagnosed in Russia. Transmission of the disease to humans is through a bite from an infected tick. Disease manifestation includes generic flu-like symptoms that can develop into encephalitis and other neurologic complications such as meningitis, seizures, loss of coordination, confusion, nausea, and vomiting.

V39.3. Packaging

Powassan virus is a Category B infectious substance with the shipping code UN 3373 because it is infectious but does not meet the criteria for Category A.

V39.4. Typical Applications

Basic medical research and medical countermeasure development (e.g., vaccine research), epidemiology, and global surveillance.

V40. *Rabies virus* and other members of the *Lyssavirus* genus

V40.1. Basic Description

Identifier/Property	Description
Type	Virus: RNA
Associated Disease	Rabies, rabies-like
Other Names	*Rabies-related Lyssavirus*
Key WMD Characteristic(s)	▸ Mortality rate varies in animals (100% in humans without immediate post-exposure vaccination) ▸ Effective aerosol
Containment and Handling	Biosafety Level 2; Biosafety Level 3 may be used if activity has high potential for producing aerosols
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wound ▸ Inhalation (lungs): Aerosols ▸ Gastrointestinal (intestine): Not a known route of exposure ▸ Injection (bloodstream): Animal bite **Host/Reservoir:** Warm blooded animals (numerous): e.g., humans, bats, dogs, cats **Vector:** Not applicable
Geographic Distribution	Worldwide (certain countries are considered rabies-free)
Zoonotic	Yes
Human Transmissibility	Yes – direct and respiratory
EU Control List Entry	1C351.a.41
Applicable AG Footnote(s)	[1]

V40.2. Notable Features

The *Lyssavirus* genus is a member of the *Rhabdoviridae* family. The most well-known species of *Lyssavirus* is *Rabies virus*. All members of the *Lyssavirus* genus manifest a rabies-like infection. Members of the *Lyssavirus* genus are found worldwide, though not all species are found in every country. For example, *Rabies virus* is the only member of the *Lyssavirus* genus found in North and South America. The World Health Organization (WHO) considers a country "rabies-free" if no indigenously acquired cases in humans or animals occur for 2 years. Therefore, several countries including the United Kingdom, Sweden, Australia, Japan, and New Zealand are considered rabies-free.

Transmission of the virus occurs through direct contact with saliva or neurological tissue (brain and spinal cord). The most common route of exposure is a bite from an infected animal where saliva is exposed through an open wound. There are a few documented cases of virus spread via inhalation of aerosolised virus particles or organ transplant using contaminated tissues in surgery. There are doubts as to whether bodily fluids such as urine, feces, and semen are capable of transmitting the virus. Similarly, consumption of milk and undercooked meat is not believed to be an effective route of transmission; however, most public health agencies still recommend avoiding ingestion of these products. Symptoms of rabies in humans include generic flu-like symptoms of fever, headache, and weakness followed by neurologic distress (anxiety, confusion, agitation, insomnia, hallucinations, partial paralysis, convulsions) and death. Vaccines are available for *Rabies virus* and are used with varying frequency worldwide. The vaccine is most commonly used in domestic pets. Vaccination for *Rabies virus* does not provide protection against all members of the *Lyssavirus* genus. Post-exposure treatment is effective if administered before a person becomes symptomatic; however, once symptomatic, cases of rabies in humans are nearly 100% fatal.

V40.3. Packaging

Rabies virus and other members of the Lyssavirus genus are Category B infectious substances with the shipping code UN 3373 because they are infectious but do not meet the criteria for Category A.

V40.4. Typical Applications

Basic medical research and medical countermeasure development (e.g., vaccine research), epidemiology, and global surveillance.

V41. Reconstructed 1918 influenza virus

V41.1. Basic Description

Identifier/Property	Description
Type	Virus: RNA
Associated Disease	Influenza
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Mortality rate: Unknown; 2.5% for 1918 influenza ▸ Effective aerosol ▸ Seasonal flu vaccine may provide limited effectiveness ▸ Effective post-exposure treatment
Containment and Handling	Biosafety Level 2
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wound ▸ Inhalation (lungs): Aerosol ▸ Gastrointestinal (intestine): Not a known route of exposure ▸ Injection (bloodstream): Not a known route of exposure **Host/Reservoir:** Humans **Vector:** Not applicable
Geographic Distribution	Not applicable. Currently limited to laboratory stockpiles
Zoonotic	Yes (suspected)
Human Transmissibility	Yes – direct and respiratory
EU Control List Entry	1C351.a.58
Applicable AG Footnote(s)	[1]

V41.2. Notable Features

Reconstructed 1918 influenza virus is a laboratory generated version of the *Influenza A virus* responsible for the 1918–1919 pandemic influenza that killed an estimated 20–50 million people worldwide. Given the lack of available technology to isolate and study viruses during the early 20th century, there is no available sample of the virus responsible for the 1918–1919 pandemic. By extracting viral genomic DNA from the preserved tissue of an autopsy sample from a 1918 influenza victim, scientists were able to create the Reconstructed 1918 influenza virus. This reconstructed virus has many characteristics of what is known about the 1918 influenza virus and is believed to have the same high-virulence traits exhibited by the original virus.[40] If released into the environment, Reconstructed 1918 influenza virus would likely cause the same symptoms in humans as the seasonal flu; fever, cough, sore throat, fatigue, headache, and nasal congestion. Severe cases may lead to pneumonia or death.

Little is known about the ability of the original 1918 influenza virus to manifest disease in animals. Recent research indicates that Reconstructed 1918 influenza virus causes death in mice and embryonated chicken eggs. If released into the environment, it is likely that Reconstructed 1918 influenza virus would have the ability to manifest disease in animals (e.g., mice and poultry) in addition to humans.

Reconstructed 1918 influenza virus is a strain of H1N1. Currently, a genetically distinct form of H1N1 is included in the seasonal influenza vaccine. Though not completely protective, it is likely that the seasonal

[40] Additional information on Reconstructed 1918 Influenza virus can be found at https://www.cdc.gov/flu/pandemic-resources/reconstruction-1918-virus.html.

influenza vaccine would provide some limited protection against severe infection with Reconstructed 1918 influenza virus.

V41.3. Packaging

Reconstructed 1918 influenza virus is a Category B infectious substance with the shipping code UN 3373 because it is infectious but does not meet the criteria for Category A.

V41.4. Typical Applications

Basic medical research and medical countermeasure development (e.g. vaccine research).

V42. *Rift Valley fever virus*

V42.1. Basic Description

Identifier/Property	Description
Type	Virus: RNA
Associated Disease	Phlebotomus fever; Rift Valley fever (RVF)
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Mortality rate 1% ▸ Potential aerosol ▸ No vaccine ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 3
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Not a known route of exposure ▸ Inhalation (lungs): Not a known route of exposure ▸ Gastrointestinal (intestine): Not a known route of exposure ▸ Injection (bloodstream): Mosquito bite **Host/Reservoir:** Sheep, cattle, goats, camels, humans **Vector:** Mosquitoes
Geographic Distribution	Africa and Arabian Peninsula
Zoonotic	Yes
Human Transmissibility	Not transmissible
EU Control List Entry	1C351.a.42
Applicable AG Footnote(s)	[1]

V42.2. Notable Features

Named for the first named outbreak of the disease in the Rift Valley, Kenya, in 1931, Rift Valley fever is primarily a disease primarily of animals, but it can also infect humans. Human infections typically result from direct contact with blood or organs of an infected animal. Other routes of transmission include the mosquito vector or contaminated or unpasteurised food and milk. *Rift Valley fever virus* generally causes mild, flu-like symptoms in humans. Three distinct and severe disease manifestations can develop in humans: ocular disease (0.5–2%), meningoencephalitis (<1%), and hemorrhagic fever (<1%). RVF in livestock can cause a mortality rate of 90% in lambs and 10% in adult sheep. The disease manifests VHF symptoms in animals in addition to extremely high abortive rates in pregnant livestock.

V42.3. Packaging

Rift Valley fever virus is a Category A infectious substance with the shipping code UN 2814 because it is capable of causing permanent disability or life-threatening or fatal disease in otherwise healthy humans or animals when exposure to it occurs.

V42.4. Typical Applications

Basic medical research and medical countermeasure development (e.g., vaccine research), epidemiology, and global surveillance.

V43. *Rinderpest virus*

V43.1. Basic Description

Identifier/Property	Description
Type	Virus: RNA
Associated Disease	Rinderpest, cattle plague, steppe murrain
Other Names	RPV
Key WMD Characteristic(s)	▸ Mortality rate 10–100% ▸ Effective aerosol ▸ Potential for socioeconomic harm ▸ Vaccine available ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 3; subject to enhanced containment for countries with vulnerable agriculture
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wound ▸ Inhalation (lungs): Aerosols ▸ Gastrointestinal (intestine): Consumption of contaminated food or milk ▸ Injection (bloodstream): Not a known route of exposure **Host/Reservoir:** Cattle, buffalo, sheep, goats, giraffe, wildebeest, yaks, gazelles, sheep, goats, pigs, zebus **Vector:** Not applicable
Geographic Distribution	Eradicated
Zoonotic	No
Human Transmissibility	Not transmissible
EU Control List Entry	1C351.a.43
Applicable AG Footnote(s)	[1]

V43.2. Notable Features

Rinderpest virus is a member of the *Paramyxoviridae* family. On May 27, 2011, the World Organisation for Animal Health recognised the world as free from rinderpest.[41] Causing severe disease in agricultural livestock for centuries, global eradication campaigns starting in the early 1900s spearheaded containment and elimination of natural disease outbreak. Originally, rinderpest was endemic to Europe and Asia and eventually spread to Africa through international cattle trade in the late 1800s. *Rinderpest virus* is capable of manifesting disease in many large mammals. However, cattle and buffalo are believed to be the host species capable of sustaining the virus in populations. Most other host species cannot transmit the virus once an individual animal is infected. Transmission occurs through direct contact with contaminated bodily fluids or tissues, inhalation of aerosolised virus particles, or consumption of milk or undercooked meat. *Rinderpest virus* infection can manifest symptomatically in two forms: peracute and acute (classic). In the peracute form, animals develop a high fever and sudden death. In the acute form, animals develop a fever, decreased appetite and milk yield, and nasal congestion. Lesions develop on the lips and mouth which slough off leaving either large gray plaques or yellow pseudomembranes. As the disease progresses, symptoms may include a dry and cracked nose, diarrhea, dehydration, and death. Rinderpest tends to be most severe in cattle and buffalo and least virulent in goats and sheep. Vaccines are available for *Rinderpest virus* and are widely used worldwide for livestock.

[41] OIE declaration on global rinderpest-free status: https://www.oie.int/for-the-media/rinderpest/.

V43.3. Packaging

Rinderpest virus is a Category A infectious substance with the shipping code UN 2900 because it is capable of causing permanent disability or life-threatening or fatal disease in otherwise healthy animals when exposure to it occurs.

V43.4. Typical Applications

Basic medical research and medical countermeasure development (e.g., vaccine research), epidemiology, and global surveillance.

V44. *Rocio virus*

V44.1. Basic Description

Identifier/Property	Description
Type	Virus: RNA
Associated Disease	Rocio viral encephalitis
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Mortality rate 4–10% ▸ Potential aerosol ▸ No vaccine ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 3
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Not a known route of exposure ▸ Inhalation (lungs): Not a known route of exposure ▸ Gastrointestinal (intestine): Not a known route of exposure ▸ Injection (bloodstream): Mosquito bite **Host/Reservoir:** Wild birds, humans **Vector:** Mosquitoes
Geographic Distribution	Brazil
Zoonotic	Yes
Human Transmissibility	Not transmissible
EU Control List Entry	1C351.a.44
Applicable AG Footnote(s)	[1]

V44.2. Notable Features

First discovered in 1975, *Rocio virus* is responsible for epidemics of severe encephalitis in Brazil. The virus is transmitted to humans by the bite of an infected mosquito. The disease progresses quickly once an individual is infected, but antiviral treatments are effective. The virus responds very well to antiviral drugs, which can reduce the mortality rate from 10% to 4%.

V44.3. Packaging

Rocio virus is a Category B infectious substance with the shipping code UN 3373 because it is infectious but does not meet the criteria for Category A.

V44.4. Typical Applications

Basic medical research and medical countermeasure development (e.g., vaccine research), epidemiology, and global surveillance.

V45. *Sabia virus*

V45.1. Basic Description

Identifier/Property	Description
Type	Virus: RNA
Associated Disease	Brazilian hemorrhagic fever (BzHF)
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Mortality rate 5–35% ▸ Effective aerosol ▸ No vaccine ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 4
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wound ▸ Inhalation (lungs): Aerosols ▸ Gastrointestinal (intestine): Not a known route of exposure ▸ Injection (bloodstream): Not a known route of exposure **Host/Reservoir:** Rodents, humans **Vector:** Not applicable
Geographic Distribution	Brazil
Zoonotic	Yes
Human Transmissibility	Yes – direct and respiratory
EU Control List Entry	1C351.a.45
Applicable AG Footnote(s)	[1]

V45.2. Notable Features

Sabia virus is a New World virus belonging to the *Arenaviridae* genus found in Brazil. To date there have only been three confirmed cases of *Sabia virus* infection, which occurred in a small outbreak in 1990. Similar to other *Arenaviridae*, *Sabia virus* is believed to be transmitted to humans directly through a rodent reservoir by exposure to aerosolised urine, feces, or other bodily fluids. Once infected, disease manifestation is that of a quickly progressing VHF.

V45.3. Packaging

Sabia virus is a Category A infectious substance with the shipping code UN 2814 because it is capable of causing permanent disability or life-threatening or fatal disease in otherwise healthy humans or animals when exposure to it occurs.

V45.4. Typical Applications

Basic medical research and medical countermeasure development (e.g., vaccine research), epidemiology, and global surveillance.

V46. *Seoul virus*

V46.1. Basic Description

Identifier/Property	Description
Type	Virus: RNA
Associated Disease	Hemorrhagic fever with renal syndrome (HFRS)
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Mortality rate 1–50% ▸ Effective aerosol ▸ No vaccine ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 3
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wound ▸ Inhalation (lungs): Aerosols ▸ Gastrointestinal (intestine): Not a known route of exposure ▸ Injection (bloodstream): Not a known route of exposure **Host/Reservoir:** Rodents, humans **Vector:** Not applicable
Geographic Distribution	Eastern Europe, East Asia
Zoonotic	Yes
Human Transmissibility	Not transmissible
EU Control List Entry	1C351.a.46
Applicable AG Footnote(s)	[1]

V46.2. Notable Features

Seoul virus is named for its first occurrence in the Republic of Korea. Like other species of Old World *Hantavirus*, *Seoul virus* is a VHF virus that causes hemorrhagic fever with renal syndrome (HFRS). Persons can contract the disease from a rodent reservoir by direct inhalation of urine, feces, or other bodily fluids.

V46.3. Packaging

Seoul virus does not have a category designation but meets the qualifications for handling as a Category A infectious substance because it is capable of causing permanent disability or life-threatening or fatal disease in otherwise healthy humans when exposure to it occurs. Therefore, *Seoul virus* should be handled with shipping code UN 2814.[42]

V46.4. Typical Applications

Basic medical research and medical countermeasure development (e.g., vaccine research), epidemiology, and global surveillance.

[42] The UN Model Regulations state that the Category A listing of infectious substances "…is not exhaustive. Infectious substances, including new or emerging pathogens, which do not appear in the table but which meet the same criteria shall be assigned to Category A. In addition, if there is doubt as to whether or not a substance meets the criteria it shall be included in Category A." See Volume I, Chapter 2 https://www.unece.org/trans/danger/publi/unrec/rev21/21files_e.html.

V47. *Severe acute respiratory syndrome-related coronavirus (SARS-related coronavirus)*

V47.1. Basic Description

Identifier/Property	Description
Type	Virus: RNA
Associated Disease	Severe acute respiratory syndrome, SARS
Other Names	SARS-CoV
Key WMD Characteristic(s)	▸ Mortality rate <9.6% ▸ Effective aerosol ▸ No vaccine ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 2; Biosafety Level 3 may be used if activity has high potential for producing aerosols
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wound ▸ Inhalation (lungs): Aerosol ▸ Gastrointestinal (intestine): Not a known route of exposure ▸ Injection (bloodstream): Not a known route of exposure **Host/Reservoir:** Humans **Vector:** Not applicable
Geographic Distribution	Asia, North and South America, Europe
Zoonotic	No
Human Transmissibility	Yes
EU Control List Entry	1C351.a.57
Applicable AG Footnote(s)	[1]

V47.2. Notable Features

The first and only documented outbreak of *Severe acute respiratory syndrome-related coronavirus (SARS-CoV)* occurred in November 2002 through July 2003. The outbreak began in Guangdong Province, China, and by its end there were 8,096 confirmed cases and 774 deaths. Most cases were concentrated in China, Hong Kong, Taiwan, Singapore, and Canada, although a total of 23 other countries across Asia, North America, South America, and Europe were also affected. Initial symptoms of severe acute respiratory syndrome (SARS) include flu-like symptoms that can manifest into more severe symptoms of shortness of breath, pneumonia, and death. There is no effective vaccine, and post-exposure treatment options are limited.

V47.3. Packaging

Severe acute respiratory syndrome-related coronavirus is a Category B infectious substance with the shipping code UN 3373 because it is infectious but does not meet the criteria for Category A.

V47.4. Typical Applications

Basic medical research and medical countermeasure development (e.g. vaccine research), epidemiology, and global surveillance.

V48. *Sheeppox virus*

V48.1. Basic Description

Identifier/Property	Description
Type	Virus: RNA
Associated Disease	Sheeppox
Other Names	Sheep pox, SPV
Key WMD Characteristic(s)	▸ Mortality rate 5–100% ▸ Effective aerosol ▸ Potential for socioeconomic harm ▸ Vaccine available ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 3; subject to enhanced containment for countries with vulnerable agriculture
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wound ▸ Inhalation (lungs): Aerosols ▸ Gastrointestinal (intestine): Not a known route of exposure ▸ Injection (bloodstream): Not a known route of exposure **Host/Reservoir:** Sheep, goats **Vector:** Not applicable
Geographic Distribution	Africa, Asia, Middle East, India
Zoonotic	No
Human Transmissibility	Not transmissible
EU Control List Entry	1C351.a.47
Applicable AG Footnote(s)	[1]

V48.2. Notable Features

Sheeppox virus belongs to the *Poxviridae* family. Although SPV generally manifests disease in sheep, certain strains of SPV can manifest symptoms in goats. Mortality rates are generally 5–10% in areas with endemic outbreaks, though mortality rates can reach <100% for imported animals. Transmission of the virus occurs through aerosolisation of virus particles by animals in close living spaces or through direct contact with infectious bodily fluids. Sheeppox manifests most commonly in two forms: papulovesicular (common) and nodular (uncommon). Symptoms include fever and pustule formation on the skin. During papulovesicular manifestation, dark scabs form over the pustule scars. In contrast, during nodular manifestation, also known as stonepox, pustules develop into nodules that eventually die and slough off the animal, leaving hairless patches. Animals that do not recover from infection develop systemic inflammation and death similar to other VHF viruses.[43]

V48.3. Packaging

Sheeppox virus is a Category A infectious substance with the shipping code UN 2900 because it is capable of causing permanent disability or life-threatening or fatal disease in otherwise healthy animals when exposure to it occurs.

[43] Additional information on *Sheeppox virus* can be found through the OIE: http://www.oie.int/fileadmin/Home/eng/Animal_Health_in_the_World/docs/pdf/Disease_cards/SHEEP_GOAT_POX.pdf.

V48.4. Typical Applications

Basic medical research and medical countermeasure development (e.g., vaccine research), epidemiology, and global surveillance.

V49. *Sin Nombre virus*

V49.1. Basic Description

Identifier/Property	Description
Type	Virus: RNA
Associated Disease	Hantavirus cardiopulmonary syndrome (HCPS or HPS)
Other Names	The nameless virus, Four Corners virus
Key WMD Characteristic(s)	▸ Mortality rate 35–67% ▸ Effective aerosol ▸ No vaccine ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 3
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wound ▸ Inhalation (lungs): Aerosols ▸ Gastrointestinal (intestine): Not a known route of exposure ▸ Injection (bloodstream): Not a known route of exposure **Host/Reservoir:** Rodents, humans **Vector:** Not applicable
Geographic Distribution	North America
Zoonotic	Yes
Human Transmissibility	Not transmissible
EU Control List Entry	1C351.a.48
Applicable AG Footnote(s)	[1]

V49.2. Notable Features

Sin Nombre virus is prevalent throughout most of North America, particularly in the western United States. The incidence of infection tends to be higher in areas where humans have frequent contact or interaction with rodents, typically in rural settings. Like other species of New World *Hantaviridae*, *Sin Nombre virus* is a VHF virus that causes hemorrhagic cardiopulmonary syndrome (HCPS). *Sin Nombre virus* can be contracted through direct contact or inhalation of rodent urine, feces, or other bodily fluids.

V49.3. Packaging

Sin Nombre virus does not have a category designation but meets the qualifications for handling as a Category A infectious substance because it is capable of causing permanent disability or life-threatening or fatal disease in otherwise healthy humans when exposure to it occurs. Therefore, *Sin Nombre virus* should be handled with shipping code UN 2814.[44]

V49.4. Typical Applications

Basic medical research and medical countermeasure development (e.g., vaccine research), epidemiology, and global surveillance.

[44] The UN Model Regulations state that the Category A listing of infectious substances "…is not exhaustive. Infectious substances, including new or emerging pathogens, which do not appear in the table but which meet the same criteria shall be assigned to Category A. In addition, if there is doubt as to whether or not a substance meets the criteria it shall be included in Category A." See Volume I, Chapter 2 https://www.unece.org/trans/danger/publi/unrec/rev21/21files_e.html.

V50. *St. Louis encephalitis virus*

V50.1. Basic Description

Identifier/Property	Description
Type	Virus: RNA
Associated Disease	Saint Louis encephalitis
Other Names	SLEV
Key WMD Characteristic(s)	▸ Mortality rate 3–30% ▸ Potential aerosol ▸ No vaccine ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 3
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Not a known route of exposure ▸ Inhalation (lungs): Not a known route of exposure ▸ Gastrointestinal (intestine): Not a known route of exposure ▸ Injection (bloodstream): Mosquito bite **Host/Reservoir:** Wild birds, monkeys, mice, humans **Vector:** Mosquitoes
Geographic Distribution	North America
Zoonotic	Yes
Human Transmissibility	Not transmissible
EU Control List Entry	1C351.a.49
Applicable AG Footnote(s)	[1]

V50.2. Notable Features

St. Louis encephalitis virus is related to other mosquito vectored species of *Flaviviridae*. SLEV is primarily restricted to the United States. Humans and animals are susceptible to disease via the bite of an infected mosquito. The virus causes an infection that is mostly asymptomatic, though it does have the ability to manifest encephalitis and other neurological symptoms in patients.

V50.3. Packaging

St. Louis encephalitis virus is a Category B infectious substance with the shipping code UN 3373 because it is infectious but does not meet the criteria for Category A.

V50.4. Typical Applications

Basic medical research and medical countermeasure development (e.g., vaccine research), epidemiology, and global surveillance.

V51. *Suid herpesvirus 1* (*Pseudorabies virus;* Aujeszkey's disease)

V51.1. Basic Description

Identifier/Property	Description
Type	Virus: DNA
Associated Disease	Aujeszky's disease, pseudorabies, mad itch (cows)
Other Names	PRV, *Aujeszky's disease virus* (ADV)
Key WMD Characteristic(s)	▸ Mortality rate varies: 1–2% (adult pigs); 10–100% (piglets and other animal species) ▸ Effective aerosol ▸ Potential for socioeconomic harm ▸ Vaccine available ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 2; subject to enhanced containment for countries with vulnerable agriculture
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wound ▸ Inhalation (lungs): Aerosols ▸ Gastrointestinal (intestine): Consumption of contaminated food, milk, or raw meat ▸ Injection (bloodstream): Not a known route of exposure **Host/Reservoir:** Pigs and nearly all mammals including cattle, sheep, goats, cats, and dogs **Vector:** Not applicable
Geographic Distribution	Europe, Southeast Asia, North and South America
Zoonotic	No
Human Transmissibility	Not transmissible
EU Control List Entry	1C351.a.19
Applicable AG Footnote(s)	[1]

V51.2. Notable Features

Suid herpesvirus 1 belongs to the *Herpesviridae* family. Also known as *Aujeszky's disease virus*, or ADV, it is known for causing disease in pigs, but nearly all mammals are susceptible with the exception of humans and certain types of apes. Pigs are the most common host for ADV. Though the virus has a broad host range, few mammalian species are capable of transmitting the virus. Eradication campaigns have successfully eliminated ADV from domestic pig herds in countries throughout Europe and North America; however, the virus remains present in wild pigs. Transmission of ADV can occur through contact with infectious bodily fluids, aerosolisation of virus particles, and consumption of tainted milk (most common for piglets) or raw meat. Symptoms of Aujeszky's disease include fever, tremors, seizures and other characteristic signs of central nervous system distress. In piglets, Aujeszky's disease is most often seen as a respiratory illness, with central nervous system complications resulting only in severe forms of the disease. The mortality rate varies as younger animals experience a more severe form of the disease, and symptoms become less virulent as animals age. Vaccines are available and used in many endemic countries.

V51.3. Packaging

Suid herpesvirus 1 is a Category B infectious substance with the shipping code UN 3373 because it is infectious but does not meet the criteria for Category A.

V51.4. Typical Applications

Basic medical research and medical countermeasure development (e.g., vaccine research), epidemiology, and global surveillance.

V52. *Swine vesicular disease virus*

V52.1. Basic Description

Identifier/Property	Description
Type	Virus: RNA
Associated Disease	Swine vesicular disease (SVD)
Other Names	SVDV, *Human coxsackievirus B5* (CV-B5), *Human enterovirus B*, *Porcine enterovirus* (PEV)
Key WMD Characteristic(s)	▸ Potential aerosol ▸ Environmentally stable ▸ Potential for socioeconomic harm ▸ Potential to damage the environment ▸ No vaccine ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 3; subject to enhanced containment for countries with vulnerable agriculture
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wound ▸ Inhalation (lungs): Not a known route of exposure ▸ Gastrointestinal (intestine): Consumption of contaminated food and water ▸ Injection (bloodstream): Not a known route of exposure **Host/Reservoir:** Pigs, humans **Vector:** Not applicable
Geographic Distribution	Europe, Asia
Zoonotic	Yes
Human Transmissibility	Yes (laboratory workers only) – direct
EU Control List Entry	1C351.a.39
Applicable AG Footnote(s)	[1]

V52.2. Notable Features

Swine vesicular disease virus is a viral species of the Picornaviridae family. SVDV causes disease in pigs; to date, humans have been infected through laboratory exposure only. Historically, outbreaks were documented in Europe and Asia, though today it is thought that the virus may be endemic to southern Italy only. Transmission can occur through direct contact with infectious bodily fluids or consumption of contaminated feed and water. Gastrointestinal exposure is common when contaminated, undercooked meat and infectious pig tissues are used in feed for domestic pigs. Symptoms of swine vesicular disease include development of lesions on the legs and mouth, weight loss, and decreased appetite. In addition, infected swine can present with neurologic symptoms including shivering, unsteady walking, and rhythmic jerking. There tend to be very low mortality rates associated with SVDV, but morbidity rates can reach 100% in pigs. Laboratory workers diagnosed with SVD generally report mild flu-like symptoms, weakness, and abdominal pain. One case resulted in meningitis. There are no reports of infection spread to farmers or veterinarians who have had direct contact with pigs. Due to the environmental stability of the virus, it can be very difficult to eradicate the virus once introduced to a novel geographic area. No vaccine is available.

V52.3. Packaging

Swine vesicular disease virus is a Category A infectious substance with the shipping code UN 2900 because it is capable of causing permanent disability or life-threatening or fatal disease in otherwise healthy animals when exposure to it occurs.

V52.4. Typical Applications

Basic medical research and medical countermeasure development (e.g., vaccine research), epidemiology, and global surveillance.

V53. *Tick-borne encephalitis virus* (Far Eastern subtype)

V53.1. Basic Description

Identifier/Property	Description
Type	Virus: RNA
Associated Disease	Tick-borne encephalitis (TBE): Far Eastern subtype
Other Names	TBEV, TBEV-FE, *Russian Spring-Summer encephalitis virus, Far Eastern tick-borne encephalitis virus*
Key WMD Characteristic(s)	▸ Mortality rate <2% ▸ Potential aerosol ▸ Effective vaccine ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 4
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Not a known route of exposure ▸ Inhalation (lungs): Not a known route of exposure ▸ Gastrointestinal (intestine): Not a known route of exposure ▸ Injection (bloodstream): Tick bite **Host/Reservoir:** Rodents, goats, sheep, cows, birds, horses, humans **Vector:** Ticks
Geographic Distribution	Eastern Europe, Russia, Asia
Zoonotic	Yes
Human Transmissibility	Not transmissible
EU Control List Entry	1C351.a.51
Applicable AG Footnote(s)	[1]

V53.2. Notable Features

Tick-borne encephalitis virus is a tick vectored species of *Flaviviridae* that causes infection in people in the central nervous system including meningitis, encephalitis, and meningoencephalitis. Far Eastern TBE is most commonly found in the very eastern part of Russia and other parts of Asia. Transmission to humans occurs directly from the bite of an infected tick, although infection can also spread from the bite of an infected reservoir animal. The disease also can be contracted from consumption of raw milk from goats, sheep, or cows, or from mother to infant.

V53.3. Packaging

Tick-borne encephalitis virus is a Category A infectious substance with the shipping code UN 2814 because it is capable of causing permanent disability or life-threatening or fatal disease in otherwise healthy humans or animals when exposure to it occurs.

V53.4. Typical Applications

Basic medical research and medical countermeasure development (e.g., vaccine research), epidemiology, and global surveillance.

V54. *Variola virus*

V54.1. Basic Description

Identifier/Property	Description
Type	Virus: DNA
Associated Disease	Smallpox, pox, red plague
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Mortality rate 35% for *Variola major* ▸ Environmentally stable ▸ Effective aerosol ▸ Effective vaccine, but public is no longer vaccinated due to eradication
Containment and Handling	Biosafety Level 4
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wound ▸ Inhalation (lungs): Aerosols ▸ Gastrointestinal (intestine): Not a known route of exposure ▸ Injection (bloodstream): Not a known route of exposure **Host/Reservoir:** Humans **Vector:** Not applicable
Geographic Distribution	Eradicated. Historically found worldwide
Zoonotic	No
Human Transmissibility	Yes – direct and respiratory
EU Control List Entry	1C351.a.52
Applicable AG Footnote(s)	[1]

V54.2. Notable Features

Smallpox is caused by two types of *Variola virus*, *Variola major* and *Variola minor*. *V. major* produces a more serious disease (mortality rate 30–35%) and is the more commonly found form of the virus; a milder form of the disease is caused by *V. minor* (mortality rate of around 1%). Disease manifestations of *V. major* include ordinary (the most common), modified (mild; vaccination is ineffective), flat (rare and severe), and hemorrhagic (rare and severe). Flat and hemorrhagic manifestations are nearly always lethal. *Variola virus* is highly infectious and is unique to other *Poxviridae* in that it only causes disease in humans. Transmission of the virus can occur through inhalation of airborne or aerosolised viral particles, or by direct contact with an infected person, their bodily fluids, or contaminated objects and surfaces. Symptoms of smallpox include high fevers, body aches, and a rash that develops from fluid-filled bumps and scabs to permanent, pitted scars. The disease predominantly spreads through direct contact with an infected person's skin or bodily fluids, but also can be spread through the air in close, confined environments.

Variola virus outbreaks have plagued civilisations for thousands of years. Due to the existence of an effective vaccine and the fact that humans are the only reservoir for the virus, the World Health Organization (WHO) spearheaded an effort to eradicate smallpox through mass vaccination. The last naturally occurring case of smallpox was in 1977. The vaccine has many potentially lethal side effects; therefore, today only medical and military personnel undergo vaccination, which means that the general population could be at risk in the event of an outbreak.

V54.3. Packaging

Variola virus is a Category A infectious substance with the shipping code UN 2900 because it is capable of causing permanent disability or life-threatening or fatal disease in otherwise healthy humans or animals when exposure to it occurs.

V54.4. Typical Applications

Basic medical research and medical countermeasure development (e.g., vaccine research), epidemiology, and global surveillance.

V55. *Venezuelan equine encephalitis virus*

V55.1. Basic Description

Identifier/Property	Description
Type	Virus: RNA
Associated Disease	Venezuelan equine encephalitis (VEE), Venezuelan equine encephalomyelitis
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Mortality rate low ▸ Potential aerosol ▸ Vaccine available and widely used in livestock, but limited use for humans ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 3
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Not a known route of exposure ▸ Inhalation (lungs): Not a known route of exposure ▸ Gastrointestinal (intestine): Not a known route of exposure ▸ Injection (bloodstream): Mosquito bite **Host/Reservoir:** Horses, donkeys, zebras, rodents, humans **Vector:** Mosquitoes
Geographic Distribution	Central and South America
Zoonotic	Yes
Human Transmissibility	Not transmissible
EU Control List Entry	1C351.a.53
Applicable AG Footnote(s)	[1]

V55.2. Notable Features

First recognised in Venezuela in 1938, *Venezuelan equine encephalitis virus* is a complex of seven different species as well as multiple subtypes and varieties. In general, VEE is a mosquito-borne disease that can affect all equine species (horses, donkeys, and zebras) and other large mammals. The virus causes progressive disorders of the central nervous system. Humans contract the virus from the bite of an infected mosquito. Symptoms for humans are generally mild and flu-like, though the disease can lead to severe complications of the central nervous system, primarily encephalitis. Disease manifestation is more commonly seen in livestock and equine than in humans. A vaccine exists that is widely used for equines, but for humans it is only used in at-risk communities like military and laboratory workers.

V55.3. Packaging

Venezuelan equine encephalitis virus is a Category A infectious substance with the shipping code UN 2814 because it is capable of causing permanent disability or life-threatening or fatal disease in otherwise healthy humans or animals when exposure to it occurs.

V55.4. Typical Applications

Basic medical research and medical countermeasure development (e.g., vaccine research), epidemiology, and global surveillance.

V56. *Vesicular stomatitis virus*

V56.1. Basic Description

Identifier/Property	Description
Type	Virus: RNA
Associated Disease	Vesicular stomatitis, Indiana fever, sore mouth
Other Names	VSV, *Vesicular stomatitis Indiana virus* (VSIV), *Cocal virus*, *Vesicular stomatitis Alagoas virus*
Key WMD Characteristic(s)	▸ Effective aerosol ▸ Potential for socioeconomic harm ▸ Effective vaccine ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 3; subject to enhanced containment for countries with vulnerable agriculture
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wound ▸ Inhalation (lungs): Aerosols ▸ Gastrointestinal (intestine): Consumption of an insect vector or contaminated food ▸ Injection (bloodstream): Insect bite **Host/Reservoir:** Numerous including horses, donkeys, mules, cattle, pigs **Vector:** Flies, midges, mosquitoes; grasshoppers (suspected)
Geographic Distribution	North and South America
Zoonotic	Yes
Human Transmissibility	Yes – direct and respiratory
EU Control List Entry	1C351.a.54
Applicable AG Footnote(s)	[1]

V56.2. Notable Features

Vesicular stomatitis virus is a member of the *Rhabdoviridae* family. *Vesicular stomatitis virus* causes vesicular stomatitis in many species of large mammals but is best known for its effect on domestic livestock. When first added to the *Rhabdoviridae* family the virus was given the name *Vesicular stomatitis virus*, but it has undergone many name changes since first discovered. VSV is also referred to as *Vesicular stomatitis Indiana virus*, *Cocal virus*, and *Vesicular stomatitis Alagoas virus*.[45]

Vesicular stomatitis is found in North and South America with endemic regions concentrated in Mexico, Central America, and northern South America. Though geographic distribution of the four vesicular stomatitis causing viruses varies, diagnosis with a particular virus is not possible without laboratory analysis. Transmission of VSV primarily occurs through bites from an insect vector (flies, midges, mosquitoes). Manual transmission is possible through contact with infectious bodily fluids and contaminated food and water. Inhalation exposure is rare and mostly confined to research and laboratory experiments. Research

[45] In 1993, *Vesicular stomatitis virus* was renamed *Vesicular stomatitis Indiana virus*. Formerly, there were three different VSV subtypes: IND-1 (classical IND), IND-2 (*Cocal virus*), and IND-3 (*Alagoas virus*). Since then, each of these has been renamed as their own virus species under the *Rhabdoviridae family*: *Vesicular stomatitis Indiana virus* (VSIV, formerly IND-1), *Cocal virus* (formerly IND-2), and *Vesicular stomatitis Alagoas virus* (formerly IND-3). In addition, there is an additional virus in the *Rhabdoviridae* family with a similar naming convention, *Vesicular stomatitis New Jersey virus*, that is also capable of manifesting vesicular stomatitis in animals. Additional information on the taxonomy history of *Vesicular stomatitis virus* can be found through the International Committee on Taxonomy of Viruses website: https://talk.ictvonline.org/taxonomy/.

experiments have shown that VSV is capable of remaining viable on species of grass for several weeks. Grasshoppers that eat the grass could potentially act as an insect vector to transmit VSV to livestock that eat the grass. It is unknown whether this route of transmission occurs in nature.

Vesicular stomatitis is named for its manifestation of vesicles, papules, erosions, and ulcers on the mouth, udders, and feet of livestock. Additional symptoms include excessive salivation, anorexia, dehydration, lameness, and weight loss. Mortality rates are relatively low for VSV, but the virus can manifest disease in up to 90% of susceptible herds.[46] Though VSV is most well known for manifesting disease in livestock, humans are also susceptible to the disease. Vaccines are available and used in geographic areas with endemic VSV.

V56.3. Packaging

Vesicular stomatitis virus is a Category A infectious substance with the shipping code UN 2900 because it is capable of causing permanent disability or life-threatening or fatal disease in otherwise healthy animals when exposure to it occurs.

V56.4. Typical Applications

Basic medical research and medical countermeasure development (e.g., vaccine research), epidemiology, and global surveillance.

[46] Additional information on *Vesicular stomatitis virus* by the OIE can be found at https://www.oie.int/fileadmin/Home/eng/Animal_Health_in_the_World/docs/pdf/Disease_cards/VESICULAR_STOMATITIS.pdf.

V57. *Western equine encephalitis virus*

V57.1. Basic Description

Identifier/Property	Description
Type	Virus: RNA
Associated Disease	Western equine encephalomyelitis (WEE)
Other Names	WEEV
Key WMD Characteristic(s)	▸ Mortality rate 4% ▸ Potential aerosol ▸ No vaccine ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 3
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Not a known route of exposure ▸ Inhalation (lungs): Not a known route of exposure ▸ Gastrointestinal (intestine): Not a known route of exposure ▸ Injection (bloodstream): Mosquito bite **Host/Reservoir:** Wild mammals, birds, humans **Vector:** Mosquitoes
Geographic Distribution	Continental United States, Canada, South America
Zoonotic	Yes
Human Transmissibility	Not transmissible
EU Control List Entry	1C351.a.55
Applicable AG Footnote(s)	[1]

V57.2. Notable Features

WEEV was first discovered in the Continental United States, Canada, and South America in 1964. It is a combination of two other species of *Alphavirus*. Similar to other encephalitis-causing species of *Alphaviridae*, the disease is spread via a mosquito vector. Primarily a disease known to cause high mortality rates in equine populations, wild mammals and birds are an effective reservoir and can experience symptoms of WEE. In humans, WEE infection is generally asymptomatic, but in a small number of cases, persons develop complications of the central nervous system including encephalitis.

V57.3. Packaging

Western equine encephalitis virus is a Category B infectious substance with the shipping code UN 3373 because it is infectious but does not meet the criteria for Category A.

V57.4. Typical Applications

Basic medical research and medical countermeasure development (e.g., vaccine research), epidemiology, and global surveillance.

V58. *Yellow fever virus*

V58.1. Basic Description

Identifier/Property	Description
Type	Virus: RNA
Associated Disease	Yellow fever, yellow jack, yellow ranier
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Mortality rate 3–50% ▸ Potential aerosol ▸ Effective vaccine, if administered pre-exposure ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 3
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Not a known route of exposure ▸ Inhalation (lungs): Not a known route of exposure ▸ Gastrointestinal (intestine): Not a known route of exposure ▸ Injection (bloodstream): Mosquito bite **Host/Reservoir:** Primates, humans **Vector:** Mosquitoes
Geographic Distribution	South America and Africa; historically found in North America
Zoonotic	Yes
Human Transmissibility	Not transmissible
EU Control List Entry	1C351.a.56
Applicable AG Footnote(s)	[1]

V58.2. Notable Features

The first recorded outbreak of yellow fever dates back to the 1600s. It is the only virus causing VHF for which there is a safe, effective vaccine. Yellow fever outbreaks are a problem in tropical and subtropical areas, particularly remote areas where vaccination coverage is low. Without preventative therapy, mortality rates can be as high as 50%. Initial symptoms are generally flu-like and can be followed by more serious symptoms indicative of VHF.

V58.3. Packaging

Yellow fever virus is a Category A infectious substance with the shipping code UN 2814 because it is capable of causing permanent disability or life-threatening or fatal disease in otherwise healthy humans or animals when exposure to it occurs.

V58.4. Typical Applications

Basic medical research and medical countermeasure development (e.g., vaccine research), epidemiology, and global surveillance.

Bacteria

B1. *Bacillus anthracis*

B1.1. Basic Description

Identifier/Property	Description
Type	Bacteria: Gram stain positive
Associated Disease	Anthrax, woolsorters' disease
Other Names	Anthrax
Key WMD Characteristic(s)	▸ Mortality rate 20–95% ▸ Effective aerosol ▸ Capable of forming environmentally stable spores ▸ No vaccine ▸ Effective post-exposure treatment
Containment and Handling	Biosafety Level 3
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wound ▸ Inhalation (lungs): Aerosols ▸ Gastrointestinal (intestine): Consumption of undercooked or raw meat products or unpasteurised dairy products ▸ Injection (bloodstream): Not a known route of exposure **Host/Reservoir:** Humans, cattle, sheep, goats, horses, pigs **Vector:** Not applicable
Geographic Distribution	Central and South America, sub-Saharan Africa, Asia, Europe, Caribbean
Zoonotic	Yes
Human Transmissibility	Not transmissible
EU Control List Entry	1C351.c.1
Applicable AG Footnote(s)	[1]

B1.2. Notable Features

Bacillus anthracis is extremely hardy in the environment, and has been causing disease in humans for centuries. The bacterium is a potent pathogen due to its release of a suite of exotoxins that are important to its ability to survive and replicate in its host. As part of the pathogen lifecycle, *B. anthracis* can sporulate in environments that lack resources for the bacteria to replicate. The spore is surrounded by a thick cell wall that is highly resilient in the environment. These spores are extremely durable and can survive extremes in temperature as well as treatment with harsh chemicals and disinfectants. *B. anthracis* spores are viable in this dormant state for decades at a time and then germinate once situated in a favorable environment.

Human infection has three different disease manifestations associated with how the agent enters the body: cutaneous, inhalational, and gastrointestinal. Cutaneous exposure creates a skin lesion that develops a black crust. Inhalation exposure symptoms are first flu-like and can lead to shock, coma, and/or pneumonia. Gastrointestinal exposure symptoms include nausea, loss of appetite, bloody diarrhea, fever, and abdominal pain. Mortality rate varies greatly based on the route of infection: inhalational (95%), gastrointestinal (50–60%), or cutaneous (25%). The most common disease manifestation for humans is cutaneous anthrax contracted from direct contact with an infected animal.

B1.3. Packaging

B. anthracis is a Category A infectious substance with the shipping code UN 2814 because it is capable of causing permanent disability or life-threatening or fatal disease in otherwise healthy humans or animals when exposure to it occurs.

B1.4. Typical Applications

Basic medical research and development (e.g., vaccine research), epidemiology, and global surveillance.

B2. *Brucella abortus*

B2.1. Basic Description

Identifier/Property	Description
Type	Bacteria: Gram stain negative
Associated Disease	Brucellosis
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Mortality rate 2–5% ▸ Potential aerosol ▸ Environmentally stable ▸ Potential for socioeconomic harm ▸ No vaccine ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 2
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wound ▸ Inhalation (lungs): Not a known route of exposure ▸ Gastrointestinal (intestine): Consumption of undercooked or raw meat products or unpasteurised dairy products ▸ Injection (bloodstream): Not a known route of exposure **Host/Reservoir:** Sheep, cattle, pigs, elk, bison, humans **Vector:** Not applicable
Geographic Distribution	Worldwide; common in the Middle East, Asia, Africa, South and Central America, the Mediterranean, and the Caribbean
Zoonotic	Yes
Human Transmissibility	Yes – direct
EU Control List Entry	1C351.c.2
Applicable AG Footnote(s)	[1]

B2.2. Notable Features

Brucella abortus as part of its lifecycle takes up residence in a host's spleen, liver, lymph nodes, and bone marrow. It is a blood-borne pathogen found primarily in cattle; however, it is capable of being transmitted to humans, who can become infected by direct contact with infectious bodily fluids, consumption of contaminated foods, or ingestion of unpasteurised animal products. Mice may also contribute to the spread of *B. abortus* by acting as an intermediate host, but this is not the most common route of transmission. Manual transmission can also occur via fomites. Documented cases of aerosol transmission are limited to laboratory infections only; otherwise, the bacteria are spread through manual transmission in the wild.

Brucellosis is an occupational disease for workers who have frequent interactions with animals (e.g., laboratory workers, veterinarians, slaughterhouse workers). *Brucella abortus* cannot replicate outside of a host cell; however, vegetative cells can survive in feces for up to 30 days. Brucellosis infections can be asymptomatic, and those that are symptomatic can vary in manifestation.

B2.3. Packaging

B. abortus is a Category B infectious substance with the shipping code UN 3373 because it is infectious but does not meet the criteria for Category A.

B2.4. Typical Applications

Basic medical research and development (e.g., vaccine research), epidemiology, and global surveillance.

B3. *Brucella melitensis*

B3.1. Basic Description

Identifier/Property	Description
Type	Bacteria: Gram stain negative
Associated Disease	Ovine brucellosis (animals); Malta fever (Humans)
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Mortality rate 2–5% ▸ Potential aerosol ▸ Environmentally stable ▸ Potential for socioeconomic harm ▸ No vaccine ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 2
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Not a known route of exposure ▸ Inhalation (lungs): Not a likely route of exposure ▸ Gastrointestinal (intestine): Consumption of undercooked or raw meat products or unpasteurised dairy products ▸ Injection (bloodstream): Not a known route of exposure **Host/Reservoir:** Sheep, cattle, goats, humans **Vector:** Not applicable
Geographic Distribution	Worldwide; common in the Middle East, Asia, Africa, South and Central America, the Mediterranean, and the Caribbean
Zoonotic	Yes
Human Transmissibility	Yes – direct
EU Control List Entry	1C351.c.3
Applicable AG Footnote(s)	[1]

B3.2. Notable Features

Brucella melitensis as part of its lifecycle takes up residence in a host's spleen, liver, lymph nodes, and bone marrow. It is a blood-borne pathogen found primarily in sheep and goats; however, it is capable of being transmitted to humans, who can become infected by direct contact with infectious bodily fluids, consumption of contaminated foods, or ingestion of unpasteurised animal products. Mice may also contribute to the spread of *B. melitensis* by acting as an intermediate host, but this is not the most common route of transmission. Manual transmission can also occur via fomites. Documented cases of aerosol transmission are limited to laboratory infections only; otherwise, the bacteria are spread through manual transmission in the wild.

Brucellosis is an occupational disease for workers who have frequent interactions with animals (e.g., laboratory workers, veterinarians, slaughterhouse workers). *Brucella melitensis* cannot replicate outside of a host cell; however, vegetative cells can survive in feces for up to 30 days. Brucellosis infections can be asymptomatic, and those that are symptomatic can vary in manifestation.

B3.3. Packaging

B. melitensis is a Category B infectious substance with the shipping code UN 3373 because it is infectious but does not meet the criteria for Category A.

B3.4. Typical Applications

Basic medical research and development (e.g., vaccine research), epidemiology, and global surveillance.

B4. *Brucella suis*

B4.1. Basic Description

Identifier/Property	Description
Type	Bacteria: Gram stain negative
Associated Disease	Swine brucellosis (pigs); undulant fever (humans)
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Mortality rate 2–5% ▸ Potential aerosol ▸ Environmentally stable ▸ Potential for socioeconomic harm ▸ No vaccine ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 2
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Direct contact with infectious animals or contaminated bodily fluids ▸ Inhalation (lungs): Not a likely route of exposure ▸ Gastrointestinal (intestine): Consumption of undercooked or raw meat products or unpasteurised dairy products ▸ Injection (bloodstream): Not a known route of exposure **Host/Reservoir:** Pigs, humans **Vector:** Not applicable
Geographic Distribution	Worldwide; common in the Middle East, Asia, Africa, South and Central America, the Mediterranean, and the Caribbean
Zoonotic	Yes
Human Transmissibility	Yes – direct
EU Control List Entry	1C351.c.4
Applicable AG Footnote(s)	[1]

B4.2. Notable Features

Brucella suis as part of its lifecycle takes up residence in a host's spleen, liver, lymph nodes, and bone marrow. It is a blood-borne pathogen found primarily in pigs; however, it is capable of being transmitted to humans, who can become infected by direct contact with infectious bodily fluids, consumption of contaminated foods, or ingestion of unpasteurised animal products.[47] Mice may also contribute to the spread of *B. suis* by acting as an intermediate host, but this is not the most common route of transmission. Manual transmission can also occur via fomites. Documented cases of aerosol transmission are limited to laboratory infections only; otherwise, the bacteria are spread through manual transmission in the wild.

Brucellosis is an occupational disease for workers who have frequent interactions with animals (lab workers, veterinarians, slaughterhouse workers). *Brucella suis* cannot replicate outside of a host cell; however, vegetative cells can survive in feces for up to 30 days. Brucellosis infections can be asymptomatic, and those that are symptomatic can vary in manifestation.

[47] World Organisation for Animal Health. https://www.oie.int/en/animal-health-in-the-world/animal-diseases/Brucellosis/.

B4.3. Packaging

B. suis is a Category B infectious substance with the shipping code UN 3373 because it is infectious but does not meet the criteria for Category A.

B4.4. Typical Applications

Basic medical research and development (e.g., vaccine research), epidemiology, and global surveillance.

B5. *Burkholderia mallei* (*Pseudomonas mallei*)

B5.1. Basic Description

Identifier/Property	Description
Type	Bacteria: Gram stain negative
Associated Disease	Glanders
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Mortality rate 5–15% ▸ Effective aerosol ▸ Potential for socioeconomic harm ▸ Potential to damage the environment ▸ No vaccine ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 3
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wounds ▸ Inhalation (lungs): Aerosols ▸ Gastrointestinal (intestine): Consumption of undercooked or raw meat products, unpasteurised dairy products, or water ▸ Injection (bloodstream): Not a known route of exposure **Host/Reservoir:** Horses, mules, donkeys, humans (rare) **Vector:** Not applicable
Geographic Distribution	Africa, Asia, Central and South America, Middle East
Zoonotic	Yes
Human Transmissibility	Yes (very rare) – direct and respiratory
EU Control List Entry	1C351.c.5
Applicable AG Footnote(s)	[1]

B5.2. Notable Features

Burkholderia mallei belongs to the family *Burkholderiaceae* and causes a disease known as glanders; it predominately affects horses and other equine species but can also manifest disease in humans. Transmission to humans occurs by direct contact with an infected animal or its body fluids or by inhalation of aerosols. The disease has been eradicated throughout North America but is still found in Africa, Asia, Central and South America, and the Middle East. Symptoms of glanders vary based on the inoculation site but can include fever, muscle aches and tightness, chest pain, headache, nasal discharge, and light sensitivity. For those that are exposed cutaneously, a localised infection with an ulcer may be the extent of symptoms. More severe forms of glanders can lead to systemic blood infections that symptomatically manifest as multiple abscesses throughout the organisms' skin, muscles, and vital internal organs.

B5.3. Packaging

B. mallei is a Category B infectious substance with the shipping code UN 3373 because it is infectious but does not meet the criteria for Category A.

B5.4. Typical Applications

Basic medical research and development (e.g., vaccine research), epidemiology, and global surveillance.

B6. Burkholderia pseudomallei (*Pseudomonas pseudomallei*)

B6.1. Basic Description

Identifier/Property	Description
Type	Bacteria: Gram stain negative
Associated Disease	Medlioidosis, Whitmore's disease
Other Names	*Pseudomonas pseudomallei*
Key WMD Characteristic(s)	▸ Mortality rate 20–50% ▸ Effective aerosol ▸ Potential for socioeconomic harm ▸ Potential to damage the environment ▸ No vaccine ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 3
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wounds ▸ Inhalation (lungs): Aerosols ▸ Gastrointestinal (intestine): Consumption of undercooked or raw meat products, unpasteurised dairy products, or water ▸ Injection (bloodstream): Not a known route of exposure **Host/Reservoir:** Sheep, goats, horses, swine, cattle, cats, dogs, humans **Vector:** Not applicable
Geographic Distribution	Southeast Asia, Northern Australia
Zoonotic	Yes
Human Transmissibility	Yes (very rare) – manual and aerosolisation
EU Control List Entry	1C351.c.6
Applicable AG Footnote(s)	[1]

B6.2. Notable Features

Burkholderia pseudomallei is a bacterium that manifests the disease melioidosis in humans and animals. The disease is concentrated to tropical climates in Southeast Asia and Northern Australia. The most common route of transmission is through contact with contaminated food and water, inhalation of dust or aerosols, or from direct contact with fomites. Human-to-human transmission is rare but can occur through contact with contaminated bodily fluids. There are four types of disease symptoms that vary based on the site of inoculation. These can include localised, pulmonary, bloodstream, or disseminated infection, the later three being more severe. Symptoms can range from generic flu-like symptoms to chest pain, anorexia, respiratory distress, joint pain, muscle tenderness, abdominal discomfort, and weight loss.

B6.3. Packaging

B. pseudomallei is a Category B infectious substance with the shipping code UN 3373 because it is infectious but does not meet the criteria for Category A.

B6.4. Typical Applications

Basic medical research and development (e.g., vaccine research), epidemiology, and global surveillance.

B7. *Chlamydia psittaci (Chlamydophila psittaci)*

B7.1. Basic Description

Identifier/Property	Description
Type	Bacteria: Gram stain negative
Associated Disease	Psittacosis
Other Names	*Chlamydophila psittaci*
Key WMD Characteristic(s)	▸ Mortality rate 5–20% ▸ Effective aerosol ▸ Potential for socioeconomic harm ▸ No vaccine ▸ Post-exposure treatment limited to few antibiotics
Containment and Handling	Biosafety Level 3
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wounds ▸ Inhalation (lungs): Aerosols ▸ Gastrointestinal (intestine): Not a known route of exposure ▸ Injection (bloodstream): Not a known route of exposure **Host/Reservoir:** Birds, sheep, goats, cows **Vector:** Not applicable
Geographic Distribution	Worldwide; common in tropical and subtropical regions
Zoonotic	Yes
Human Transmissibility	Yes – direct
EU Control List Entry	1C351.c.7
Applicable AG Footnote(s)	[1]

B7.2. Notable Features

Chlamydia psittaci belongs to the bacterial family *Chlamydiaceae*, and as part of its lifecycle replicates inside host cells. The bacteria create a systemic infection in the host, meaning that bacteria are shed through the feces and other bodily fluids. Although the bacteria can survive in several host species, it is most commonly found in birds; therefore, feathers can carry and serve as a transmission pathway for the pathogen. Inhalational transmission can occur from aerosolisation of feces, urine, and other bodily fluids. Increased incidences of psittacosis are observed in poultry processing plants, veterinarians, bird owners, and pet shop employees. Disease manifestation in humans includes atypical pneumonia, high fever, diarrhea, joint pain, eye infection, nosebleeds, and impaired immune function.

B7.3. Packaging

C. psittaci is a Category B infectious substance with the shipping code UN 3373 because it is infectious but does not meet the criteria for Category A.

B7.4. Typical Applications

Basic medical research and development (e.g., vaccine research), epidemiology, and global surveillance.

B8. *Clostridium argentinense* (formerly known as *Clostridium botulinum* – Type G) botulinum neurotoxin producing strains

B8.1. Basic Description

Identifier/Property	Description
Type	Bacteria: Gram stain positive
Associated Disease	Botulism
Other Names	*C. subterminale, C. hastiforme, C. botulinum* toxin group G
Key WMD Characteristic(s)	▸ Mortality rate 5–10% ▸ Potential aerosol ▸ Potential for socioeconomic harm ▸ Potential to damage the environment ▸ No vaccine ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 2
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wounds ▸ Inhalation (lung): Not a known route of exposure ▸ Gastrointestinal (intestine): Consumption of undercooked or raw meat products, unpasteurised dairy products, or water ▸ Injection (bloodstream): Not a known route of exposure **Host/Reservoir:** Humans, livestock **Vector:** Not applicable
Geographic Distribution	Worldwide
Zoonotic	Yes
Human Transmissibility	Yes (suspected) – direct
EU Control List Entry	1C351.c.8
Applicable AG Footnote(s)	[1]

B8.2. Notable Features

Clostridium argentinense is a spore-forming bacterium that produces Type G botulinum toxin, an AG-controlled neurotoxin that causes flaccid muscular paralysis in both humans and animals. Similar to other species in the *Clostridium* genus, the bacteria occur naturally in soil as spores that are tolerant to extreme environmental conditions. Not all strains of *C. argentinense* contain the genes required to produce botulinum neurotoxin. Only those strains that are capable of producing botulinum neurotoxin are controlled by the AG.

Botulism is commonly associated with ingesting improperly preserved foods, though transmission can occur through contact with the feces, urine, and bodily fluids of an infected individual. Foodborne outbreaks of botulism are rare, and botulinum toxin Type G has never been linked to documented outbreak.

B8.3. Packaging

C. argentinense is a Category A infectious substance with the shipping code UN 2814 because it is capable of causing permanent disability or life-threatening or fatal disease in otherwise healthy humans or animals when exposure to it occurs.

B8.4. Typical Applications

C. argentinense is used for basic medical research and development (e.g., vaccine research), epidemiology, and global surveillance. At this time, the Type G botulinum toxin produced by *C. argentinense* is not used for cosmetic and therapeutic purposes like Types A and B.

B9. *Clostridium baratii*, botulinum neurotoxin producing strains

B9.1. Basic Description

Identifier/Property	Description
Type	Bacteria: Gram stain positive
Associated Disease	Botulism
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Mortality rate 5–10% ▸ Potential aerosol ▸ Potential for socioeconomic harm ▸ Potential to damage the environment ▸ No vaccine ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 2
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wounds ▸ Inhalation (lungs): Not a known route of exposure ▸ Gastrointestinal (intestine): Consumption of undercooked or raw meat products, unpasteurised dairy products, or water ▸ Injection (bloodstream): Not a known route of exposure **Host/Reservoir:** Humans, livestock **Vector:** Not applicable
Geographic Distribution	Worldwide
Zoonotic	Yes
Human Transmissibility	Yes (suspected) – direct
EU Control List Entry	1C351.c.9
Applicable AG Footnote(s)	[1]

B9.2. Notable Features

Clostridium baratii is a spore-forming bacterium that produces Type F botulinum toxin, an AG-controlled neurotoxin that causes flaccid muscular paralysis in its host. The neurotoxin is produced when the bacteria move from spores to germination. Similar to other species in the *Clostridium* genus, the bacteria occur naturally in soil as spores that are tolerant to extreme environmental conditions. Not all strains of *C. baratti* contain the genes required to produce botulinum neurotoxin. Only those strains that are capable of producing botulinum neurotoxin are controlled by the AG.

Botulism is commonly associated with ingesting improperly preserved foods, though transmission can occur through contact with feces, urine, and bodily fluids of an infected individual. There have only been a handful of laboratory confirmed cases of *C. baratii* infections to date.

B9.3. Packaging

C. baratti is a Category A infectious substance with the shipping code UN 2814 because it is capable of causing permanent disability or life-threatening or fatal disease in otherwise healthy humans or animals when exposure to it occurs.

B9.4. Typical Applications

C. baratti is used for basic medical research and development (e.g., vaccine research), epidemiology, and global surveillance. At this time, the Type F botulinum toxin produced by *C. baratti* is not used for cosmetic or therapeutic purposes like Types A and B.

B10. *Clostridium botulinum*

B10.1. Basic Description

Identifier/Property	Description
Type	Bacteria: Gram stain positive
Associated Disease	Botulism
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Mortality rate 5–10% ▸ Potential aerosol ▸ Potential for socioeconomic harm ▸ No vaccine ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 2
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wounds ▸ Inhalation (lungs): Not a known route of exposure ▸ Gastrointestinal (intestine): Consumption of undercooked or raw meat products or unpasteurised dairy products ▸ Injection (bloodstream): Not a known route of exposure **Host/Reservoir:** Humans, livestock **Vector:** Not applicable
Geographic Distribution	Worldwide
Zoonotic	Yes
Human Transmissibility	Yes (suspected) – direct
EU Control List Entry	1C351.c.10
Applicable AG Footnote(s)	[1]

B10.2. Notable Features

Clostridium botulinum is a spore-forming bacterium that produces several potent neurotoxins that cause flaccid muscular paralysis in its host. These neurotoxins are known as botulinum toxins (Types A–H) and are also controlled by the AG. Similar to other species in the *Clostridium* genus, the bacteria occur naturally in soil as spores that are tolerant to extreme environmental conditions. Botulism is commonly associated with ingesting improperly preserved foods, though transmission can occur through contact with the feces, urine, and bodily fluids of an infected individual.

B10.3. Packaging

C. botulinum is a Category A infectious substance with the shipping code UN 2814 because it is capable of causing permanent disability or life-threatening or fatal disease in otherwise healthy humans or animals when exposure to it occurs.

B10.4. Typical Applications

Botulinum toxin (Types A and B), produced by *C. botulinum*, is widely used for cosmetic applications, medical procedures, and as a therapeutic for certain kinds of chronic medical conditions (e.g., dystonia and other movement disorders). In addition, *C. botulinum* is used for basic medical research and development (e.g., vaccine research), epidemiology, and global surveillance.

B11. *Clostridium butyricum*, botulinum neurotoxin producing strains

B11.1. Basic Description

Identifier/Property	Description
Type	Bacteria: Gram stain positive
Associated Disease	Botulism
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Mortality rate 5–10% ▸ Potential aerosol ▸ Potential for socioeconomic harm ▸ Potential to damage the environment ▸ No vaccine ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 2
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wounds ▸ Inhalation (lungs): Not a known route of exposure ▸ Gastrointestinal (intestine): Consumption of undercooked or raw meat products, unpasteurised dairy products, or water ▸ Injection (bloodstream): Not a known route of exposure **Host/Reservoir:** Humans, livestock **Vector:** Not applicable
Geographic Distribution	Worldwide
Zoonotic	Yes
Human Transmissibility	Yes (suspected) – direct
EU Control List Entry	1C351.c.11
Applicable AG Footnote(s)	[1]

B11.2. Notable Features

Clostridium butyricum is a spore-forming bacterium that produces Type E botulinum toxin, an AG-controlled neurotoxin that causes flaccid muscular paralysis in its host. Similar to other species in the *Clostridium* genus, the bacteria occur naturally in soil as spores that are tolerant to extreme environmental conditions. Not all strains of *C. butyricum* contain the genes required to produce botulinum neurotoxin. Only those strains that are capable of producing botulinum neurotoxin are controlled by the AG.

Botulism is commonly associated with ingesting improperly preserved foods, though transmission can occur through contact with feces, urine, and bodily fluids of an infected individual. There have only been a handful of laboratory confirmed cases of *C. butyricum* infections to date.

B11.3. Packaging

C. butyricum is a Category A infectious substance with the shipping code UN 2814 because it is capable of causing permanent disability or life-threatening or fatal disease in otherwise healthy humans or animals when exposure to it occurs.

B11.4. Typical Applications

C. butyricum is used for basic medical research and development (e.g., vaccine research), epidemiology, and global surveillance.

B12. *Clostridium perfringens*, epsilon toxin producing types[3]

B12.1. Basic Description

Identifier/Property	Description
Type	Bacteria: Gram stain positive
Associated Disease	Food poisoning, clostridial myonecrosis, clostridial necrotizing enteritis
Other Names	*Clostridium welchii, Bacillus welchii*
Key WMD Characteristic(s)	▸ Mortality rate varies (clostridial necrotising enteritis: 15–25%) ▸ Potential for socioeconomic harm ▸ No vaccine ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 2
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wounds ▸ Inhalation (lungs): Not a known route of exposure ▸ Gastrointestinal (intestine): Consumption of undercooked or raw meat products or unpasteurised dairy products ▸ Injection (bloodstream): Not a known route of exposure **Host/Reservoir:** Humans, cattle, pigs, poultry, fish **Vector:** Not applicable
Geographic Distribution	Worldwide
Zoonotic	Yes
Human Transmissibility	Not transmissible
EU Control List Entry	1C351.c.12
Applicable AG Footnote(s)	[1] [3]

B12.2. Notable Features

Clostridium perfringens is a spore-forming bacterium that occurs naturally in soils and the intestinal tracts of vertebrates and insects. There are five types of *C. perfringens* (A–E). Types B and D produce epsilon toxin and are therefore controlled by the AG. *C. perfringens* is a common source for food-borne illnesses, especially because spores are able to withstand the high temperatures of cooking. Gastrointestinal illness usually resolves within 24 hours of symptom manifestation. In extreme cases, a more severe condition can develop (clostridial necrotising enteritis) leading to deep tissue infections and ultimately resulting in muscle necrosis and gas gangrene. This condition is caused by release of a suite of toxins that can cause systemic spread of the infection within the body and lead to death.

Footnote [3] of this list applies to *C. perfringens* only. It states:

> It is understood that limiting this control to epsilon toxin-producing strains of *Clostridium perfringens* therefore exempts from control the transfer of other *Clostridium perfringens* strains to be used as positive control cultures for food testing and quality control

B12.3. Packaging

C. perfringens is a Category B infectious substance with the shipping code UN 3373 because it is infectious but does not meet the criteria for Category A.

B12.4. Typical Applications

Basic medical research and development (e.g., vaccine research), epidemiology, and global surveillance.

B13. *Coxiella burnetii*

B13.1. Basic Description

Identifier/Property	Description
Type	Bacteria: Gram stain negative
Associated Disease	Q fever, query fever
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Mortality rate 1–2% ▸ Effective aerosol ▸ Environmentally stable spores ▸ Potential for socioeconomic harm ▸ Potential to damage the environment ▸ Vaccine available for livestock ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 3
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wounds ▸ Inhalation (lungs): Aerosols ▸ Gastrointestinal (intestine): Consumption of undercooked or raw meat products, unpasteurised dairy products, or water ▸ Injection (bloodstream): Not a known route of exposure **Host/Reservoir:** Humans, sheep, cattle, goats **Vector:** Not applicable
Geographic Distribution	Worldwide except New Zealand
Zoonotic	Yes
Human Transmissibility	Yes (rare) – direct and respiratory
EU Control List Entry	1C351.c.13
Applicable AG Footnote(s)	[1]

B13.2. Notable Features

Coxiella burnetii is a member of the family *Coxiellaceae* and can create spores that are extremely durable in varying environmental conditions. *C. burnetii* is the causative agent of Q fever in humans, sheep, cattle, and goats. Initial symptoms of Q fever include flu-like symptoms in addition to nausea, vomiting, diarrhea, and abdominal and chest pain. If a more systemic infection develops in a host (5% of those infected), symptoms may include pneumonia, central nervous system complications, or inflammation of the liver and heart tissue. Infected animals shed the bacteria through their feces, urine, and other bodily fluids. Humans contract the disease through inhalation of aerosolised bacterial particles or through direct contact with an infected animal.

B13.3. Packaging

C. burnetii is a Category A infectious substance with the shipping code UN 2814 because it is capable of causing permanent disability or life-threatening or fatal disease in otherwise healthy humans or animals when exposure to it occurs.

B13.4. Typical Applications

Basic medical research and development (e.g., vaccine research), epidemiology, and global surveillance.

B14. *Francisella tularensis*

B14.1. Basic Description

Identifier/Property	Description
Type	Bacteria: Gram stain negative
Associated Disease	Tularemia (also known as rabbit fever or deer fly fever)
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Mortality rate 5–60% ▸ Potential aerosol ▸ Potential for socioeconomic harm ▸ Potential to damage the environment ▸ No vaccine ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 2
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wound ▸ Inhalation (lungs): Aerosols ▸ Gastrointestinal (intestine): Consumption of undercooked or raw meat products, unpasteurised dairy products, or water ▸ Injection (bloodstream): Tick or fly bite **Host/Reservoir:** Birds, reptiles, fish, invertebrates, mammals, humans **Vector:** Hard ticks, biting flies
Geographic Distribution	Northern Hemisphere: North America, Europe, North Africa, Middle East, and North Asia
Zoonotic	Yes
Human Transmissibility	Not transmissible
EU Control List Entry	1C351.c.14
Applicable AG Footnote	[1]

B14.2. Notable Features

Francisella tularensis belongs to the family *Francisellaceae* and causes the disease tularemia. Tularemia can affect humans and animals, and is contracted through inhalation of aerosolised bacteria particles or direct contact with contaminated water, food, or bodily fluids of an infected organism. Transmission can also occur through the consumption of undercooked or raw meat products, unpasteurized dairy products, or water. There are four subspecies of *F. tularensis*, though only two subspecies are known to cause disease; Type A is highly virulent and found in North America, and Type B is mostly avirulent and found in Europe and Asia. In humans, tularemia can manifest as six different disease forms varying with inoculation site. Severe disease is mostly associated with systemic infection, which typically results from transmission via ingestion or inhalation.

B14.3. Packaging

F. tularensis is a Category A infectious substance with the shipping code UN 2814 because it is capable of causing permanent disability or life-threatening or fatal disease in otherwise healthy humans or animals when exposure to it occurs.

B14.4. Typical Applications

Basic medical research and development (e.g., vaccine research), epidemiology, and global surveillance.

B15. *Mycoplasma capricolum* subspecies *capripneumoniae* ("strain F38")

B15.1. Basic Description

Identifier/Property	Description
Type	Bacteria: Gram stain negative
Associated Disease	Contagious caprine pleuropneumonia (CCPP)
Other Names	*Mycoplasma* biotype F-38, MccF38
Key WMD Characteristic(s)	▸ Mortality rate <80% ▸ Effective aerosol ▸ Potential for socioeconomic harm ▸ Vaccine available ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 3; subject to enhanced containment for countries with vulnerable agriculture
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wound ▸ Inhalation (lungs): Aerosols ▸ Gastrointestinal (intestine): Not a known route of exposure ▸ Injection (bloodstream): Not a known route of exposure **Host/Reservoir:** Goats, sheep **Vector:** Not applicable
Geographic Distribution	Africa, Middle East, Asia (India and Pakistan)
Zoonotic	No
Human Transmissibility	Not transmissible
EU Control List Entry	1C351.c.15
Applicable AG Footnote(s)	[1]

B15.2. Notable Features

Mycoplasma capricolum subspecies *capripneumoniae* is a member of the *Mycoplamataceae* family and causes contagious caprine plueropenumonia (CCPP) in goats. Though CCPP is predominately a disease that affects goats, a few documented cases have been reported in sheep. It is unknown whether CCPP affects large, wild ruminants (e.g., wild goats and ibex). CCPP outbreaks have been documented in Africa, the Middle East, and Asia (India and Pakistan). The most common route of exposure occurs through inhalation of aerosolised bacteria particles, because CCPP is a respiratory disease. Manual transmission can occur through direct contact with bodily fluids, though this route of exposure is less common. Symptoms of CCPP can manifest in three forms: peracute, acute, and chronic. Peracute CCPP has few clinical symptoms except for rapid death. Acute CCPP presents with fever, lethargy, anorexia, profuse coughing, excessive saliva, pain, and death. Chronic CCPP includes fever, cough, nasal discharge, and lethargy. Vaccines are available and used in domestic goats in geographic areas with endemic CCPP.

B15.3. Packaging

Mycoplasma capricolum subspecies *capripneumoniae* is a Category B infectious substance with the shipping code UN 3373 because it is infectious but does not meet the criteria for Category A.

B15.4. Typical Applications

Basic medical research and medical countermeasure development (e.g., vaccine research), epidemiology, and global surveillance.

B16. *Mycoplasma mycoides* subspecies *mycoides* SC (small colony)

B16.1. Basic Description

Identifier/Property	Description
Type	Bacteria: Gram stain negative
Associated Disease	Contagious bovine pleuropneumonia (CBPP)
Other Names	MmmSC
Key WMD Characteristic(s)	▸ Mortality rate 30–80% ▸ Effective aerosol ▸ Vaccine available ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 3; subject to enhanced containment for countries with vulnerable agriculture
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wound ▸ Inhalation (lungs): Aerosols ▸ Gastrointestinal (intestine): Not a known route of exposure ▸ Injection (bloodstream): Not a known route of exposure **Host/Reservoir:** Cattle, buffalo, bison, yak, sheep **Vector:** Not applicable
Geographic Distribution	Africa, Asia, Middle East, Europe
Zoonotic	No
Human Transmissibility	Not transmissible
EU Control List Entry	1C351.c.16
Applicable AG Footnote(s)	[1]

B16.2. Notable Features

Mycoplasma mycoides subspecies *mycoides* small colony causes contagious bovine pleuropneumonia (CBPP) in large ruminants (e.g., cattle, buffalo, and bison). Though disease outbreaks occurred historically in Africa, Asia, the Middle East, and Europe, the disease is considered eradicated in Europe. CBPP is endemic to parts of Africa. Disease transmission occurs through direct contact with infectious bodily fluids or aerosolisation of bacteria particles. CBPP can manifest as four different distinct types: peracute, acute, subacute, or chronic. Peracute CBPP is known for killing animals with no symptoms other than fever. Acute cases are characterised by fever, loss of appetite, respiratory distress, arthritis, and joint swelling. Subacute CBPP symptoms are similar to yet less pronounced than acute CBPP. Both acute and subacute CBPP can develop into chronic CBPP. Symptoms of chronic CBPP include chronic low-grade fever and respiratory distress. The disease is considered chronic because animals take a very long time to recover. Vaccines are available and used in geographic areas with endemic CBPP.

B16.3. Packaging

Mycoplasma mycoides subspecies *mycoides* Small Colony is a Category A infectious substance with the shipping code UN 2900 because it is capable of causing permanent disability or life-threatening or fatal disease in otherwise healthy animals when exposure to it occurs.

B16.4. Typical Applications

Basic medical research and medical countermeasure development (e.g., vaccine research), epidemiology, and global surveillance.

B17. *Rickettsia prowazekii*

B17.1. Basic Description

Identifier/Property	Description
Type	Bacteria: Gram stain negative
Associated Disease	Typhus fever, Brill-Zinsser disease
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Mortality rate 10–40% ▸ Potential aerosol ▸ No vaccine ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 3
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wound ▸ Inhalation (lungs): Not a known route of exposure ▸ Gastrointestinal (intestine): Not a known route of exposure ▸ Injection (bloodstream): Louse bite **Host:** Squirrels **Vector:** Lice, fleas
Geographic Distribution	Worldwide
Zoonotic	Yes
Human Transmissibility	Not transmissible
EU Control List Entry	1C351.c.17
Applicable AG Footnote(s)	[1]

B17.2. Notable Features

Rickettsia prowazekii is a member of the family *Rickettsiaceae* that infects the host through an insect vector. Carried by the human body louse, the lice transmit the bacteria through biting or shedding into an open wound. Disease manifestation of *R. prowazekii* is typhus fever, and outbreaks tend to be seasonally associated with cold months. Once infected, dormant, asymptomatic infections known as Brill-Zinsser disease can persist in humans for years. Symptoms of epidemic typhus initially include generic flu-like symptoms followed by a rash on the trunk of the body, haemorrhage, hypotension, nausea, vomiting, and confusion.

B17.3. Packaging

R. prowazekii is a Category B infectious substance with the shipping code UN 3373 because it is infectious but does not meet the criteria for Category A.

B17.4. Typical Applications

Basic medical research and development (e.g., vaccine research), epidemiology, and global surveillance.

B18. *Salmonella enterica* subspecies *enterica* serovar *Typhi* (*Salmonella typhi*)

B18.1. Basic Description

Identifier/Property	Description
Type	Bacteria: Gram stain negative
Associated Disease	Typhoid fever
Other Names	*Salmonella typhi*
Key WMD Characteristic(s)	▸ Mortality rate 12–30% ▸ Potential for socioeconomic harm ▸ Potential to damage the environment ▸ Effective vaccine ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 2
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Not a known route of exposure ▸ Inhalation (lungs): Not a known route of exposure ▸ Gastrointestinal (intestine): Consumption of contaminated food or water ▸ Injection (bloodstream): Not a known route of exposure **Host/Reservoir:** Humans **Vector:** Not applicable
Geographic Distribution	Central and South America, Eastern Europe, Asia, Africa
Zoonotic	No
Human Transmissibility	Yes – direct
EU Control List Entry	1C351.c.18
Applicable AG Footnote(s)	[1]

B18.2. Notable Features

Salmonella enterica subspecies *enterica* serovar *Typhi*, also known as *Salmonella typhi, belongs* to the family *Enterobacteriaceae* and is the causative agent of typhoid fever. *Salmonella typhi* can only live in humans and is transmitted in the feces or urine. Once recovered from typhoid fever, some persons become carriers of the bacteria (i.e., they can infect other persons but do not have any active symptoms of the disease). A common source of disease spread is sewage in addition to contaminated food supplies or water sources. Persons with typhoid fever can manifest with symptoms including high fever, stomach pains, headache, loss of appetite, and rash.

B18.3. Packaging

Salmonella enterica subspecies *enterica* serovar *Typhi* is a Category B infectious substance with the shipping code UN 3373 because it is infectious but does not meet the criteria for Category A.

B18.4. Typical Applications

Basic medical research and development (e.g., vaccine research), epidemiology, and global surveillance.

B19. Shiga toxin producing *Escherichia coli* (STEC) of serogroups O26, O45, O103, O104, O111, O121, O145, O157, and other shiga toxin producing serogroups[4]

B19.1. Basic Description

Identifier/Property	Description
Type	Bacteria: Gram stain negative
Associated Disease	Food poisoning; hemolytic uremic syndrome (HUS)
Other Names	STEC, VTEC, EHEC
Key WMD Characteristic(s)	▸ Potential for socioeconomic harm ▸ Potential to damage the environment ▸ No vaccine ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 2
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Not a known route of exposure ▸ Inhalation (lungs): Not a known route of exposure ▸ Gastrointestinal (intestine): Consumption of contaminated food or water ▸ Injection (bloodstream): Not a known route of exposure **Host:** Cattle, goats, sheep, deer, elk, humans **Vector:** Not applicable
Geographic Distribution	Worldwide
Zoonotic	Yes
Human Transmissibility	Yes – direct
EU Control List Entry	1C351.c.19
Applicable AG Footnote(s)	[1] [4]

B19.2. Notable Features

Escherichia coli belongs to the family *Enterobacteriaceae* and is the causative agent of gastrointestinal disease, including food poisoning and hemolytic uremic syndrome. Like other bacteria strains in the *Enterobacteriaceae* family, many *E. coli* strains are non-pathogenic; however, the strains covered by this control list entry produce shiga toxin and can cause serious illness. Shiga toxin producing *E. coli* (STEC) may also be referred to as verocytotoxin-producing *E. coli* (VTEC) or enterohemorrhagic *E. coli* (EHEC), as acknowledged in footnote [4]. The bacteria are transmitted to humans and animals through ingestion of contaminated food products, water, or fecal matter. Additional examples include spread through undercooked meats, unpasteurised dairy products or fruit juices, contaminated produce or water, or direct contact with farm animals or their environment. Large outbreaks are often linked to commercial-scale food distribution networks, resulting in major recalls of consumer goods.

Footnote [4] of this list applies to this entry only. It states:

> Shiga toxin producing *Escherichia coli* (STEC) includes *inter alia* enterohaemorrhagic *E. coli* (EHEC), verotoxin producing *E. coli* (VTEC) or verocytotoxin producing *E. coli* (VTEC).

B19.3. Packaging

E. coli is a Category B infectious substance with the shipping code UN 3373 because it is infectious but does not meet the criteria for Category A.

B19.4. Typical Applications

Basic medical research and development (e.g., vaccine research), epidemiology, and global surveillance.

B20. *Shigella dysenteriae*

B20.1. Basic Description

Identifier/Property	Description
Type	Bacteria: Gram stain negative
Associated Disease	Shigellosis, bacillary dysentery
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Mortality rate 1–20% ▸ Potential for socioeconomic harm ▸ Potential to damage the environment ▸ No vaccine ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 2
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Not a known route of exposure ▸ Inhalation (lungs): Not a known route of exposure ▸ Gastrointestinal (intestine): Consumption of contaminated food or water ▸ Injection (bloodstream): Not a known route of exposure **Host/Reservoir:** Humans **Vector:** Not applicable
Geographic Distribution	Worldwide
Zoonotic	No
Human Transmissibility	Yes – direct
EU Control List Entry	1C351.c.20
Applicable AG Footnote(s)	[1]

B20.2. Notable Features

Shigella dysenteriae belongs to the family *Enterobacteriaceae* and is the causative agent of bacillary dysentery or shigellosis. Many different kinds of bacteria can cause dysentery, but *S. dysenteriae* is particularly noteworthy because it produces the potent shiga toxin, which is also controlled by the AG. The bacteria can be transmitted through infected fecal matter. Therefore, the most common source of disease spread is sewage in addition to contaminated food supplies or water sources. *S. dysenteriae* causes severe diarrhea that can only be attributed to the bacteria through laboratory sampling.

B20.3. Packaging

S. dysenteriae is a Category B infectious substance with the shipping code UN 3373 because it is infectious but does not meet the criteria for Category A.

B20.4. Typical Applications

Basic medical research and development (e.g., vaccine research), epidemiology, and global surveillance.

B21. *Vibrio cholerae*

B21.1. Basic Description

Identifier/Property	Description
Type	Bacteria: Gram stain negative
Associated Disease	Cholera
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Mortality rate 50–60% ▸ Potential to damage the environment ▸ Vaccine available ▸ Effective post-exposure treatment
Containment and Handling	Biosafety Level 2
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Not a likely route of exposure ▸ Inhalation (lungs): Not a known route of exposure ▸ Gastrointestinal (intestine): Contaminated food and water ▸ Injection (bloodstream): Not a known route of exposure **Host/Reservoir:** Humans **Vector:** Not applicable
Geographic Distribution	Worldwide in humans, free living in salt water
Zoonotic	No
Human Transmissibility	Not transmissible
EU Control List Entry	1C351.c.21
Applicable AG Footnote(s)	[1]

B21.2. Notable Features

Vibrio cholera belongs to the family *Vibrionaceae* and is the causative agent of cholera. Cholera outbreaks occur naturally in coastal and brackish waters, typically during the warm summer months. The bacteria can be transmitted through infected fecal matter. Therefore, the most common source of disease spread is sewage in addition to contaminated food supplies or water sources. Cholera is an acute diarrheal illness caused by infection of the small intestine. The bacteria release cholera toxin (also controlled by the AG) causing massive quantities of watery diarrhea. The resultant rapid loss of body fluids leads to dehydration, shock, and death if untreated. The mortality rate can drop to only 1% if treatment is given, including restoration of fluids and important nutrients to the body. A vaccine is available and used in populations with endemic cholera outbreaks; however, the vaccine has been shown to provide incomplete immunity for a relatively short period of time. As such, prevention measures are focused generally on improving sanitation, food supplies, and water sources.

B21.3. Packaging

V. cholera is a Category B infectious substance with the shipping code UN 3373 because it is infectious but does not meet the criteria for Category A.

B21.4. Typical Applications

Basic medical research and development (e.g., vaccine research), epidemiology, and global surveillance.

B22. *Yersinia pestis*

B22.1. Basic Description

Identifier/Property	Description
Type	Bacteria: Gram stain negative
Associated Disease	Plague
Other Names	*Pasteurella pestis*
Key WMD Characteristic(s)	▸ Mortality rate 50–90% ▸ Effective aerosol ▸ No vaccine ▸ Effective post-exposure treatment
Containment and Handling	Biosafety Level 3
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wounds ▸ Inhalation (lungs): Aerosols ▸ Gastrointestinal (intestine): Not a likely route of exposure ▸ Injection (bloodstream): Flea bite **Host/Rodents:** Rodents, prairie dogs, ferrets, marmot, humans **Vector:** Fleas
Geographic Distribution	Africa, South America, North America, Asia
Zoonotic	Yes
Human Transmissibility	Yes – direct and respiratory
EU Control List Entry	1C351.c.22
Applicable AG Footnote(s)	[1]

B22.2. Notable Features

Yersinia pestis belongs to the family *Enterobacteriaceae* and is the causative agent of the plague. *Y. pestis* has a broad animal host range; this can have a devastating impact on various food webs as well as establishing many possible routes of disease transmission to humans. Fleas can also act as a vector for transmission to animals and humans. There are three forms of the plague: bubonic, septicemic, and pneumonic. Bubonic plague causes extreme swelling of the lymph glands. Septicemic plague typically develops secondarily to the bubonic plague, and results from infection of the blood. Pneumonic plague is the most severe form and is contracted by inhalation of infectious material.

The plague is responsible for numerous well-documented epidemics throughout history, primarily as a consequence of overpopulation and poor sanitation. Thousands of plague cases are reported annually worldwide. *Y. pestis* can be effectively treated with antibiotics, but early diagnosis is critical, particularly for severe infections of the blood (septicemic plague) and lungs (pneumonic plague).

B22.3. Packaging

Y. pestis is a Category A infectious substance with the shipping code UN 2814 because it is capable of causing permanent disability or life-threatening or fatal disease in otherwise healthy humans or animals when exposure to it occurs.

B22.4. Typical Applications

Basic medical research and development (e.g., vaccine research), epidemiology, and global surveillance.

Toxins as follows and subunits thereof:[5]

T1. Abrin

T1.1. Basic Description

Identifier/Property	Description
Type	Toxin
Other Names	Toxalbumin, agglutinin, crab's eyes, Indian licorice seed, prayer bead
Associated Disease	None; see symptoms in Notable Features
Produced By (Scientific Name)	Rosary pea or jequirity pea plant: *Abrus precatorius*
Key WMD Characteristic(s)	▸ Potential aerosol ▸ No antitoxin ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 2; Biosafety Level 3 is advised if activity has high potential for generating aerosols
Exposure Routes	**Exposure:** ▸ Cutaneous (skin): Not a known route of exposure ▸ Inhalation (lungs): Not a known route of exposure ▸ Gastrointestinal (intestine): Consumption of seeds or contaminated food or water ▸ Injection (bloodstream): Not a known route of exposure **Host/reservoir:** Not applicable **Vector:** Not applicable
Endemic Range	Worldwide; warm and tropical climates
CAS#	1393-62-0
EU Control List Entry	1C351.d.12
Applicable AG Footnote(s)	[1] [5]

T1.2. Notable Features

Abrin toxin is found in the coatings of seeds produced by the ornamental rosary pea or jequirity pea. The rosary pea is indigenous to the tropics where it has historically been used as a herbal remedy and as decoration in beaded jewelry. The rosary pea is easily recognisable due to its red coat with a black spot on one end. Potent toxicity of the rosary pea is widely recognised. Similar to ricin, abrin potently inhibits the ability of a cell to make protein, causing cell and organ failure.

Exposure to even a small amount of abrin may be fatal. Specific symptoms of abrin poisoning depend on the route of exposure and dose. Symptoms of initial abrin consumption are localised to the gastrointestinal system and include vomiting and bloody diarrhea. Inhalation exposure would result in difficulty breathing, fever, cough, nausea, and tightness in the chest. Later symptoms of severe exposure for all transmission routes can develop into seizures, multi-organ failure, and death.

Figure T1.A. *Top: abrin seed pod and plant. Bottom: abrin seeds.*

T1.3. Packaging

Abrin is assigned UN number 3172 (toxins extracted from living sources, liquid) or UN number 3462 (toxins extracted from living sources, solid).

T1.4. Typical Applications

Abrin is being investigated as a possible cancer treatment.

T2. Aflatoxins

T2.1. Basic Description

Identifier/Property	Description
Type	Toxin
Other Names	Mycotoxins, *Aspergillus flavus* toxins
Associated Disease	Aflatoxicosis
Produced By (Scientific Name)	Several fungi, including *Aspergillus flavus* and *Aspergillus parasiticus*
Key WMD Characteristic(s)	▸ Toxin produced by environmentally stable spores ▸ No antitoxin ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 2; Biosafety Level 3 is advised if activity has high potential for generating aerosols
Exposure Routes	**Exposure:** ▸ Cutaneous (skin): Direct absorption to bloodstream ▸ Inhalation (lungs): Not a known route of exposure ▸ Gastrointestinal (intestine): Consumption of contaminated crops, grains, or milk ▸ Injection (bloodstream): Not a known route of exposure **Host/reservoir:** Not applicable **Vector:** Not applicable
Endemic Range	Worldwide
CAS#[1]	Aflatoxin B1: 1162-65-8 Aflatoxin B2: 7220-81-7 Aflatoxin G1: 1165-39-5 Aflatoxin G2: 7241-98-7
EU Control List Entry	1C351.d.11
Applicable AG Footnote(s)	[1] [5]

T2.2. Notable Features

Aflatoxins are produced by naturally occurring fungi. These toxin-producing fungi become inadvertently incorporated into the food supply by infecting crops, mostly during the drying stage; they subsequently transmit the disease to humans and animals that ingest contaminated products. Aflatoxins have been detected in many consumer goods, including cereal crops, peanut butter, cooking oils, cassava, chili peppers, sorghum, sunflower seeds, spices, eggs, milk, meat, and even cosmetics. Humans are more tolerant of aflatoxins than animals, and thus incidences of acute aflatoxicosis in humans are generally rare. However, chronic exposure for those who work in the livestock and agricultural industry is of concern as significant doses are necessary in order for the toxins to manifest clinically significant symptoms. Cumulative exposure to aflatoxins has the potential to cause liver cancer in addition to manifesting more short-term effects like acute liver failure, haemorrhage, gastrointestinal distress, and coma.

T2.3. Packaging

Aflatoxins are assigned UN number 3172 (toxins extracted from living sources, liquid) or UN number 3462 (toxins extracted from living sources, solid).

[48] These are the major aflatoxins only

T2.4. Typical Applications

Aflatoxins are used as reference standards for screening commercial crops for contamination. They are also used in basic biomedical research to produce cell culture models of liver cancer that can be used to investigate potential cancer therapies.

T3. Botulinum toxins[6]

T3.1. Basic Description

Identifier/Property	Description
Type	Toxin
Other Names	Botulinum toxins (A–H): 8 distinct botulinum toxins
Associated Disease	Botulism
Produced By (Scientific Name)	Bacteria: *Clostridium botulinum, C. butyricum, C. baratii,* and *C. argentinense*
Key WMD Characteristic(s)	▸ Potential aerosol ▸ Toxin-producing bacteria form environmentally stable spores ▸ Potential for socioeconomic harm ▸ Effective antitoxin
Containment and Handling	Biosafety Level 2; Biosafety Level 3 may be used if activity has high potential for producing aerosols
Exposure Routes	**Exposure:** ▸ Cutaneous (skin): Not a known route of exposure ▸ Inhalation (lungs): Not a known route of exposure ▸ Gastrointestinal (intestine): Consumption of foods or water containing botulinum toxin or toxin-producing bacteria ▸ Injection (bloodstream): Direct poisoning from misapplication of botulinum toxin prescribed to treat a medical condition **Host/Reservoir:** Not applicable **Vector:** Not applicable
Endemic Range	Worldwide; soil and untreated water.
CAS #	Neurotoxin A: 93384-43-1 Neurotoxin B: 93384-44-2 Neurotoxin C: 93384-45-3 Neurotoxin D: 93384-46-4 Neurotoxin E: 93384-47-5 Neurotoxin F: 107231-15-2 Neurotoxin G: 107231-16-3 Neurotoxin H: to be determined
EU Control List Entry	1C351.d.1
Applicable AG Footnote(s)	[1] [5] [6]

T3.2. Notable Features

Botulinum toxins are neurotoxins produced by a variety of different species within the genus *Clostridium*; these species include *C. botulinum*, *C. butyricum*, *C. baratii*, and *C. argentinense*, all of which also are controlled by the AG. Botulinum toxins cause botulism, a paralytic illness. Typical symptoms of botulism include blurred vision, difficulty speaking, jaw weakness, droopy eyelids, and loss of head control. Left untreated, the disease can result in respiratory failure, permanent nerve damage, or death. Antitoxins have been developed to treat individuals exposed to botulinum toxins or infected with botulinum-toxin-producing bacteria. However, treatment is only effective if begun immediately upon suspicion of botulism.

Footnote [6] of this list applies to botulinum toxins and excludes certain botulinum toxins from control. It states:

Excluding botulinum toxins in product form meeting all of the following criteria:

- are pharmaceutical formulations designed for testing and human administration in the treatment of medical conditions;
- are pre-packaged for distribution as clinical or medical products; and
- are authorised by a state authority to be marketed as clinical or medical products.[49]

T3.3. Packaging

Botulinum toxins are assigned UN number 3172 (toxins extracted from living sources, liquid) or UN number 3462 (toxins extracted from living sources, solid).

T3.4. Typical Applications

In addition to basic research into the biology of botulinum toxins and development of antitoxins, botulinum toxins are an area of active pharmaceutical research. Currently, neurotoxins A and B are the primary active ingredients in prescription medicines (e.g., Botox®) used to relax or weaken overactive muscles.[50] The same properties of botulinum toxins that make them a biological weapon concern (i.e., ability to cause muscle paralysis) also make these toxins a highly effective cosmetic and pharmaceutical therapy when applied directly to muscles in small, localised amounts. For example, when injected locally under the skin, botulinum toxin can remove wrinkles, treat misaligned eye syndrome, treat migraine headaches, and eliminate excess sweating.

[49] See Footnote [6] in the AG Human and Animal Pathogens and Toxins Control List: https://www.dfat.gov.au/publications/minisite/theaustraliagroupnet/site/en/human_animal_pathogens.html.

[50] See U.S. National Institutes of Health summary information page on Botox: http://www.nlm.nih.gov/medlineplus/botox.html.

T4. Cholera toxin

T4.1. Basic Description

Identifier/Property	Description
Type	Toxin
Other Names	Blue death, rice water
Associated Disease	Cholera
Produced By (Scientific Name)	Bacteria: *Vibrio cholerae*
Key WMD Characteristic(s)	▸ Potential to damage the environment ▸ No antitoxin ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 2; Biosafety Level 3 is advised if activity has high potential for generating aerosols
Exposure Routes	**Exposure:** ▸ Cutaneous (skin): Not a likely route of exposure ▸ Inhalation (lungs): Not a likely route of exposure ▸ Gastrointestinal (intestine): Consumption of contaminated food or water ▸ Injection (bloodstream): Not a known route of exposure **Host/reservoir:** Not applicable **Vector:** Not applicable
Endemic Range	Worldwide; untreated fresh water, estuaries
CAS#	9012-63-9
EU Control List Entry	1C351.d.13
Applicable AG Footnote(s)	[1] [5]

T4.2. Notable Features

Cholera is an infection of the small intestines caused by the bacterium *Vibrio cholerae*. The infecting bacteria release cholera toxin, which causes the cells of the intestines to release massive amounts of water, resulting in watery diarrhea. Cholera affects millions of people worldwide, mainly throughout developing countries suffering from poor sanitation, inadequate food, and water supplies, or plagued by war or natural disaster. Natural outbreaks of cholera can develop from algal blooms that then infect local shellfish living in the affected water. The primary symptoms of cholera are profuse diarrhea and vomiting of clear fluid. An infected person can lose as much as 5 gallons of fluid a day; severe dehydration and electrolyte imbalance is fatal.

T4.3. Packaging

Cholera toxin is assigned UN number 3172 (toxins extracted from living sources, liquid) or UN number 3462 (toxins extracted from living sources, solid).

T4.4. Typical Applications

Cholera toxin is a widely used and important pharmacological tool in cell biology research for studying the molecules cells use to communicate with one another. It is used in cell culture experiments, cancer research, and production of antibodies.

T5. *Clostridium perfringens* alpha, beta 1, beta 2, epsilon and iota toxins

T5.1. Basic Description

Identifier/Property	Description
Type	Toxin
Other Names	Epsilon toxin
Associated Disease	None; see symptoms in Notable Features
Produced By (Scientific Name)	Bacteria: *Clostridium perfringens* types B and D, *Clostridium welchii*
Key WMD Characteristic(s)	▸ Potential aerosol ▸ Toxin-producing bacteria form environmentally stable spores ▸ No antitoxin ▸ Limited to post-exposure treatment
Containment and Handling	Biosafety Level 2
Exposure Routes	**Exposure:** ▸ Cutaneous (skin): Open wound ▸ Inhalation (lungs): Aerosols ▸ Gastrointestinal (intestine): Consumption of contaminated water and food ▸ Injection (bloodstream): Not a known route of exposure **Host/Reservoir:** Not applicable **Vector:** Not applicable
Endemic Range	Worldwide; intestines of animals, humans, and insects
CAS#	Not applicable
EU Control List Entry	1C351.d.2
Applicable AG Footnote(s)	[1] [5]

T5.2. Notable Features

C. perfringens bacteria produce several exotoxins, including the five lethal types listed in this control entry. The bacteria are spore-forming and many strains are part of the healthy intestinal flora of humans, animals, and insects. However, certain other strains are also the third most common cause of food poisoning in the United Kingdom and the United States. This is primarily due to inadequately prepared meat and poultry containing high levels of *C. perfringens* toxins alpha, beta1, beta2, epsilon, and iota. These toxins cause necrotic damage to human tissue and muscle, killing these cells. Treatment of toxin exposure involves excision of the affected tissue, amputation, and antibiotics. Antitoxins exist to several *C. Perfringens* toxins, but their application appears focused on preventing toxin-induced sickness among newborn animals. All toxins can be transmitted in contaminated food or water. Epsilon toxin is capable of being aerosolised.

T5.3. Packaging

C. perfringens alpha, beta 1, beta 2, epsilon, and iota toxins are assigned UN number 3172 (toxins extracted from living sources, liquid) or UN 3462 (toxins extracted from living sources, solid).

T5.4. Typical Applications

Basic biomedical research and development, particularly the study of *C. perfringens* and the development of antitoxins.

T6. Conotoxins[6]

T6.1. Basic Description

Identifier/Property	Description
Type	Toxin
Other Names	α–, δ–, κ–, μ–, ω-conotoxin: 5 primary toxin families
Associated Disease	None; see symptoms in Notable Features
Produced by (Scientific Name)	Pacific cone snails of the genus *Conus*, including but not limited to: *Conus geographus* and *Conus magus*
Key WMD Characteristic(s)	▸ Potential aerosol ▸ Environmentally stable toxin ▸ No antitoxin ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 2 should be used for most work with conotoxins; Biosafety Level 3 should be used for large scale production or activities having high potential for aerosol
Exposure Routes	**Exposure:** ▸ Cutaneous (skin): Not a known route of exposure ▸ Inhalation (lungs): Not a known route of exposure ▸ Gastrointestinal (intestine): Not a known route of exposure ▸ Injection (bloodstream): Cone snail sting **Host/Reservoir:** Not applicable **Vector:** Not applicable
Endemic Range	Warm and tropical oceans; marine snails
CAS#[4]	α-conotoxin GI:76862-65-2 conotoxin GIV: 81133-24-6 ω-conotoxin GIVA: 106375-28-4 μ-conotoxin GIIIA: 129129-65-3 μ-conotoxin GIIIB: 140678-12-2 α-conotoxin MI: 83481-45-2 ω-conotoxin MVIIA: 107452-89-1 ω-conotoxin MVIIC: 147794-23-8 α-Conotoxin AulB: 216299-21-7
EU Control List Entry	1C351.d.3
Applicable AG Footnote(s)	[1] [5] [6]

[51] The following list is representative only. There are numerous additional conotoxins and many have not been assigned CAS registry numbers. Despite the absence of a finite list, conotoxin nomenclature is very consistent with the format: W-conotoxin XYZ.
W: a Greek letter (α, δ, κ, μ, ω, etc.) describing the family.
X: the first letter of the conus species of isolation.
Y: a Roman numeral describing the three-dimensional structure of the protein.
Z: an optional letter (A, B, C, etc.) for variants with same three-dimensional structure.

T6.2. Notable Features

Conotoxins are a diverse[52] group of peptide neurotoxins naturally produced by predatory cone snails, which are found in warm waters and coral reefs throughout the Pacific and Australia. The venom containing the toxin functions as a natural defence for these animals and is their primary mechanism for immobilising prey. Humans can survive a sting from one of several species of small cone snails but will likely suffer from some of the following symptoms: weakness, speech difficulties, drooping eyelids, poor coordination, absence of the gag reflex, generalised numbness, urinary retention, double vision, and respiratory distress. Stings from larger tropical cone snails are generally fatal to humans.

Figure T6.A. *Cone shell snails are equipped with an extendable arm (red tip, right) for delivering venom to their prey.*

Footnote [6] of this list applies to conotoxins and excludes certain conotoxins from control. It states:

Excluding conotoxins in product form meeting all of the following criteria:

- are pharmaceutical formulations designed for testing and human administration in the treatment of medical conditions;
- are pre-packaged for distribution as clinical or medical products; and
- are authorised by a state authority to be marketed as clinical or medical products.[53]

T6.3. Packaging

Conotoxins are assigned UN number 3172 (toxins extracted from living sources, liquid) or UN number 3462 (toxins extracted from living sources, solid).

T6.4. Typical Applications

Conotoxins are widely used pharmacological tools in biomedical research and development, particularly as a key reagent in basic neuroscience research. New conotoxins continue to be identified. In addition, conotoxins have garnered attention as the basis for developing new compounds or chemistries having pharmacological or therapeutic applications, especially in the treatment of severe or chronic pain. Many conotoxins considered important tools in basic biomedical research are produced by either “milking” and subsequently purifying venom from captive cone snails or chemical peptide synthesis; the latter is possible due to the small size of conotoxins (20–30 amino acids).

[52] See the following online conotoxin resource: http://www.conoserver.org/.

[53] See Footnote [6] in the AG Human and Animal Pathogens and Toxins Control List: https://www.dfat.gov.au/publications/minisite/theaustraliagroupnet/site/en/human_animal_pathogens.html.

T7. Diacetoxyscirpenol

T7.1. Basic Description

Identifier/Property	Description
Type	Toxin
Other Names	Trichothecene
Associated Disease	None; see symptoms in Notable Features
Produced By (Scientific Name)	Fungi of several genuses including *Fusarium*
Key WMD Characteristic(s)	▸ Potential aerosol ▸ No antitoxin ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 2; Biosafety Level 3 is advised if activity has high potential for generating aerosols
Exposure Routes	**Exposure:** ▸ Cutaneous (skin): Not a known route of exposure ▸ Inhalation (lungs): Not a known route of exposure ▸ Gastrointestinal (intestine): Consumption of contaminated grains ▸ Injection (bloodstream): Not a known route of exposure **Host/reservoir:** Not applicable **Vector:** Not applicable
Endemic Range	Temperate regions; North and South America, Europe, Asia
CAS#	2270-40-8
EU Control List Entry	1C351.d.14
Applicable AG Footnote(s)	[1] [5]

T7.2. Notable Features

Diacetoxyscirpenol is one of a group of trichothecene toxins produced at varying levels across several genera of fungi. Diacetoxyscirpenol is considered mostly an agricultural concern as it can cause tissue death, decreased activity, diarrhea, and weight loss in livestock.

T7.3. Packaging

Diacetoxyscirpenol is assigned UN number 3172 (toxins extracted from living sources, liquid) or UN number 3462 (toxins extracted from living sources, solid).

T7.4. Typical Applications

Basic biomedical research and development.

T8. HT-2 toxin

T8.1. Basic Description

Identifier/Property	Description
Type	Toxin
Other Names	Trichothecene
Associated Disease	Alimentary toxic aleukia
Produced By (Scientific Name)	Fungi of several genera including *Fusarium*
Key WMD Characteristic(s)	▸ Mortality rate 10–60% ▸ Potential aerosol ▸ No antitoxin ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 2; Biosafety Level 3 is advised if activity has high potential for generating aerosols
Exposure Routes	**Exposure:** ▸ Cutaneous (skin): Skin blistering ▸ Inhalation (lungs): Not a known route of exposure ▸ Gastrointestinal (intestine): Consumption of contaminated grains ▸ Injection (bloodstream): Not a known route of exposure **Host/reservoir:** Not applicable **Vector:** Not applicable
Endemic Range	Temperate regions; North and South America, Europe, Asia
CAS#	26934-87-2
EU Control List Entry	1C351.d.16
Applicable AG Footnote(s)	[1] [5]

T8.2. Notable Features

HT-2 toxin is one of is one of a group of toxins produced by fungi. These fungi naturally develop in or on cereals and grains in the field during wet conditions. HT-2 toxin is a derivative of T-2 toxin produced when T-2 toxin is metabolised by its fungi producer. Therefore, HT-2 toxin will always be found occurring with the presence of T-2 toxin. When measuring exposure of the two toxins, both have an additive effective in terms of disease manifestation and are therefore considered separate entities for the purpose of both scientific research and AG control. Symptoms of exposure tend to be localised to the digestive system, causing alimentary toxic alukeia and tissue death in the upper intestinal tract. Symptoms also can include generic flu-like symptoms, eye infection, haemorrhage, and death.

T8.3. Packaging

HT-2 toxin is assigned UN number 3172 (toxins extracted from living sources, liquid) or UN number 3462 (toxins extracted from living sources, solid).

T8.4. Typical Applications

HT-2 toxin is used as a reference standard for screening commercial crops for trichothecene contamination.

T9. Microcystins (Cyanoginosins)

T9.1. Basic Description

Identifier/Property	Description
Type	Toxin
Other Names	Cyclic heptapeptide (7-amino acids) hepatotoxins (liver toxins), Cyanotoxins, toxins produced by cyanobacteria
Associated Disease	None; see symptoms in Notable Features
Produced by (Scientific Name)	Several cyanobacteria species, including *Microcystis aeruginosa, Planktothrix rubescens, Planktothrix agardhii*
Key WMD Characteristic(s)	▸ Potential aerosol ▸ Environmentally stable toxin ▸ No antitoxin ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 2; Biosafety Level 3 is advised if activity has high potential for generating aerosols
Exposure Routes	**Exposure:** ▸ Cutaneous (skin): Open wound ▸ Inhalation (lungs): Not a known route of exposure ▸ Gastrointestinal (intestine): Consumption of contaminated seafood, shellfish, or water ▸ Injection (bloodstream): Not a known route of exposure **Host/reservoir:** Not applicable **Vector:** Not applicable
Endemic Range	Worldwide; potential for accumulation in shellfish
CAS#[7]	Microcystin-LR: 101043-37-2 Microcystin-LA: 96180-79-9 Microcystin-RR: 111755-37-4 Microcystin LF: 154037-70-4 Microcystin LW: 157622-02-1 Microcystin-LY: 123304-10-9 Microcystin-YR: 101064-48-6 Microcystin-WR: 138234-58-9
EU Control List Entry	1C351.d.10
Applicable AG Footnote(s)	[1] [5]

T9.2. Notable Features

Microcystins are produced by several cyanobacteria (blue-green algae). There are more than 80 known toxic variants of microcystins, some of which are toxic to humans. Microcystin-containing algae blooms are a problem worldwide, most often associated with nutrient overloading in water bodies stemming from agricultural runoff. Once ingested, microcystins mostly accumulate in the liver, with lower levels residing in the blood stream or tissue. Microcystins can damage the liver irreversibly, and a link between microcystin toxin levels in the liver and certain types of liver cancer has been proposed. Although microcystins preferentially target the liver, the toxin can also create gastrointestinal symptoms and skin rash based on

[54] Several toxins have not been assigned CAS registry numbers.

route of transmission. Although microcystins generally exact their damage gradually, high concentrations of microcystins in drinking water can result in death.

T9.3. Packaging

Microcystins are assigned UN number 3172 (toxins extracted from living sources, liquid) or UN number 3462 (toxins extracted from living sources, solid).

T9.4. Typical Applications

Microcystins are key tools in cell biology research studying the molecules cells use to communicate. In addition, microcystins are used as reference standards for kits designed to detect microcystins in water.

T10. Modeccin

T10.1. Basic Description

Identifier/Property	Description
Type	Toxin
Other Names	Not applicable
Associated Disease	None; see symptoms in Notable Features
Produced By (Scientific Name)	Plant: *Adenia digitata or Modecca digitata* (synonym)
Key WMD Characteristic(s)	▸ Potential aerosol ▸ Environmentally stable toxin ▸ No antitoxin ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 2; Biosafety Level 3 is advised if activity has high potential for generating aerosols
Exposure Routes	**Exposure:** ▸ Cutaneous (skin): Not a known route of exposure ▸ Inhalation (lungs): Not a known route of exposure ▸ Gastrointestinal (intestine): Consumption of plant root or other foods containing toxin ▸ Injection (bloodstream): Not a known route of exposure **Host/reservoir:** Not applicable **Vector:** Not applicable
Endemic Range	Southern Africa; natural plant product
CAS#	65988-88-7
EU Control List Entry	1C351.d.17
Applicable AG Footnote(s)	[1] [5]

T10.2. Notable Features

Modeccin is a toxic compound present in the roots of the native plant *Adenia digitata* in southern Africa. This plant belongs to a genus which includes a number of species that produce a combination of potent toxins. Modeccin has an extremely low lethal dose. Symptoms of modeccin consumption are localised to the gastrointestinal system and include vomiting and bloody diarrhea. It is expected that due to its similarity in structure to other toxins such as ricin and abrin, inhalation exposure would result in difficulty breathing, fever, cough, nausea, and tightness in the chest. Severe exposure for all transmission routes can lead to seizures, multi-organ failure, and death.

T10.3. Packaging

Modeccin is assigned UN number 3172 (toxins extracted from living sources, liquid) or UN number 3462 (toxins extracted from living sources, solid).

T10.4. Typical Applications

The potent ability of modeccin to inhibit protein synthesis has led to investigation of modeccin as a possible medical treatment against cancerous tumours.

T11. Ricin

T11.1. Basic Description

Identifier/Property	Description
Type	Toxin
Other Names	Not applicable
Associated Disease	None; see symptoms in Notable Features
Produced by (Scientific Name)	Castor bean plant: *Ricinus communis*
Key WMD Characteristic(s)	▸ Potential aerosol ▸ Environmentally stable toxin ▸ No antitoxin ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 2; Biosafety Level 3 is advised if activity has high potential for generating aerosols
Exposure Routes	**Exposure:** ▸ Cutaneous (skin): Not a known route of exposure ▸ Inhalation (lungs): Not a known route or exposure ▸ Gastrointestinal (intestine): Consumption of castor beans or castor bean products in which the ricin toxin has not been inactivated ▸ Injection (bloodstream): Direct poisoning **Host/Reservoir:** Not applicable **Vector:** Not applicable
Endemic Range	Mediterranean, Middle East; castor bean plant
CAS#	Subunit A: 96638-28-7 Subunit B: 96638-29-8
EU Control List Entry	1C351.d.4
Applicable AG Footnote(s)	[1] [5]

T11.2. Notable Features

Ricin is a toxin produced naturally by the castor oil plant native to the Mediterranean and the Middle East. Ricin can be extracted from the bean itself or from residues left over from the processing of castor beans for castor oil. Castor oil is produced all over the world for legitimate applications (see more in Typical Applications).

Figure T11.A. *Left: castor plant. Right: castor beans.*

Symptoms of ricin consumption are localised to the gastrointestinal system and include vomiting and bloody diarrhea. Inhalation exposure would result in difficulty breathing, fever, cough, nausea, and tightness in the chest. Later symptoms of severe exposure for all transmission routes can include seizures, multi-organ failure, and death. There is no approved antitoxin for ricin; however, successful clinical trials have been completed for RiVax®, an

anti-ricin vaccine.[55] Absent an anti-ricin therapy, the only marginally effective strategy involves cleaning or physically removing ricin from the body.[56]

Ricin is one of two toxins (the other being saxitoxin) listed in Schedule 1A of the Chemical Weapons Convention.

T11.3. Packaging

Ricin is assigned UN number 3172 (toxins extracted from living sources, liquid) or UN number 3462 (toxins extracted from living sources, solid).

T11.4. Typical Applications

Despite the common occurrence and use of castor beans, accidental exposure to ricin would be unlikely. This is because legitimate processing of castor beans or their mash easily inactivates the ricin toxin, allowing the beans and their products to be used safely for other purposes (e.g., animal feed).

Ricin has been shown experimentally to be an effective treatment against certain types of cancers.[57] Anti-cancer properties make sense, given ricin's potent ability to disrupt certain cellular processes; however, ricin is not presently a licensed and approved anti-cancer therapy. Research and experimental studies with the toxin do exist and appear principally aimed at improving delivery and target specificity for potential therapeutic applications.

[55] RiVax Ricin Toxin Vaccine Information: https://emergency.cdc.gov/agent/ricin/facts.asp.

[56] U.S. CDC Facts About Ricin: https://emergency.cdc.gov/agent/ricin/facts.asp.

[57] Ibid.

T12. Saxitoxin

T12.1. Basic Description

Identifier/Property	Description
Type	Toxin
Other Names	STX
Associated Disease	Paralytic shellfish poisoning (PSP)
Produced By (Scientific Name)	Marine dinoflagellates and cyanobacteria
Key WMD Characteristic(s)	▸ Effective aerosol ▸ Environmentally stable toxin ▸ No antitoxin ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 2; Biosafety Level 3 is advised if activity has high potential for generating aerosols
Exposure Routes	**Exposure:** ▸ Cutaneous (skin): Open wounds ▸ Inhalation (lungs): Aerosols ▸ Gastrointestinal (intestine): Consumption of contaminated food or water, generally fish. ▸ Injection (bloodstream): Not a likely route of exposure **Host/reservoir:** Not applicable **Vector:** Not applicable
Endemic Range	Oceans worldwide; fish and shellfish accumulate saxitoxin when their food chain includes toxic algal blooms
CAS#	35523-89-8
EU Control List Entry	1C351.d.5
Applicable AG Footnote(s)	[1] [5]

T12.2. Notable Features

The best known of the paralytic shellfish toxins (PST), saxitoxin is a neurotoxin produced naturally by certain species of marine microorganisms. Often as a result of a toxic algal bloom, the saxitoxin moves species by species through the food chain, starting with filter-feeding shellfish (e.g., clams, mussels, and scallops) and certain finfish which accumulate the toxin. Human consumption of contaminated shellfish results in paralytic shellfish poisoning. Symptoms of exposure can onset as early as a few minutes after exposure. Initial symptoms include tingling or burning around exposed areas, progressing within one day to paralysis and death.

Historically, saxitoxin has been used as a name for a group of related neurotoxins: saxitoxin (STX), neosaxitoxin (NSTX), gonyautoxins (GTX), and decarbamoylsaxitoxin (dcSTX). All cause paralysis. Despite the common use of "saxitoxin" to refer to the entire group of paralytic shellfish poisoning toxins, only one of these toxins has the scientific name saxitoxin.

Saxitoxin is one of two toxins (the other being ricin) listed in Schedule 1A of the Chemical Weapons Convention.

T12.3. Packaging

Saxitoxin is assigned UN number 3172 (toxins extracted from living sources, liquid) or UN number 3462 (toxins extracted from living sources, solid).

T12.4. Typical Applications

Saxitoxin is routinely used in cellular and molecular biology research, particularly research that seeks to detect saxitoxin in fish prior to human consumption and research into saxitoxin antidotes.

T13. Shiga toxins (shiga-like toxins, verotoxins, and verocytotoxins)

T13.1. Basic Description

Identifier/Property	Description
Type	Toxin
Other Names	Shiga toxins (Stx, Stx1, Stx2), shiga-like toxins (SLT-1, SLT-2), verotoxins, verocytotoxins
Associated Disease	Not applicable
Produced by (Scientific Name)	Bacteria: *Shigella dysenteriae, Shigatoxigenic Escherichia coli*
Key WMD Characteristic(s)	▸ Potential aerosol ▸ Potential to damage the environment ▸ No antitoxin ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 2; Biosafety Level 3 is advised if activity with toxin or toxin-producing bacteria has high potential for producing aerosols
Exposure Routes	**Exposure:** ▸ Cutaneous (skin): Not a known route of exposure ▸ Inhalation (lungs): Not a known route of exposure ▸ Gastrointestinal (intestine): Consumption of contaminated food or water ▸ Injection (bloodstream): Not a known route of exposure **Host/Reservoir:** Not applicable **Vector:** Not applicable
Endemic Range	Worldwide; found in untreated water.
CAS#	75757-64-1
EU Control List Entry	1C351.d.6
Applicable AG Footnote(s)	[1] [5]

T13.2. Notable Features

Shiga toxin describes a number of related toxins. Shiga toxins are produced by several species of bacterium in the *Shigella* genus. Additionally, several *Escherichia coli* strains produce shiga toxins, including serotypes O157:H7, O104:H4 and other enterohemorrhagic *E. coli,* that are also controlled by the AG. Historically, shiga toxins produced by *E. coli* (Stx1, Stx2) were also known as shiga-like toxins (SLT-1, -2), verotoxins, or verocytotoxins. leading cause of bacterial intestine infections. Additionally, shiga toxin producing E. coli have been linked to hemolytic-uremic syndrome (HUS). The group of bacteria that produce shiga toxins are a leading cause of bacterial intestine infections. Although humans are susceptible to shiga toxins, large mammals like cattle, swine, and deer are not; however, these animals can pass and spread bacteria and toxin in their feces.

Toxin-producing bacteria are transmitted through consumption of contaminated foods, including undercooked meat, unpasteurised juices, raw milk and produce, and contaminated water. *Shigella dystenteriae* infections are particularly problematic in developing countries that do not have access to clean water. Depending on the severity and duration of toxin exposure, symptoms can range from mild intestinal disease to severe hemorrhagic diarrhea and kidney failure. Treatment for exposure to shiga toxin or the toxin-producing bacteria is generally limited to supportive care such as hydration, unless the exposure symptoms have progressed to organ failure. Antitoxin treatments are currently under research.

T13.3. Packaging

Shiga toxin is assigned UN number 3172 (toxins extracted from living sources, liquid) or UN number 3462 (toxins extracted from living sources, solid).

T13.4. Typical Applications

In addition to basic medical research and development, such as the effort to produce antitoxin therapies, shiga toxin is being actively investigated for development as a potential cancer treatment. Certain cancer cells are known to be highly susceptible to destruction by shiga toxins.

T14. *Staphylococcus aureus* enterotoxins, hemolysin alpha toxin, and toxic shock syndrome toxin (formerly known as Staphylococcus enterotoxin F)

T14.1. Basic Description

Identifier/Property	Description
Type	Toxin
Other Names	Not applicable
Associated Disease	Staphylococcal enterotoxin B poisoning, Gastroenteritis.
Produced By (Scientific Name)	Bacteria: *Staphylococcus aureus, Staphylococcus pyogenes*.
Key WMD Characteristic(s)	▸ Environmentally stable toxin ▸ No antitoxin ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 2; Biosafety Level 3 is advised if activity has high potential for generating aerosols
Exposure Routes	**Exposure:** ▸ Cutaneous (skin): Open wound ▸ Inhalation (lungs): Not a known route of exposure ▸ Gastrointestinal (intestine): Consumption of contaminated food ▸ Injection (bloodstream): Not a known route of exposure **Host/reservoir:** Not applicable **Vector:** Not applicable
Endemic Range	Worldwide
CAS#[11]	Enterotoxin A: 642595-84-4 Enterotoxin B: 11100-45-1 Hemolysin alpha toxin: 94716-94-6
EU Control List Entry	1C351.d.7
Applicable AG Footnote(s)	[1] [5]

T14.2. Notable Features

Staphylococcus aureus is a common cause for food poisoning, although exposure can also result in skin infections and respiratory disease. *S. aureus* is commonly found in both humans and animals and has the ability to produce several types of toxins. There are at least 10 different staphylococcal enterotoxins that create gastrointestinal distress in the host. Hemolysin alpha toxin adds to the pathogenicity and virulence of the bacteria. Toxic shock syndrome (TSS) toxin can cause toxic shock syndrome in humans. Symptoms of TSS include fever, weakness, and confusion and can progress to coma and death. Although exposure to the toxins may not result in death, the resulting symptoms can be extremely debilitating.

T14.3. Packaging

Staphylococcal enterotoxins are assigned UN number 3172 (toxins extracted from living sources, liquid) or UN number 3462 (toxins extracted from living sources, solid).

[58] Several toxins have not been assigned CAS registry numbers.

T14.4. Typical Applications

Staphyloccocal enterotoxins are used as reference standards in the development of tests to screen food for contamination.

T15. T-2 toxin

T15.1. Basic Description

Identifier/Property	Description
Type	Toxin
Other Names	Trichothecene
Associated Disease	Alimentary toxic aleukia
Produced By (Scientific Name)	Fungi of several genera including *Fusarium*
Key WMD Characteristic(s)	▸ Mortality rate 10–60% ▸ Potential aerosol ▸ No antitoxin ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 2; Biosafety Level 3 is advised if activity has high potential for generating aerosols
Exposure Routes	**Exposure:** ▸ Cutaneous (skin): Skin blistering ▸ Inhalation (lungs): Not a known route of exposure ▸ Gastrointestinal (intestine): Consumption of contaminated grains ▸ Injection (bloodstream): Not a known route of exposure **Host/reservoir:** Not applicable **Vector:** Not applicable
Endemic Range	Temperate regions; North and South America, Europe, Asia
CAS#	21259-20-1
EU Control List Entry	1C351.d.15
Applicable AG Footnote(s)	[1] [5]

T15.2. Notable Features

T-2 toxin is one of is one of a group of toxins produced by several genera of fungi. These fungi naturally develop in or on cereals and grains in the field during wet conditions. Depending on the route of exposure, T-2 toxin creates blistering on the skin in addition to eye irritation in both animals and humans. T-2 toxin is unique in that it creates blistering upon contact with the skin even without the presence of an open wound. Symptoms of severe exposure tend to be localised to the digestive system, causing alimentary toxic alukeia and tissue death in the upper intestinal tract. Symptoms also can include generic flu-like symptoms, eye infection, haemorrhage, and death.

T15.3. Packaging

T-2 toxin is assigned UN number 3172 (toxins extracted from living sources, liquid) or UN number 3462 (toxins extracted from living sources, solid).

T15.4. Typical Applications

T-2 toxin is used as a reference standard for screening commercial crops for trichothecene contamination.

T16. Tetrodotoxin

T16.1. Basic Description

Identifier/Property	Description
Type	Toxin
Other Names	Tarichatoxin, Spheroidine, Maculotoxin, Fugu poison, TTX
Associated Disease	Pufferfish poisoning, Fugu poisoning, Tetradon poisoning
Produced by (Scientific Name)	Several bacteria species including *Pseudoalteromonas haloplanktis tetraodonis* that lives inside the fugu fish
Key WMD Characteristic(s)	▸ No antitoxin ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 2; Biosafety Level 3 is advised if activity has high potential for generating aerosols
Exposure Routes	**Exposure:** ▸ Cutaneous (skin): Not a known route of exposure ▸ Inhalation (lungs): Not a known route of exposure ▸ Gastrointestinal (intestine): Consumption of contaminated foods ▸ Injection (bloodstream): Not a likely route of exposure **Host/reservoir:** Not applicable **Vector:** Not applicable
Endemic Range	South America, Africa, Southeast Asia; seawater and freshwater pufferfish
CAS#	4368-28-9
EU Control List Entry	1C351.d.8
Applicable AG Footnote(s)	[1] [5]

T16.2. Notable Features

Tetrodotoxin (TTX) is a potent neurotoxin found in the liver and sex organs of certain types of marine life: pufferfish, porcupinefish, ocean sunfish, triggerfish, blue-ringed octopus, rough skinned newt, predatory moon snails, toads, sea stars, angelfish, certain types of marine worms, and crabs. Tetrodotoxin is produced by symbiotic bacteria present within these fish and animals. The toxin attacks nerve cells, causing paralysis of muscle, including the diaphragm (respiratory failure), heart (increased heart rate), and the nervous system. There is no known antitoxin for tetrodotoxin in humans.

Human exposure to tetrodotoxin is most frequently associated with consumption of the pufferfish and other marine or freshwater animals that harbour the toxin-producing bacterium. In Japan, the pufferfish is a delicacy and chefs preparing fugu are specially trained and take great precautions to ensure negligible levels of the toxin are present. However, the gastronomic experience is still considered heightened by a tingling sensation and slight

Figure T16.A. *The pufferfish, fugu, commonly recognised for producing tetrodotoxin. While all parts of the fish contain the toxin, the reproductive organs are the most toxic.*

numbess of the mouth and throat caused by exposure to the negligible amounts of TTX remaining in the properly processed fish.

T16.3. Packaging

Tetrodotoxin is assigned UN number 3172 (toxins extracted from living sources, liquid) or UN number 3462 (toxins extracted from living sources, solid).

T16.4. Typical Applications

Tetrodotoxin is a widely used pharmacological tool in basic biomedical research because it completely inhibits the nervous system. Clinical trials have also been conducted to investigate the utility of tetrodotoxin as a pain reliever or analgesic. Tetrodotoxin was used in certain Haitian ceremonies in which a near-lethal dose of toxin (prepared as “zombie powder”) was administered, causing the person to remain conscious but in a near-death, catatonic state for up to several days.

T17. Viscumin (Viscum album lectin 1)

T17.1. Basic Description

Identifier/Property	Description
Type	Toxin
Other Names	Mistletoe lectin 1
Associated Disease	None; see symptoms in Notable Features
Produced By (Scientific Name)	Plant: *Viscum album*
Key WMD Characteristic(s)	▸ Potential aerosol ▸ Environmentally stable toxin ▸ No antitoxin ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 2; Biosafety Level 3 is advised if activity has high potential for generating aerosols
Exposure Routes	**Exposure:** ▸ Cutaneous (skin): Not a known route of exposure ▸ Inhalation (lungs): Not a known route of exposure ▸ Gastrointestinal (intestine): Consumption of contaminated food, water, or mistletoe extracts in herbal products ▸ Injection (bloodstream): Not a known route of exposure **Host/reservoir:** Not applicable **Vector:** Not applicable
Endemic Range	Europe, southern Asia; natural plant product
CAS#	223577-45-5
EU Control List Entry	1C351.d.19
Applicable AG Footnote(s)	[1] [5]

T17.2. Notable Features

Viscum album is a species of mistletoe that is native to Europe and southern Asia and produces the toxin viscumin, which is a potentially cytotoxic compound. Exposure to excessive quantities of viscum album lectin 1 can manifest undesirable symptoms; gastrointestinal distress including nausea, vomiting, and diarrhea can result. Other symptoms can include dilated pupils, seizures, delirium, hallucinations, heart attack, and even death. Mistletoe is not commercially available worldwide, although derived extracts may be present in herbal preparations or remedies used in alternative medicine in areas outside of where the plant is naturally found.

T17.3. Packaging

Viscumin is assigned UN number 3172 (toxins extracted from living sources, liquid) or UN number 3462 (toxins extracted from living sources, solid).

T17.4. Typical Applications

Viscumin may be used in research investigating potential applications for the treatment of cancerous tumours and degenerative inflammation. Mistletoe extracts, including viscumin, have been used for centuries as a herbal remedy for numerous ailments (see Notable Features). The plant extracts are often used in homeopathic medicine to treat high blood pressure, dizziness, and arthritis.

T18. Volkensin

T18.1. Basic Description

Identifier/Property	Description
Type	Toxin
Other Names	Volkensin
Associated Disease	None; see symptoms in Notable Features
Produced By (Scientific Name)	Plant: *Adenia volkensii*, also known as Passionflower or kilyambiti plant
Key WMD Characteristic(s)	▸ Potential aerosol ▸ Environmentally stable toxin ▸ No antitoxin ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 2; Biosafety Level 3 is advised if activity has high potential for generating aerosols
Exposure Routes	**Exposure:** ▸ Cutaneous (skin): Not a known route of exposure ▸ Inhalation (lungs): Not a known route of exposure ▸ Gastrointestinal (intestine): Consumption of plant root or root extract ▸ Injection (bloodstream): Not a known route of exposure **Host/Reservoir:** Not applicable **Vector:** Not applicable
Endemic Range	East Africa; natural plant product
CAS#	91933-11-8
EU Control List Entry	1C351.d.18
Applicable AG Footnote(s)	[1] [5]

T18.2. Notable Features

A natural defence compound produced by the roots of the East African tree, *Adenia volkensii*, volkensin is primarily thought to ward off insect pests. Symptoms of volkensin consumption are localised to the gastrointestinal system and include vomiting and bloody diarrhea. It is expected that due to its similarity in structure to other toxins such as ricin and abrin, inhalation exposure would result in difficulty breathing, fever, cough, nausea, and tightness in the chest. Severe exposure for all transmission routes can lead to seizures, multi-organ failure, and death.

T18.3. Packaging

Volkensin is assigned UN number 3172 (toxins extracted from living sources, liquid) or UN number 3462 (toxins extracted from living sources, solid).

T18.4. Typical Applications

Basic biomedical research. The potent ability of modeccin to inhibit protein synthesis has led to investigation of modeccin as a possible medical treatment against cancerous tumours.

Fungi

F1. *Coccidioides immitis*

F1.1. Basic Description

Identifier/Property	Description
Type	Fungus
Associated Disease	Coccidioidomycosis, valley fever
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Effective aerosol ▸ Environmentally stable spores ▸ No vaccine ▸ Limited post-exposure treatment
Containment and Handling	Biosafety level 3
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wound ▸ Inhalation (lungs): Aerosols ▸ Gastrointestinal (intestine): Not a known route of exposure ▸ Injection (bloodstream): Not a known route of exposure **Host/Reservoir:** Not applicable **Vector:** Not applicable
Geographic Distribution	Southwest United States
Zoonotic	Yes
Human Transmissibility	Not transmissible
EU Control List Entry	1C351.e.1
Applicable AG Footnote(s)	[1]

F1.2. Notable Features

Coccidioides immitis is a spore-forming pathogenic fungus that is endemic to the dry soils of desert regions throughout parts of the southwestern United States. This fungus is a common cause of pneumonia. The spores are inhaled through dust, creating infection in the lungs, though the fungi can manifest symptoms in other systems and organs in the body. Exposure is virtually unavoidable; as much as 60% of the resident populations in endemic areas become infected. In most cases, infection resolves naturally without medical treatment. Severe infection can progress to chronic pneumonia or develop into a more severe disease called coccidioidomycosis.

Coccidioidomycosis is difficult to diagnose clinically due to its nonspecific symptoms. Illness is often marked by continuous fever, weight loss (as much as 10%), intense night sweats, and fluid on the lung(s). Antifungal therapy may last 6 months or possibly up to 1 year. More severe cases can require lifelong treatment.

F1.3. Packaging

Coccidioides immitis is a Category A infectious substance with the shipping code UN 2900 because it is capable of causing permanent disability or life-threatening or fatal disease in otherwise healthy humans or animals when exposure to it occurs.

F1.4. Typical Applications

Basic medical research and medical countermeasure development, epidemiology, and global surveillance.

F2. *Coccidioides posadasii*

F2.1. Basic Description

Identifier/Property	Description
Type	Fungus
Associated Disease	Coccidioidomycosis, valley fever
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Effective aerosol ▸ Environmentally stable spores ▸ No vaccine ▸ Limited post-exposure treatment
Containment and Handling	Biosafety level 3
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wound ▸ Inhalation (lungs): Aerosols ▸ Gastrointestinal (intestine): Not a known route of exposure ▸ Injection (bloodstream): Not a known route of exposure **Host/Reservoir:** Not applicable **Vector:** Not applicable
Geographic Distribution	Southwest United States, Central and South America
Zoonotic	Yes
Human Transmissibility	No
EU Control List Entry	1C351.e.2
Applicable AG Footnote(s)	[1]

F2.2. Notable Features

Coccidioides posadasii is a spore-forming pathogenic fungus that is endemic to the dry soils of desert regions throughout parts of the southwestern United States, as well as Central and South America. This fungus is a common cause of pneumonia. The spores are inhaled through dust, creating infection in the lungs, though the fungi can manifest symptoms in other systems and organs in the body. Exposure is virtually unavoidable; as much as 60% of the resident populations in endemic areas become infected. In most cases, infection resolves naturally without medical treatment. Severe infection can progress to chronic pneumonia or develop into a more severe disease called coccidioidomycosis.

Coccidioidomycosis is difficult to diagnose clinically due to its nonspecific symptoms. Illness is often marked by continuous fever, weight loss (as much as 10%), intense night sweats, and fluid on the lung(s). Antifungal therapy may last 6 months or possibly up to 1 year. More severe cases can require lifelong treatment.

F2.3. Packaging

Coccidioides posadasii is a Category A infectious substance with the shipping code UN 2900 because it is capable of causing permanent disability or life-threatening or fatal disease in otherwise healthy humans or animals when exposure to it occurs.

F2.4. Typical Applications

Basic medical research and medical countermeasure development, epidemiology, and global surveillance.

Genetic Elements and Genetically-modified Organisms

Any genetically-modified organism[1] which contains, or genetic element[2] that codes for:

G1. any gene or genes specific to any listed virus; or

G2. any gene or genes specific to any listed bacterium[3] or fungus, and which

a. in itself or through its transcribed or translated products represents a significant hazard to human, animal or plant health, or

b. could endow or enhance pathogenicity[4]; or

G3. any listed toxins or their sub-units.

Technical note:

1. *Genetically-modified organisms include organisms in which the nucleic acid sequences have been created or altered by deliberate molecular manipulation.*
2. *Genetic elements include, inter alia: chromosomes, genomes, plasmids, transposons, vectors, and inactivated organisms containing recoverable nucleic acid fragments, whether genetically modified or unmodified, or chemically synthesized in whole or in part. For the purposes of the genetic elements control, nucleic acids from an inactivated organism, virus, or sample are considered 'recoverable' if the inactivation and preparation of the material is intended or known to facilitate isolation, purification, amplification, detection, or identification of nucleic acids.*
3. *These controls do not apply to nucleic acid sequences of shiga toxin producing Escherichia coli of serogroups O26, O45, O103, O104, O111, O121, O145, O157, and other shiga toxin producing serogroups, other than those genetic elements coding for shiga toxin, or for its subunits.*
4. *'Endow or enhance pathogenicity' is defined as when the insertion or integration of the nucleic acid sequence or sequences is/are likely to enable or increase a recipient organism's ability to be used to deliberately cause disease or death. This might include alterations to, inter alia: virulence, transmissibility, stability, route of infection, host range, reproducibility, ability to evade or suppress host immunity, resistance to medical countermeasures, or detectability.*

Basic Description

The AG's List of Human and Animal Pathogens and Toxins prescribes controls on genetic elements that contain nucleic acid sequences (DNA or RNA) that code for: any gene specific to a listed virus, or any listed toxin and toxin subunit. Controls also apply to any gene specific to a listed bacterium or fungus which "represents a significant hazard to human, animal, or plant health" or "could endow or enhance pathogenicity." The AG defines "endow or enhance pathogenicity" as when the insertion or integration of the nucleic acid sequence or sequences is/are likely to enable or increase a recipient organism's ability to be used to deliberately cause disease or death. The AG further presents a non-exhaustive list of possible organism alterations that might lead a genetic element or a genetically modified organism to be controlled such as changes to: virulence, transmissibility, stability, route of infection, host range, reproducibility, ability to evade or suppress host immunity, resistance to medical countermeasures, or detectability.

Some common examples that could be used to transfer genetic information of AG-listed pathogens and toxins are genomes, chromosomes, transposons, plasmids, and vectors. A genome contains the entire genetic instructions found in a cell and is encoded by DNA. Most often this DNA is organised into packages called chromosomes. "Transposon" is a general term for a large family of particular DNA sequences that

naturally can change position within a genome. Plasmids are small circular DNA molecules found in many cells that often carry small numbers of genes. Vectors are smaller plasmids commonly used in molecular biology to carry a desired DNA sequence or gene into a target cell.[59]

The AG also includes "inactivated organisms containing recoverable nucleic acid fragments" of an AG-listed pathogen as a controlled genetic element. This is an important consideration because life science and public health researchers frequently inactivate live biological pathogens for safe handling and transportation when agent viability is not required to address a question under study. While methods of inactivation terminate pathogen viability and render the organisms unable to replicate or cause disease, the condition of their nucleic acids can range from completely intact to thoroughly destroyed. In many cases, these inactivated pathogen samples are considered controlled genetic elements because the nucleic acids are often recoverable for future molecular or synthetic biology applications. Nucleic acids in these same inactivated samples are also a potential means for proliferators to acquire genetic information encoding for listed pathogens or toxins. This is why the AG considers inactivated organisms to contain recoverable nucleic acids, "if the inactivation and preparation of the material is intended or known to facilitate isolation, purification, amplification, detection, or identification of nucleic acids." Several examples are provided in the next section.

Genetically modified organisms include organisms in which the genetic material (nucleic acid sequences) has been created or altered by deliberate molecular manipulation. Genetically modified organisms are very common in life science and public health research. Two historical examples of genetically modified organisms include bacteria genetically modified to produce the human insulin hormone protein (Humulin) and bacteria genetically modified to produce human growth hormone protein (Protropin). These biological products of genetically modified organisms were among the first approved by the U.S. Food and Drug Administration in 1982 and 1985 respectively.[60]

Examples of Genetic Elements and Genetically Modified Organisms

The following provides illustrative examples of items that may or may not be considered controlled genetic elements and genetically modified organisms. The scenarios are based on published scientific research, but provide examples only. They should not substitute for considering all the facts pertinent to an actual license application.

Synthesis of conotoxins by non-pathogenic bacteria

Two examples of materials covered by this entry are related to the synthesis of conotoxins by bacteria. Conotoxins are very short (20–40 amino acid) peptides normally produced by *Conus* sea snails. Another way to obtain conotoxins is to synthesize them in bacteria. For production in bacteria, the conotoxin gene is inserted into a plasmid vector and transferred to the bacteria *Escherichia coli*. For the purposes of AG controls, the plasmid vector containing the conotoxin gene would be considered a controlled genetic element because its DNA codes for an AG-listed toxin. The *E. coli* containing the plasmid with the conotoxin gene would be considered a controlled genetically modified organism because the nucleic acid sequences were created or altered by deliberate molecular manipulation to contain a controlled genetic element. This example illustrates the importance of controlling genetic elements and genetically modified organisms in addition to pathogens and toxins themselves.

Isolated genes for Foot-and-mouth disease virus coat proteins

As discussed in the Introduction to Pathogens and Toxins, viruses are comprised of genetic material packaged inside a protein coat. The coat proteins are encoded by specific genes in the virus genome and these coat proteins are necessary for a virus to complete its lifecycle by infecting a target cell. Biomedical researchers frequently study coat proteins in isolation to better understand how virus particles enter and

[59] See Glossary of Genetic Terms from U.S. National Human Genome Research Institute (https://www.genome.gov/genetics-glossary) and Transposons: The Jumping Genes from Nature Education (https://www.nature.com/scitable/topicpage/transposons-the-jumping-genes-518)

[60] See the U.S. National Library of Medicine online interactive exhibit "From DNA to Beer: Harnessing Nature in Medicine and Industry" (https://www.nlm.nih.gov/exhibition/fromdnatobeer/exhibition-tinkering-with-DNA.html; https://www.nlm.nih.gov/exhibition/fromdnatobeer/exhibition-interactive/recombinant-DNA/recombinant-dna-technology-alternative.html)

make copies of themselves within a host cell. In some studies, genes encoding coat proteins of *Foot-and-mouth disease virus* (FMDV) have been inserted into plasmid DNA vectors and studied separate from their associated virus. For the purposes of AG controls, a DNA plasmid vector containing a gene for a FMDV (or other listed virus) coat protein would be considered a controlled genetic element because it contains a nucleic acid sequence specific to a listed virus.

Rapidly inactivated Ebolavirus for nucleic acid analysis

Preventing the rapid spread of *Ebolavirus* requires medical professionals and their support staffs to quickly and safely determine whether a patient has been infected. A typical protocol involves using the polymerase chain reaction or PCR to detect the presence of *Ebolavirus* RNA in a blood sample. Typically, *Ebolavirus* RNA can be detected before a patient presents symptoms of infection. Prior to testing for *Ebolavirus* RNA, the *Ebolavirus* pathogenicity must be inactivated by several possible methods, including acid, organic solvent, detergent, or heat. The methods all eliminate the ability of the sample for further infect, but *Ebolavirus* RNA and DNA remain stable. For the purposes of AG controls, an *Ebolavirus* sample inactivated to remove virus pathogenicity by a method intended or known to facilitate isolation, purification, amplification, detection or identification of nucleic acids would be considered a controlled genetic element because it contained an inactivated listed pathogen with recoverable nucleic acids.

Bacillus anthracis virulence factors

Bacillus anthracis exists in two forms during its life cycle: a growing vegetative state and a dormant spore. The vegetative form produces several virulence factors that are responsible for toxicity of the vegetative bacteria and the formation of the spore. These virulence factors are encoded by two virulence plasmids called pXO1, which contains exotoxins and pXO2, which encodes the proteins required for production of the spore capsule. For the purposes of AG controls, both virulence plasmids would be considered controlled genetic elements since they are both required to endow or enhance pathogenicity of listed pathogen *B. anthracis*. The pathogenicity of *B. anthracis* comes from both its ability to produce exotoxins as a vegetative (growing) bacteria and its ability to escape the vegetative state and infect more target hosts by forming spores.

Altered pathogenicity of Elizabethkingia anophelis by acquired mutations

Elizabethkingia anophelis is not an AG-listed pathogen. It is a soil-living bacterium normally harmless to humans. In 2016 in the United States, there was a small outbreak of highly pathogenic *Elizabethkingia anophelis*, which killed 20 persons out of 65 infected persons.[61] Subsequent analysis revealed that the pathogenic *Elizabethkingia anophelis* strain had acquired several mutations to its genome at a faster than normal rate, which permitted the strain to evolve several pathogenic characteristics rapidly. For the purposes of AG controls, the pathogenic strain of *Elizabethkingia anophelis* would not be considered a controlled genetically modified organism because it did not contain a genetic element specific from a listed pathogen nor were the mutations to its genome a result of deliberate molecular manipulation. However, proposed export of the highly pathogenic strain of *Elizabethkingia anophelis* could still be reviewed under catch-all provisions.

[61] https://www.cdc.gov/elizabethkingia/outbreaks/index.html

This page intentionally left blank.

Warning List[1]

These sections provide basic descriptions, notable features, packaging information, and typical applications for items on the Warning List of the Control List of Human and Animal Pathogens and Toxins. Section numbers match the AG Warning List entry numbers. The complete AG control language as of its February 2020 revision is found in Appendix A.

It should be noted that all Warning List items are subject to a footnote clarifying the forms of material covered by each entry:

- Biological agents are controlled when they are an isolated live culture of a pathogen agent, or a preparation of a toxin agent which has been isolated or extracted from any source, or material including living material which has been deliberately inoculated or contaminated with the agent. Isolated live cultures of a pathogen agent include live cultures in dormant form or in dried preparations, whether the agent is natural, enhanced, or modified.
- An agent is covered by this list except when it is in the form of a vaccine. A vaccine is a medicinal product in a pharmaceutical formulation licensed by, or having marketing or clinical trial authorisation from, the regulatory authorities of either the country of manufacture or of use, which is intended to stimulate a protective immunological response in humans or animals in order to prevent disease in those to whom or to which it is administered.

Other footnotes apply to a subset of listed items. The footnote numbers, with links to the respective text, are noted in the Basic Description table for each pathogen and toxin.

Bacteria

WB1. *Clostridium tetani*[7]

WB1.1. Basic Description

Identifier/Property	Description
Type	Bacteria: Gram stain positive
Associated Disease	Tetanus, lock jaw
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Mortality rate 30% ▸ Potential aerosol ▸ Environmentally stable spores ▸ Effective vaccine ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 2
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wound ▸ Inhalation (lungs): Not a known route of exposure ▸ Gastrointestinal (intestine): Not a known route of exposure ▸ Injection (bloodstream): Skin punctures **Host/Reservoir:** Not applicable **Vector:** Not applicable
Geographic Distribution	Worldwide
Zoonotic	Yes
Human Transmissibility	Not transmissible
EU Control List Entry	Not applicable
Applicable AG Footnote(s)	[1] [7]

WB1.2. Notable Features

Clostridium tetani is a spore-forming bacterium that inhabits soils and the digestive tracts of humans and animals. *C. tetani* produces two potent neurotoxins with a very low lethal dose in humans; these toxins spread from the infection site throughout the body in the lymphatic and vascular systems to cause tetanus. Tetanus targets the central nervous system and manifests spastic paralysis characterised by generalised rigidity and convulsive muscle spasms. The tetanus vaccine was developed in 1924 and today is one of the most frequently used vaccines worldwide.

WB1.3. Packaging

Clostridium tetani is a Category B infectious substance with the shipping code UN 3373 because it is infectious but does not meet the criteria for Category A.

WB1.4. Typical Applications

Basic medical research and medical countermeasure development, epidemiology, and global surveillance.

WB2. *Legionella pneumophila*

WB2.1. Basic Description

Identifier/Property	Description
Type	Bacteria: Gram stain negative
Associated Disease	Legionnaires' disease, legionellosis, Pontiac fever
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Mortality rate 5–30% ▸ Effective aerosol ▸ No vaccine ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 2
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Not a known route of exposure ▸ Inhalation (lungs): Aerosols ▸ Gastrointestinal (intestine): Not a known route of exposure ▸ Injection (bloodstream): Not a known route of exposure **Host/reservoir:** Amoeba, humans **Vector:** Not applicable
Geographic Distribution	Worldwide (water environments)
Zoonotic	Yes
Human Transmissibility	Not transmissible
EU Control List Entry	Not applicable
Applicable AG Footnote(s)	[1]

WB2.2. Notable Features

Legionella pneumophila is the bacterium acting as the causative agent of Legionnaires' disease. This bacterium acts as a parasite infecting amoeba as part of its lifecycle. The amoeba also provide environmental protection to the bacteria (e.g., from disinfection by chlorination). *L. pneumophila* can grow quickly in warm water such as hot tubs, cooling towers, fountains, drinking water supplies, and hot water tanks. Infected individuals that are otherwise healthy will typically not become ill or will only experience mild symptoms (i.e., Pontiac fever) that resolve without medical treatment. The elderly, infants, individuals with chronic respiratory conditions, or the immune-compromised are at an elevated risk of becoming ill. Initial symptoms are flu-like and later symptoms can include diarrhea, nausea, or pneumonia. Infection with *L. pneumophila* is most commonly seen in humans. However, a small number of documented cases have been reported in calves. Experimental infection with *L. pneuophila* proves other mammalian species are subject to potential infection: guinea pigs, rats, mice, marmosets, and monkeys.

WB2.3. Packaging

Legionella pneumophila is a Category B infectious substance with the shipping code UN 3373 because it is infectious but does not meet the criteria for Category A.

WB2.4. Typical Applications

Basic medical research and medical countermeasure development, epidemiology, and global surveillance.

WB3. *Yersinia pseudotuberculosis*

WB3.1. Basic Description

Identifier/Property	Description
Type	Bacteria: Gram stain negative
Associated Disease	Far East scarlet-like fever, yersiniosis
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Mortality rate 11% ▸ Potential aerosol ▸ Potential for socioeconomic harm ▸ No vaccine ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 2
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Not a known route of exposure ▸ Inhalation (lungs): Not a likely route of exposure ▸ Gastrointestinal (intestine): Consumption of undercooked or raw meat products, unpasteurised dairy products, or water ▸ Injection (bloodstream): Not a known route of exposure **Host/Reservoir:** Animals, birds, humans **Vector:** Not applicable
Geographic Distribution	Worldwide
Zoonotic	Yes
Human Transmissibility	Not transmissible
EU Control List Entry	Not applicable
Applicable AG Footnote(s)	[1]

WB3.2. Notable Features

Yersinia pseudotuberculosis is a bacterium that causes tuberculosis-like symptoms in animals and Far East scarlet-like fever in humans. Infection targets the intestinal tract, liver, spleen, and lymph nodes. This is primarily a bacterium that manifests disease in animal hosts such as livestock and birds. Incidental exposure to humans generally occurs as the result of consumption of contaminated food or water. In humans, symptoms include fever, abdominal pain, and gastroenteritis. Individuals who have routine contact with animals are at an elevated risk of exposure.

WB3.3. Packaging

Yersinia pseudotuberculosis is a Category B infectious substance with the shipping code UN 3373 because it is infectious but does not meet the criteria for Category A.

WB3.4. Typical Applications

Basic medical research and medical countermeasure development, epidemiology, and global surveillance.

WB4. Other strains of *Clostridium* species that produce botulinum neurotoxin[8]

WB4.1. Basic Description

Identifier/Property	Description
Type	Bacteria: Gram stain positive
Associated Disease	Botulism
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Potential aerosol ▸ Environmentally stable
Containment and Handling	Biosafety Level 2
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Open wound ▸ Inhalation (lungs): Possible aerosols ▸ Gastrointestinal (intestine): Consumption of contaminated food or water ▸ Injection (bloodstream): Not a likely route of exposure **Host/Reservoir:** Varies (likely humans and/or livestock) **Vector:** Not applicable
Geographic Distribution	Potentially worldwide in soils
Zoonotic	Yes
Human Transmissibility	Not transmissible
EU Control List Entry	Not applicable; botulinum toxins produced by these bacteria are controlled under 1C351.d.1
Applicable AG Footnote(s)	[1] [8]

WB4.2. Notable Features

These are any *Clostridium* bacteria that are capable of producing botulinum toxins. The bacteria are spore forming, occur naturally in soil, and are tolerant of most environmental conditions, especially temperature extremes. Botulinum toxins are highly poisonous neurotoxins causing muscle paralysis and are controlled by the AG. There are eight known types of botulinum toxins, so this entry applies to any *Clostridium* species that produces even one of these toxin types, regardless of whether it affects animals, humans, or both.

WB4.3. Packaging

Clostridium species are Category B infectious substances with the shipping code UN 3373 because it is infectious but does not meet the criteria for Category A.

WB4.4. Typical Applications

Basic medical research and medical countermeasure development, epidemiology, and global surveillance.

WB5. *Bacillus cereus biovar anthracis*

WB5.1. Basic Description

Identifier/Property	Description
Type	Bacteria : Gram stain positive
Associated Disease	Anthrax-like disease
Scientific Name	*Bacillus cereus biovar anthracis*
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Capable of forming environmentally stable spores ▸ Effective aerosol ▸ No vaccine ▸ Effective post-exposure treatment
Containment and Handling	Biosafety Level 3
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): open wound ▸ Inhalation (lungs): Aerosols ▸ Gastrointestinal (intestine): Not a likely route of exposure ▸ Injection (bloodstream): Not a known route of exposure **Host/reservoir:** Humans, chimpanzes, gorillas, elephants, goats **Vector:** Not applicable
Geographic Distribution	Worldwide
Zoonotic	Yes
Human Transmissibility	Not transmissible
EU Control List Entry	Not applicable
Applicable AG Footnote(s)	[1]

WB5.2. Notable Features

Bacillus cereus biovar anthracis is a bacterium that causes anthrax-like symptoms in a range of wild and domestic animals. It is capable of forming highly resistant spores that are extremely durable and can survive extremes in temperature as well as treatment with harsh chemicals and disinfectants.

B. cereus biovar anthracis can refer to several known strains that contain functional anthracis-like genes and have caused fatal inhalational anthrax-like disease in primates (gorilla and chimpanzee), elephants and goats. Other strains have been isolated from cases of severe and fatal pneumonia, and cutaneous anthrax-like disease.

WB5.3. Packaging

B. cereus biovar anthracis is a Category B infectious substance with the shipping code UN 3373 because it is infectious but does not meet the criteria for Category A.

WB5.4. Typical Applications

Basic medical research and medical countermeasure development (e.g. vaccine research), epidemiology, and global surveillance.

Fungi

WF1. *Fusarium langsethiae*

WF1.1. Basic Description

Identifier/Property	Description
Type	Fungi
Associated Disease	Alimentary toxic aleukia, scab
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Mortality rate 60% ▸ Potential for socioeconomic harm ▸ No vaccine ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 1
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Not a known route of exposure ▸ Inhalation (lungs): Not a known route of exposure ▸ Gastrointestinal (intestine): Consumption of contaminated foods ▸ Injection (bloodstream): Not a known route of exposure **Host/reservoir:** Plants **Vector:** Not applicable
Geographic Distribution	Worldwide
Zoonotic	Yes
Human Transmissibility	Not transmissible
EU Control List Entry	Not applicable
Applicable AG Footnote(s)	[1]

WF1.2. Notable Features

Fusarium langsethiae is a fungus capable of manifesting disease in both animals and plants. The pathogen has several different strains capable of producing T-2 toxin, which is controlled by the AG. Predominately, *F. langsethiae* is found in plants. Humans and animals are subject to infection through ingestion of contaminated food; the fungus reproduces quickly in improperly stored grain, creating the toxin. The toxin causes the disease alimentary toxic aleukia, which manifests symptoms including nausea, vomiting, reduced blood cell count, haemorrhaging, skin inflammation, and even death.

WF1.3. Packaging

Fusarium langsethiae is a Category B infectious substance with the shipping code UN 3373 because it is infectious but does not meet the criteria for Category A.

WF1.4. Typical Applications

Basic medical research and medical countermeasure development, epidemiology, and global surveillance.

WF2. *Fusarium sporotrichioides*

WF2.1. Basic Description

Identifier/Property	Description
Type	Fungi
Associated Disease	Alimentary toxic aleukia, scab
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Mortality rate 60% ▸ Potential for socioeconomic harm ▸ No vaccine ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 1
Exposure/Infection Routes	**Exposure:** ▸ Cutaneous (skin): Not a known route of exposure ▸ Inhalation (lungs): Not a known route of exposure ▸ Gastrointestinal (intestine): Consumption of contaminated foods ▸ Injection (bloodstream): Not a known route of exposure **Host/reservoir:** Plants **Vector:** Not applicable
Geographic Distribution	Worldwide
Zoonotic	Yes
Human Transmissibility	Not transmissible
EU Control List Entry	Not applicable
Applicable AG Footnote(s)	[1]

WF2.2. Notable Features

Fusarium sporotrichioides is a fungus capable of manifesting disease in both animals and plants. The pathogen has several different strains capable of producing T-2 toxin, which is controlled by the AG. Predominately, *F. sporotrichioides* is found in plants. Humans and animals are subject to infection through ingestion of contaminated food; the fungus reproduces quickly in improperly stored grain, creating the toxin. The toxin causes the disease alimentary toxic aleukia, which manifests symptoms including nausea, vomiting, reduced blood cell count, haemorrhaging, skin inflammation, and even death.

WF2.3. Packaging

Fusarium sporotrichioides is a Category B infectious substance with the shipping code UN 3373 because it is infectious but does not meet the criteria for Category A.

WF2.4. Typical Applications

Basic medical research and medical countermeasure development, epidemiology, and global surveillance.

List of Plant Pathogens for Export Control

The following sections provide basic descriptions of and information on the notable features, packaging, and typical applications of items on the Australia Group List of Plant Pathogens for Export Control.[62] In addition to Core List pathogens, this section also includes pathogens on the Items for Inclusion in Awareness Raising Guidelines and a section on Genetic Elements and Genetically-modified Organisms. Explanations of terms used in the opening table for each pathogen are provided in Appendix D. See the Glossary for technical terms used in this Handbook.

[62] The current AG control language may be found online at: https://www.dfat.gov.au/publications/minisite/theaustraliagroupnet/site/en/plants.html

This page intentionally left blank.

Core List

Bacteria

PB1. *Xanthomonas albilineans*

PB1.1. Basic Description

Identifier/Property	Description
Type	Bacteria: Gram stain negative
Associated Disease	Leaf scald
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Potential for socioeconomic harm ▸ Potential to damage the environment ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 1; subject to enhanced containment for countries with vulnerable agriculture
Exposure / Infection Routes	**Exposure:** ▸ Cutaneous (plant surface): Direct contact ▸ Injection (internal plant tissues): Not a known route of exposure **Host/Reservoir:** Soil, water, sugarcane **Vector:** Not applicable
Geographic Distribution	Tropical and subtropical regions where sugarcane is grown
EU Control List Entry	1C354.b.1
Applicable AG Footnotes	None

PB1.2. Notable Features

Xanthomonas albilineans is a bacterial plant pathogen that is responsible for a serious disease in sugarcane known as leaf scald disease. Symptoms of leaf scald disease can range from a single white, narrow, and sharply defined stripe to complete wilting and death of infected leaves, leading to plant death as seen in Figure PB1.A. The bacterial pathogen produces a toxin, albicidin, that has both phytotoxic (inhibits plant photosynthesis by targeting the chloroplast) and antibacterial functions. *X. albilineans* is unique in that it colonises only the plant xylem. Transmission of the disease is thought to be primarily by humans and contaminated harvesting equipment, though it is suspected that transmission via wind or insect vectors are possible. There is no effective treatment for the disease once a plant is infected.

Figure PB1.A. *Rice plant with leaf scald infection.*

PB1.3. Packaging

The shipping practices for plant pathogens are not addressed in current international guidelines. Additional information on the shipment of plant pathogens can be found in the Introduction to Pathogens and Toxins.

PB1.4. Typical Applications

Basic agricultural disease research and development, epidemiology, and global surveillance.

PB2. *Xanthomonas axonopodis* pv. *citri* (*Xanthomonas campestris* pv. *citri A*) [*Xanthomonas campestris* pv. *citri*]

PB2.1. Basic Description

Identifier/Property	Description
Type	Bacteria: Gram stain negative
Associated Disease	Citrus canker
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Environmentally stable ▸ Potential for socioeconomic harm ▸ Potential to damage the environment ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 1; subject to enhanced containment for countries with vulnerable agriculture
Exposure / Infection Routes	**Exposure:** ▸ Cutaneous (plant surface): Direct contact ▸ Injection (internal plant tissues): Not a known route of exposure **Host/Reservoir:** Soil, water, citrus **Vector:** Not applicable
Geographic Distribution	Worldwide – citrus growing countries
EU Control List Entry	1C354.b.2
Applicable AG Footnotes	None

PB2.2. Notable Features

Likely originating from Southeast Asia, *Xanthomonas axonopodis* pathovar *citri* (also known as *Xanthomonas campestris* pathovar *citri A* and *Xanthomonas campestris* pathovar *citri*) causes the plant disease citrus canker, which affects citrus production worldwide. The bacterial pathogen is highly persistent and extremely difficult to successfully eradicate from affected groves. Infection produces lesions on leaves, stems, and fruit, causing premature leaf drop and fruit development. Symptoms of diseased fruit can be seen in Figure PB2.A. Affected fruit is safe to consume because the bacteria does not manifest disease in humans, but is considered unsightly and cannot be traded or sold. *X. axonopodis* pv. *citri* is currently considered to cause three forms of citrus canker: Asiatic canker (Cancrosis A) is the most widespread and severe, Cancrosis B is found in South America, and Cancrosis C only infects key limes and bitter oranges. The bacteria are spread by contaminated equipment, rain, or wind, and enter the plant through the leaves. Disease progression is exacerbated by an insect known as the Asian citrus leafminer whose feeding on citrus plants creates lesions that heighten a plant's susceptibility to infection. Disease control mechanisms include pest

Figure PB2.A. *Citrus fruit with citrus canker infection.*

management strategies and the production of disease-resistant citrus cultivars. If the disease cannot be properly controlled or managed, the grove is often destroyed in order to prevent future spreading. There is no effective treatment for the disease once a plant is infected.

PB2.3. Packaging

The shipping practices for plant pathogens are not addressed in current international guidelines. Additional information on the shipment of plant pathogens can be found in the Introduction to Pathogens and Toxins.

PB2.4. Typical Applications

Basic agricultural disease research and development, epidemiology, and global surveillance.

PB3. *Xanthomonas oryzae* pv. *oryzae* (*Pseudomonas campestris* pv. *oryzae*)

PB3.1. Basic Description

Identifier/Property	Description
Type	Bacteria: Gram stain negative
Associated Disease	Bacteria blight, rice blight, bacterial leaf blight (BLB), Kresek disease
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Potential for socioeconomic harm ▸ Potential to damage the environment ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 1; subject to enhanced containment for countries with vulnerable agriculture
Exposure / Infection Routes	**Exposure:** ▸ Cutaneous (plant surface): Direct contact ▸ Injection (internal plant tissues): Not a known route of exposure **Host/Reservoir:** Soil, water, rice, sedges, grasses **Vector:** Not applicable
Geographic Distribution	Asian-Indian rice growing areas
EU Control List Entry	1C354.b.3
Applicable AG Footnotes	None

PB3.2. Notable Features

Xanthomonas oryzae pathovar *oryzae* (also known as *Pseudomonas campestris* pathovar *oryzae*) causes bacterial blight on rice and grasses. Bacterial blight of rice can be tremendously destructive to high-yield rice cultivars and hybrid cultivars. Disease transmission occurs by wind, rain, the use of contaminated irrigation water, and the planting of cultivars from infected crop. The bacteria enter the plant through natural pores in the leaf or by contaminated seeds. Characteristic signs of blight infection are lesions and discolouration of the affected leaves as seen in Figure PB3.A. Management practices are generally well established and cultivars resistant to the bacteria are available. However, there is no effective treatment for the disease once a plant is infected.

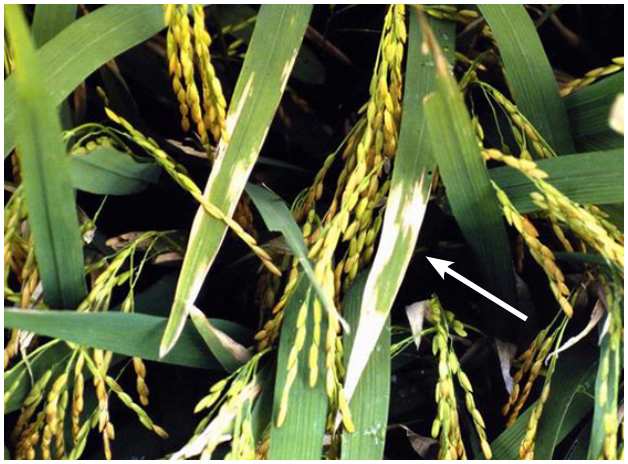

Figure PB3.A. *Rice plant with rice blight infection.*

PB3.3. Packaging

The shipping practices for plant pathogens are not addressed in current international guidelines. Additional information on the shipment of plant pathogens can be found in the Introduction to Pathogens and Toxins.

PB3.4. Typical Applications

Basic agricultural disease research and development, epidemiology, and global surveillance.

PB4. *Clavibacter michiganensis* subsp. *sepedonicus* (*Corynebacterium michiganensis* subsp. *sepedonicum* or *Corynebacterium sepedonicum*)

B4.1. Basic Description

Identifier/Property	Description
Type	Bacteria: Gram stain positive
Associated Disease	Ring rot
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Environmentally stable ▸ Potential for socioeconomic harm ▸ Potential to damage the environment ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 1; subject to enhanced containment for countries with vulnerable agriculture
Exposure / Infection Routes	**Exposure:** ▸ Cutaneous (plant surface): Direct contact ▸ Injection (internal plant tissues): Beetle, leafhopper, or aphid bite **Host/Reservoir:** Potatoes **Vector:** Beetles, leafhoppers, aphids
Geographic Distribution	Worldwide
EU Control List Entry	1C354.b.4
Applicable AG Footnotes	None

PB4.2. Notable Features

This plant pathogen is most commonly known for its ability to cause ring rot disease in potato tubers. Although other *Clavibacter michiganensis* subspecies are known to cause ring rot in other plant species like tomatoes, corn, and alfalfa, the specific subspecies on the AG Plant Pathogen Control List, *Clavibacter michiganensis* subspecies *sepedonicus* (also known as *Corynebacterium michiganensis* subspecies *sepedonicum* or *Corynebacterium sepedonicum*), is specific to potato tubers. The disease is common worldwide, with the exception of Australia. The bacteria is transmitted to the host plant through wounds via contaminated soil, water, vegetative waste, seeds from infected plants, or an insect vector. Insect vectors include several species of beetles, leafhoppers, and aphids. The bacteria manifest a systemic vascular infection in the host plant. Infectious bacteria can stay present on contaminated surfaces, equipment, and tools for years. Symptoms of disease include blackening or browning of tubers around a vascular ring as seen in Figure PB4.A. During later stages of disease, the plant will experience leaf wilting and discolouration of stem tissues. There are no chemical treatments for plants that have ring rot, and there are currently no known resistant varieties of plant species. Often, infected crops are destroyed to prevent outbreaks. There is no effective treatment for the disease once a plant is infected.

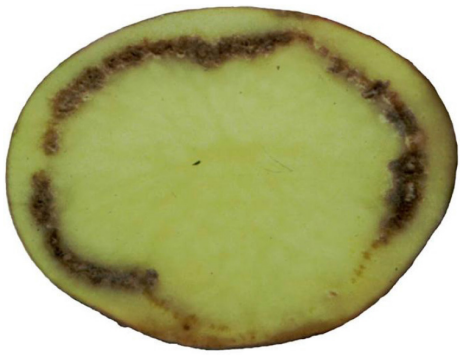

Figure PB4.A. *Potato tuber with ring rot infection.*

PB4.3. Packaging

The shipping practices for plant pathogens are not addressed in current international guidelines. Additional information on the shipment of plant pathogens can be found in the Introduction to Pathogens and Toxins.

PB4.4. Typical Applications

Basic agricultural disease research and development, epidemiology, and global surveillance.

PB5. *Ralstonia solanacearum*, race 3, biovar 2

PB5.1. Basic Description

Identifier/Property	Description
Type	Bacteria: Gram stain negative
Associated Disease	Bacterial wilt, brown rot, southern wilt, granville wilt (tobacco)
Other Names	*Pseudomonas solanacearum*
Key WMD Characteristic(s)	▸ Potential for socioeconomic harm ▸ Potential to damage the environment ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 2; subject to enhanced containment for countries with vulnerable agriculture
Exposure / Infection Routes	**Exposure:** ▸ Cutaneous (plant surface): Direct contact ▸ Injection (internal plant tissues): Not a known route of exposure **Host/Reservoir:** Soil, water, tomato, pepper, eggplant, potato, tobacco **Vector:** Not applicable
Geographic Distribution	Worldwide; soil and infected plant materials
EU Control List Entry	1C354.b.5
Applicable AG Footnotes	None

PB5.2. Notable Features

This soilborne plant pathogen is found mostly in tropical highland regions and is capable of infecting several economically important crops. *Ralstonia solanacearum* is a bacterial species with several different races and biovars of varying pathogenicity and geographic distribution. The potato is extremely susceptible to *Ralstonia solanacearum*, race 3, biovar 2. The disease it causes, bacterial wilt, is known to occur worldwide. Disease is spread in irrigation waters, contaminated plant materials, infected soil or weeds, or simply plant-to-plant spreading of the bacteria. *R. solanacearum* enters a plant through root wounds or cracks. Bacterial wilt disease results as the colonising bacteria consume interior plant matter and block the host's vascular system, creating the symptoms shown in Figure PB5.A. Diagnosis of the disease is challenging as symptoms are similar to other bacterial infections, root damage, drought, and nutrient deficiency. Once the disease is confirmed, quarantine and sanitation procedures are used for effective containment and elimination of the disease. There is no effective treatment for the disease once a plant is infected.

Figure PB5.A. *Plant with bacterial wilt.*

PB5.3. Packaging

The shipping practices for plant pathogens are not addressed in current international guidelines. Additional information on the shipment of plant pathogens can be found in the Introduction to Pathogens and Toxins.

PB5.4. Typical Applications

Basic agricultural disease research and development, epidemiology, and global surveillance.

Fungi

PF1. *Colletotrichum kahawae* (*Colletotrichum coffeanum* var. *virulans*)

PF1.1. Basic Description

Identifier/Property	Description
Type	Fungus
Associated Disease	Coffee berry disease (CBD)
Other Names	Green berry anthracnose
Key WMD Characteristic(s)	▸ Potential for socioeconomic harm ▸ Potential to damage the environment ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 3; subject to enhanced containment for countries with vulnerable agriculture
Exposure / Infection Routes	**Exposure:** ▸ Cutaneous (plant surface): Direct contact ▸ Injection (internal plant tissues): Not a known route of exposure **Host/Reservoir:** Soil, water, coffee bean plants **Vector:** Not applicable
Geographic Distribution	Africa
EU Control List Entry	1C354.c.1
Applicable AG Footnotes	None

PF1.2. Notable Features

First reported in 1922, *Colletotrichum kahawae* (also known as *Colletotrichum coffeanum* variety *virulans*) causes catastrophic disease in Arabic coffee beans. This fungal pathogen is currently confined to the African continent. This pathogen is capable of infecting plants at any stage of development without any signs or symptoms of disease. Only when the plant sets fruit does the disease reveal itself, ruining berries and spreading throughout the coffee grove as seen in Figure PF1.A. The fungus is transmitted by spores that are easily spread by water, wind, animals or coffee pickers. There is no effective treatment for the disease once a plant is infected.

Figure PF1.A. *Coffee bean plant with coffee berry disease infection.*

PF1.3. Packaging

The shipping practices for plant pathogens are not addressed in current international guidelines. Additional information on the shipment of plant pathogens can be found in the Introduction to Pathogens and Toxins.

PF1.4. Typical Applications

Basic agricultural disease research and development, epidemiology, and global surveillance.

PF2. *Cochliobolus miyabeanus* (*Helminthosporium oryzae*)

PF2.1. Basic Description

Identifier/Property	Description
Type	Fungus
Associated Disease	Rice brown spot, blight disease of rice
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Potential for socioeconomic harm ▸ Potential to damage the environment ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 1; subject to enhanced containment for countries with vulnerable agriculture
Exposure / Infection Routes	**Exposure:** ▸ Cutaneous (plant surface): Direct contact ▸ Injection (internal plant tissues): Not a known route of exposure **Host/Reservoir:** Rice **Vector:** Not applicable
Geographic Distribution	Worldwide
EU Control List Entry	1C354.c.2
Applicable AG Footnotes	None

PF2.2. Notable Features

Known as the cause of the Bengal famine of 1943, the *Cochliobolus miyabeanus* (also known as *Helminthosporium oryzae*) fungus is a highly aggressive pathogen of rice. The disease spreads easily as the fungus produces spores that are carried in rice seed and can be transmitted quickly by wind, rain, insects, or animals. The pathogen produces several toxins that function to kill the host. Disease symptoms develop gradually and emerge as small purple-brown spots that enlarge into lesions with necrotic centres as seen in Figure PF2.A. There is no effective treatment for the disease once a plant is infected.

Figure PF2.A. *Rice plant with brown spot infection.*

PF2.3. Packaging

The shipping practices for plant pathogens are not addressed in current international guidelines. Additional information on the shipment of plant pathogens can be found in the Introduction to Pathogens and Toxins.

PF2.4. Typical Applications

Basic agricultural disease research and development, epidemiology, and global surveillance.

PF3. *Microcyclus ulei* (syn. *Dothidella ulei*)

PF3.1. Basic Description

Identifier/Property	Description
Type	Fungus
Associated Disease	South American leaf blight
Other Names	*Aphosphaeria ulei, Fusicladium ulei*
Key WMD Characteristic(s)	▸ Environmentally stable spores ▸ Potential for socioeconomic harm ▸ Potential to damage the environment ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 3; subject to enhanced containment for countries with vulnerable agriculture
Exposure / Infection Routes	**Exposure:** ▸ Cutaneous (plant surface): Direct contact ▸ Injection (internal plant tissues): Not a known route of exposure **Host/Reservoir:** Soil, water, rubber plants **Vector:** Not applicable
Geographic Distribution	Latin America, Caribbean
EU Control List Entry	1C354.c.3
Applicable AG Footnotes	None

PF3.2. Notable Features

Microcyclus ulei (also known as *Dothidella ulei*) causes South American leaf blight in certain species of rubber plants found in Latin America and the Caribbean. This invasive fungus is capable of producing spores that are easily dispersed by wind, water, insects, or animals. Signs of disease include the appearance of green masses on young leaves that become gray as the fungus spreads and reproduces as seen in Figure PF3.A. Eventually the spots converge to kill the leaves. Rubber plants with mature leaves are not susceptible to the disease, making the fungus a greater threat to young plants and plants that seasonally grow new leaves. A number of fungicides can kill *M. ulei*; however, quarantine remains the primary management strategy. There is no effective treatment for the disease once a plant is infected.

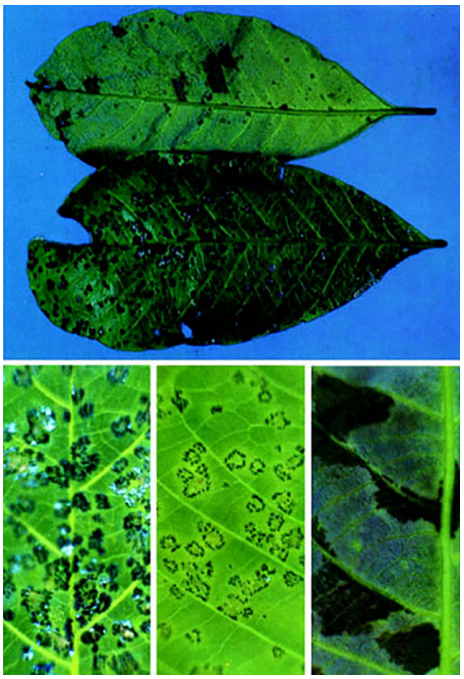

Figure PF3.A. *Rubber plant leaves with South American leaf blight. Lower images show enlargements of leaves highlighting infection.*

PF3.3. Packaging

The shipping practices for plant pathogens are not addressed in current international guidelines. Additional information on the shipment of plant pathogens can be found in the Introduction to Pathogens and Toxins.

PF3.4. Typical Applications

Basic agricultural disease research and development, epidemiology, and global surveillance.

PF4. *Puccinia graminis* ssp. *graminis* var. *graminis* / *Puccinia graminis* ssp. *graminis* var. *stakmanii* (*Puccinia graminis* [syn. *Puccinia graminis* f. sp. *tritici*])

PF4.1. Basic Description

Identifier/Property	Description
Type	Fungus
Associated Disease	Stem rust, black rust, cereal rusts
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Environmentally stable spores ▸ Potential for socioeconomic harm ▸ Potential to damage the environment ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 1; subject to enhanced containment for countries with vulnerable agriculture
Exposure / Infection Routes	**Exposure:** ▸ Cutaneous (plant surface): Direct contact ▸ Injection (internal plant tissues): Not a known route of exposure **Host/Reservoir:** Wheat, barley, barberry **Vector:** Not applicable
Geographic Distribution	Africa, Asia, Middle East
EU Control List Entry	1C354.c.4
Applicable AG Footnotes	None

PF4.2. Notable Features

Puccinia graminis subspecies *graminis* variety *graminis* is a fungus that has the ability to manifest disease in the cereal crops wheat, barley, and barberry. The fungus has the ability to produce spores that are capable of travelling long distances. The fungus is transmitted to the plant host via the outer epidermal tissues of the plant stalk. As the fungus penetrates into the internal vascular tissues, the plant experiences a reduction in plant growth and seed yield. Fungal infection can ruin an entire crop in approximately 3 weeks. The characteristic sign of disease is the presence of dark red, blister-like pustules that are loosely attached to aboveground plant parts as seen in Figure PF4.A. Prior to harvest the site of infection turns black, the fungus is securely rooted in the host, and the crop dies. This particular variety of *P. graminis* is of concern because it contains a highly virulent strain referred to as Ug99. There are many strains of *P. graminis* fungi that cause stem rust, and many wheat cultivars have been engineered with genes to increase resistance to infection. However, Ug99 is unique in that all current wheat cultivars are susceptible to infection. There is no effective treatment for the disease once a plant is infected.

Figure PF4.A. *Wheat with stem rust infection.*

PF4.3. Packaging

The shipping practices for plant pathogens are not addressed in current international guidelines. Additional information on the shipment of plant pathogens can be found in the Introduction to Pathogens and Toxins.

PF4.4. Typical Applications

Basic agricultural disease research and development, epidemiology, and global surveillance.

PF5. *Puccinia striiformis* (syn. *Puccinia glumarum*)

PF5.1. Basic Description

Identifier/Property	Description
Type	Fungus
Associated Disease	Stripe rust, yellow rust, glume rust
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Environmentally stable spores ▸ Potential for socioeconomic harm ▸ Potential to damage the environment ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 1; subject to enhanced containment for countries with vulnerable agriculture
Exposure / Infection Routes	**Exposure:** ▸ Cutaneous (plant surface): Direct contact ▸ Injection (internal plant tissues): Not a known route of exposure **Host/Reservoir:** Soil, water, wheat, barley, triticale **Vector:** Not applicable
Geographic Distribution	Europe, Australia
EU Control List Entry	1C354.c.5
Applicable AG Footnotes	None

PF5.2. Notable Features

Puccinia striiformis (also known as *Puccinia glumarum*) is a fungal pathogen of cereal crops such as wheat and barley. There are nine different strains of this *Puccinia striiformis* that are differentiated mostly by the host plant that it mostly commonly infects. Spores infect aboveground plant tissues, forming yellow-orange pustules arranged in stripes as seen in Figure PF5.A. Stripe rust can infect both summer and winter wheat, reducing yield by as much as 40%. Chemical control and propagation of resistant cultivars have decreased the frequency of strip rust epidemics; however, there is no effective treatment for the disease once a plant is infected.

Figure PF5.A. *Wheat with stripe rust infection.*

PF5.3. Packaging

The shipping practices for plant pathogens are not addressed in current international guidelines. Additional information on the shipment of plant pathogens can be found in the Introduction to Pathogens and Toxins.

PF5.4. Typical Applications

Basic agricultural disease research and development, epidemiology, and global surveillance.

PF6. *Magnaporthe oryzae* (*Pyricularia oryzae*)

PF6.1. Basic Description

Identifier/Property	Description
Type	Fungus
Associated Disease	Rice blast, rice blast fungus, rice rotten neck, rice seedling blight, blast of rice pitting disease, ryegrass blast, johnson spot
Other Names	*Magnaporthe grisea*
Key WMD Characteristic(s)	▸ Environmentally stable spores ▸ Potential for socioeconomic harm ▸ Potential to damage the environment ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 1; subject to enhanced containment for countries with vulnerable agriculture
Exposure / Infection Routes	**Exposure:** ▸ Cutaneous (plant surface): Direct contact ▸ Injection (internal plant tissues): Not a known route of exposure **Host/Reservoir:** Soil, water, rice, grass **Vector:** Not applicable
Geographic Distribution	Worldwide
EU Control List Entry	1C354.c.6
Applicable AG Footnotes	None

PF6.2. Notable Features

Magnaporthe oryzae (also known as *Pyricularia oryzae*) is a fungus that causes rice blast in rice plants. Though the fungus has the ability to manifest disease in multiple species of grass, it is of concern due to its economic impact as a crop disease affecting rice. The fungus is particularly virulent because it infects both aboveground and belowground plant structures. Disease symptoms on aboveground plant parts include white-grey lesions with darker borders on plant shoots, while older lesions are elliptical or spindle shaped with necrotic borders as seen in Figures PF6.A and PF6.B. Infection impacts seed production and yield by inhibiting the maturation process of the grain. Rice blast is also caused by genetically similar fungus known as *Magnaporthe grisea*. Disease manifestation between these two species is identical and much of the current scientific literature uses these two names synonymously to describe rice blast. There is no effective treatment for the disease once a plant is infected.

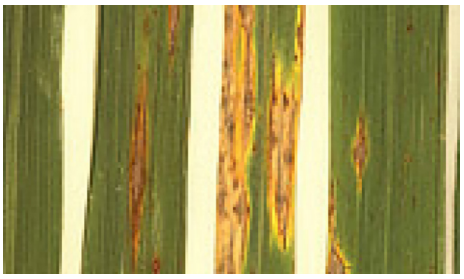

Figure PF6.A. *Rice plant leaves with rice blast.*

Figure PF6.B. *Rice plant nodes with rice blast.*

PF6.3. Packaging

The shipping practices for plant pathogens are not addressed in current international guidelines. Additional information on the shipment of plant pathogens can be found in the Introduction to Pathogens and Toxins.

PF6.4. Typical Applications

Basic agricultural disease research and development, epidemiology, and global surveillance.

PF7. *Peronosclerospora philippinensis* (*Peronosclerospora sacchari*)

PF7.1. Basic Description

Identifier/Property	Description
Type	Fungus-like protist
Associated Disease	Philippine downy mildew
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Environmentally stable spores ▸ Potential for socioeconomic harm ▸ Potential to damage the environment ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 2; subject to enhanced containment for countries with vulnerable agriculture
Exposure / Infection Routes	**Exposure:** ▸ Cutaneous (plant surface): Direct contact of exposure ▸ Injection (internal plant tissues): Not a known route of exposure **Host/Reservoir:** Soil, water, grasses, sorghum, sugarcane, maize **Vector:** Not applicable
Geographic Distribution	Asia
EU Control List Entry	1C354.c.7
Applicable AG Footnotes	None

PF7.2. Notable Features

First identified in the Philippines around 1900, this fungus-like pathogen is actually a protist. Considered one of many water molds, *Peronosclerospora philippinensis* (also known as *Peronosclerospora sacchari*) manifests symptoms of Philippine downy mildew including chlorosis (yellow discolouration) and downiness (soft, grey mildew appearance). The pathogen spreads through the entire plant host, except for the roots, stunting growth, reproduction, and crop yield. There is no effective treatment for the disease once a plant is infected.

PF7.3. Packaging

The shipping practices for plant pathogens are not addressed in current international guidelines. Additional information on the shipment of plant pathogens can be found in the Introduction to Pathogens and Toxins.

PF7.4. Typical Applications

Basic agricultural disease research and development, epidemiology, and global surveillance.

PF8. *Sclerophthora rayssiae* var. *zeae*

PF8.1. Basic Description

Identifier/Property	Description
Type	Fungus-like protist
Associated Disease	Brown stripe downy mildew
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Environmentally stable spores ▸ Potential for socioeconomic harm ▸ Potential to damage the environment ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 2; subject to enhanced containment for countries with vulnerable agriculture
Exposure / Infection Routes	**Exposure:** ▸ Cutaneous (plant surface): Direct contact ▸ Injection (internal plant tissues): Not a known route of exposure **Host/Reservoir:** Soil, water, maize, grasses **Vector:** Not applicable
Geographic Distribution	India, Asia, United States
EU Control List Entry	1C354.c.8
Applicable AG Footnotes	None

PF8.2. Notable Features

First discovered in India, *Sclerophthora rayssiae* variety *zeae* is a fungus-like pathogen that is actually a protist and has the ability to manifest disease in maize and certain grass species. Annual crop yield losses for maize can range from 20–90%. Plant infection is limited to the leaves, causing legions and chlorosis (yellowing) as seen in Figure PF8.A. If the infection starts before the plant has the ability to flower, the plant is likely to die or produce small seeds, severely disrupting crop production. The disease is transmitted from infected seeds or by overwintering of infected plant debris. Crop losses and severity of the disease is positively correlated to soil temperatures and annual precipitation. There is no effective treatment for the disease once a plant is infected.

Figure PF8.A. *Leaves with brown stripe downy mildew infection.*

PF8.3. Packaging

The shipping practices for plant pathogens are not addressed in current international guidelines. Additional information on the shipment of plant pathogens can be found in the Introduction to Pathogens and Toxins.

PF8.4. Typical Applications

Basic agricultural disease research and development, epidemiology, and global surveillance.

PF9. *Synchytrium endobioticum*

PF9.1. Basic Description

Identifier/Property	Description
Type	Fungus
Associated Disease	Potato wart, black scab
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Environmentally stable spores ▸ Potential for socioeconomic harm ▸ Potential to damage the environment ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 3; subject to enhanced containment for countries with vulnerable agriculture
Exposure / Infection Routes	**Exposure:** ▸ Cutaneous (plant surface): Direct contact ▸ Injection (internal plant tissues): Not a known route of exposure **Host/Reservoir:** Soil, water, potato **Vector:** Not applicable
Geographic Distribution	Worldwide except in tropical regions
EU Control List Entry	1C354.c.9
Applicable AG Footnotes	None

PF9.2. Notable Features

Synchytrium endobioticum causes potato wart. Also known as black scab, this disease is one that many worldwide consider the single most important potato disease to quarantine. The fungus is transmitted to its host plant via motile spores located in the soil. The fungus continues to create infection in the potato plant while contaminating the soil as long as suitable environmental conditions are present (warm temperature, high humidity). The infected site of the host swells to form a thick walled wart which surrounds and encases the fungus as seen in Figure PF9.A. In autumn, the wart rots and is released into the soil to overwinter in a dormant state. In this dormant state, the fungus can maintain viability for up to 30 years. Potato wart disease is regarded as a zero tolerance, quarantine organism internationally; detection is likely to prompt quarantine and containment actions. There is no effective treatment for the disease once a plant is infected.

Figure PF9.A. *Potatoes with potato warts.*

PF9.3. Packaging

The shipping practices for plant pathogens are not addressed in current international guidelines. Additional information on the shipment of plant pathogens can be found in the Introduction to Pathogens and Toxins.

PF9.4. Typical Applications

Basic agricultural disease research and development, epidemiology, and global surveillance.

PF10. *Tilletia indica*

PF10.1. Basic Description

Identifier/Property	Description
Type	Fungus
Associated Disease	Karnal bunt, partial bunt
Other Names	Neovossia indica
Key WMD Characteristic(s)	▸ Environmentally stable spores ▸ Potential for socioeconomic harm ▸ Potential to damage the environment ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 1; subject to enhanced containment for countries with vulnerable agriculture
Exposure / Infection Routes	**Exposure:** ▸ Cutaneous (plant surface): Direct contact ▸ Injection (internal plant tissues): Not a known route of exposure **Host/Reservoir:** Soil, water, wheat, rye **Vector:** Not applicable
Geographic Distribution	India, Middle East, North Africa, United States
EU Control List Entry	1C354.c.10
Applicable AG Footnotes	None

PF10.2. Notable Features

Named for an outbreak in the city of Karnal, India, in the early 1930s, *Tilletia indica* is a fungus that primarily affects wheat and other grain crops. The infection is usually localised in crop kernels, surviving on seed nutritional stores while rendering the crop unusable due to foul odour and taste. Diseased crop yields have no value even as milled flour. The disease is spread through wind, rain, irrigation systems, contaminated seed, soiled farm equipment, and the manure of farm animals. Fungal spores can survive in the soil for years in the absence of a host. Detection and confirmation of the disease will prompt quarantine and containment actions to interrupt the life cycle of the fungus and prevent further exposure. Seeds infected with karnal blunt can be seen in Figure PF10.A. There is no effective treatment for the disease once a plant is infected.

Figure PF10.A. *Seeds infected with karnal bunt.*

PF10.3. Packaging

The shipping practices for plant pathogens are not addressed in current international guidelines. Additional information on the shipment of plant pathogens can be found in the Introduction to Pathogens and Toxins.

PF10.4. Typical Applications

Basic agricultural disease research and development, epidemiology, and global surveillance.

PF11. *Thecaphora solani*

PF11.1. Basic Description

Identifier/Property	Description
Type	Fungus
Associated Disease	Potato Smut
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Environmentally stable spores ▸ Potential for socioeconomic harm ▸ Potential to damage the environment ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level Unknown
Exposure / Infection Routes	**Exposure:** ▸ Cutaneous (plant surface): Direct contact ▸ Injection (internal plant tissues): Not a known route of exposure **Host/Reservoir:** Soil, potatoes **Vector:** Not applicable
Geographic Distribution	Central and South America
EU Control List Entry	1C354.c.11
Applicable AG Footnotes	None

PF11.2. Notable Features

Thecaphora solani is a fungus that causes potato smut in potatoes in South America. The fungus survives in soil or infected plant debris; fungal spores are highly resistant in the environment and can remain viable for many years. The plant is not symptomatic above ground, though infected tubers are misshapen, hard, and have swellings on the surface. Affected tubers can appear discoloured, and brown spore balls will form in the flesh of the potato as seen in Figures PF11.A and PF11.B. Since the disease occurs primarily underground, dispersal is rather limited, and disease transmission generally occurs from planting infected tubers. There is no effective treatment for the disease once a plant is infected.

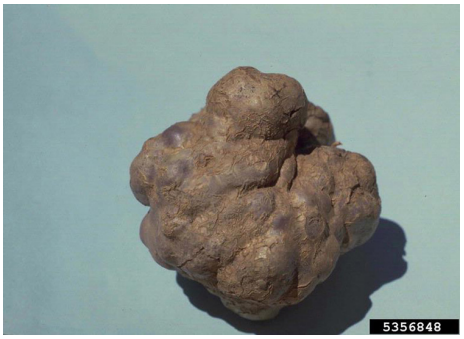

Figure PF11.A. *Potato with smut infection.*

Figure PF11.B. *Inside of potato with smut infection.*

PF11.3. Packaging

The shipping practices for plant pathogens are not addressed in current international guidelines. Additional information on the shipment of plant pathogens can be found in the Introduction to Pathogens and Toxins.

PF11.4. Typical Applications

Basic agricultural disease research and development, epidemiology, and global surveillance.

Viruses

PV1. *Andean potato latent virus* (*Potato Andean latent tymovirus*)

PV1.1. Basic Description

Identifier/Property	Description
Type	Virus: RNA
Associated Disease	Potato mottle, mosaic
Other Names	APLV
Key WMD Characteristic(s)	▸ Potential for socioeconomic harm ▸ Potential to damage the environment ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 1; subject to enhanced containment for countries with vulnerable agriculture
Exposure / Infection Routes	**Exposure:** ▸ Cutaneous (plant surface): Direct contact ▸ Injection (internal plant tissues): Beetle bite **Host/Reservoir:** Soil, potatoes **Vector:** Beetles
Geographic Distribution	South America
EU Control List Entry	1C354.a.1
Applicable AG Footnotes	None

PV1.2. Notable Features

Andean potato latent virus (also known as *Potato Andean latent tymovirus*) was first described in 1966 as affecting potato production in the Andean highlands of South America. The virus can be transmitted from infected to healthy tubers by direct contact, infected seeds, or an insect vector (beetle). Tuber-to-tuber transmission is possible as the virus can enter a latent phase in which infected plants reveal only slight or no symptoms of the disease. The virus can remain in this latent stage for years, only becoming virulent after several generations of vertical transmission in potato cultivars. When symptomatic, potato cultivars can present with mild to severe mosaic patterns on leaves with dead spots and leaf-tip curling or death. There is no effective treatment for the disease once a plant is infected.

PV1.3. Packaging

The shipping practices for plant pathogens are not addressed in current international guidelines. Additional information on the shipment of plant pathogens can be found in the Introduction to Pathogens and Toxins.

PV1.4. Typical Applications

Basic agricultural disease research and development, epidemiology, and global surveillance.

PV2. *Potato spindle tuber viroid*

PV2.1. Basic Description

Identifier/Property	Description
Type	Viroid: RNA
Associated Disease	Spindle tuber disease
Other Names	PSTVd
Key WMD Characteristic(s)	▸ Potential for socioeconomic harm ▸ Potential to damage the environment ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 1; subject to enhanced containment for countries with vulnerable agriculture
Exposure / Infection Routes	**Exposure:** ▸ Cutaneous (plant surface): Direct contact ▸ Injection (internal plant tissues): Aphid bite **Reservoir:** Potatoes, tomatoes, peppers **Vector:** Aphids
Geographic Distribution	North America, The Caribbean, Russia, South Africa
EU Control List Entry	1C354.a.2
Applicable AG Footnotes	None

PV2.2. Notable Features

This pathogen is the first viroid identified for control by the AG. Unlike a virus which is comprised of both a protein coat and genetic material, a viroid only consists of a small circular RNA molecule. Several strains of the *Potato spindle tuber viroid* have been identified that have the ability to cause disease in potatoes, tomatoes, and several strains of peppers. Disease manifestation can vary depending on host, generation, and environmental conditions. Common symptoms include leaf discolouration, leaf elongation, slowed sprouting rate, stunted growth, and slowed or incomplete fruit ripening. The stunted growth of potato tubers with PSTVd is shown in Figure PV2.A. Transmission of the viroid can occur via infected seeds and pollen, insects, or mechanical transmission. Since there is no known natural resistance to the PSTVd, the disease often spreads rapidly, attacking all host varieties and cultivars. PSTVd can also be transmitted via the aphid, an insect vector, when spread as a co-infection with *Potato leafroll virus*. Containment and elimination strategies are limited to removal of infected plants and planting uninfected tubers. There is no effective treatment for the disease once a plant is infected.

Figure PV2.A. *Comparison of healthy potato tubers (top) and potato tubers infected with PSTVd (bottom).*

PV2.3. Packaging

The shipping practices for plant pathogens are not addressed in current international guidelines. Additional information on the shipment of plant pathogens can be found in the Introduction to Pathogens and Toxins.

PV2.4. Typical Applications

Basic agricultural disease research and development, epidemiology, and global surveillance.

Genetic Elements and Genetically Modified Organisms

Any genetically-modified organism[1] which contains, or genetic element[2] that codes for:

PG1. any gene or genes specific to any listed virus; or

PG2. any gene or genes specific to any listed bacterium or fungus, and which

a. in itself or through its transcribed or translated products represents a significant hazard to human, animal or plant health, or

b. could endow or enhance pathogenicity[3].

Technical note:

1. *Genetically-modified organisms include organisms in which the nucleic acid sequences have been created or altered by deliberate molecular manipulation.*

2. *Genetic elements include, inter alia: chromosomes, genomes, plasmids, transposons, vectors, and inactivated organisms containing recoverable nucleic acid fragments, whether genetically modified or unmodified, or chemically synthesized in whole or in part. For the purposes of the genetic elements control, nucleic acids from an inactivated organism, virus, or sample are considered 'recoverable' if the inactivation and preparation of the material is intended or known to facilitate isolation, purification, amplification, detection, or identification of nucleic acids.*

3. *'Endow or enhance pathogenicity' is defined as when the insertion or integration of the nucleic acid sequence or sequences is/are likely to enable or increase a recipient organism's ability to be used to deliberately cause disease or death. This might include alterations to, inter alia: virulence, transmissibility, stability, route of infection, host range, reproducibility, ability to evade or suppress host immunity, resistance to countermeasures, or detectability.*

Basic Description

The AG's List of Plant Pathogens prescribes controls on genetic elements that contain nucleic acid sequences (DNA or RNA) that code for: any gene specific to a listed virus or any gene specific to a listed bacterium or fungus, which "represents a significant hazard to human, animal, or plant health" or "could endow or enhance pathogenicity." The AG defines "endow or enhance pathogenicity" as when the insertion or integration of the nucleic acid sequence or sequences is/are likely to enable or increase a recipient organism's ability to be used to deliberately cause disease or death. The AG further presents a non-exhaustive list of possible organism alterations that might lead a genetic element or a genetically modified organism to be controlled, such as changes to: virulence, transmissibility, stability, route of infection, host range, reproducibility, ability to evade or suppress host immunity, resistance to medical countermeasures, or detectability.

Some common examples of elements that could be used to transfer genetic information of AG-listed pathogens are genomes, chromosomes, transposons, plasmids, and vectors. A genome contains the entire genetic instructions found in a cell and is encoded by DNA. Most often this DNA is organised into packages called chromosomes. "Transposon" is a general term for a large family of particular DNA sequences that naturally can change position within a genome. Plasmids are small circular DNA molecules found in many cells that often carry small numbers of genes. Vectors are smaller plasmids commonly used in molecular biology to carry a desired DNA sequence or gene into a target cell.[63]

[63] See Glossary of Genetic Terms from U.S. National Human Genome Research Institute (https://www.genome.gov/genetics-glossary) and Transposons: The Jumping Genes from *Nature Education* (http://www.nature.com/scitable/topicpage/transposons-the-jumping-genes-518).

The AG also includes "inactivated organisms containing recoverable nucleic acid fragments" of an AG-listed pathogen as controlled genetic elements. This is an important consideration because life science and public health researchers frequently inactivate live biological pathogens for safe handling and transportation when agent viability is not required to address a question under study. While methods of inactivation terminate pathogen viability and render the organisms unable to replicate or cause disease, the condition of their nucleic acids can range from completely intact to thoroughly destroyed. In many cases, these inactivated pathogen samples are considered controlled genetic elements because the nucleic acids are often recoverable for future molecular or synthetic biology applications. Nucleic acids derived from these same inactivated samples are also a potential means for proliferators to acquire genetic information encoding for listed pathogens or toxins. This is why the AG considers inactivated organisms to contain recoverable nucleic acids, "if the inactivation and preparation of the material is intended or known to facilitate isolation, purification, amplification, detection, or identification of nucleic acids."

This page intentionally left blank.

Items for Inclusion in Awareness Raising Guidelines

These sections provide basic descriptions, notable features, packaging information, and typical applications for Items for Inclusion in Awareness Raising Guidelines of the Control List of Plant Pathogens. Section numbers match the AG Awareness Raising Guidelines entry numbers.

This page intentionally left blank.

Bacteria

PWB1. *Xylella fastidiosa*

PWB1.1. Basic Description

Identifier/Property	Description
Type	Bacteria: Gram stain negative
Associated Disease	Phony peach disease, bacterial leaf scorch, oleander leaf scorch, Pierce's disease, citrus variegated chlorosis
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Potential for socioeconomic harm ▸ Potential to damage the environment ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 3; subject to enhanced containment for countries with vulnerable agriculture
Exposure / Infection Routes	**Exposure:** ▸ Cutaneous (plant surface): Not a likely route of exposure ▸ Injection (internal plant tissues): Leafhopper or sharpshooter bite **Host/Reservoir:** Grape plants, olive trees, oleanders, citrus plants **Vector:** Leafhoppers, sharpshooters
Geographic Distribution	North America, Central America, South America
EU Control List Entry	Not applicable
Applicable AG Footnotes	None

PWB1.2. Notable Features

The principal hosts of *Xylella fastidiosa* are grapevines. Disease transmission primarily occurs through an insect vector, the glassy-winged sharpshooter, though the bacteria can also be spread through the soil and planting of infected seeds and cultivars. The insect vector is responsible for the expansion of host range plants beyond grapes to include olive, citrus, plum, peach, almond, and oleander. The distribution of *X. fastidiosa* is primarily constrained by climate as it cannot withstand freezing temperatures.

X. fastidiosa is spread by sucking insects (namely the glassy-winged sharpshooter) that feed on the fluids from internal tissues of plants. The bacterium adheres to the mouthparts of the vector and is released when it feeds again. When a host plant becomes infected, the bacterium produces a gelatinous material within the vascular tissues, preventing the movement of water throughout the plant. Leaves turn yellow-brown before dropping, shoot production declines, and within 5 years the infected host will die. There is no effective treatment for the disease once a plant is infected.

PWB1.3. Packaging

The shipping practices for plant pathogens are not addressed in current international guidelines. Additional information on the shipment of plant pathogens can be found in the Introduction to Pathogens and Toxins.

PWB1.4. Typical Applications

Basic agricultural disease research and development, epidemiology, and global surveillance.

Fungi

PWF1. *Phoma tracheiphila* (*Deuterophoma tracheiphila*)

PWF1.1. Basic Description

Identifier/Property	Description
Type	Fungus
Associated Disease	Mal secco, citrus wilt, wilt of citrus, mal fulminante, mal nero
Other Names	*Bakerophoma tracheiphila*
Key WMD Characteristic(s)	▸ Environmentally stable spores ▸ Potential for socioeconomic harm ▸ Potential to damage the environment ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 2; subject to enhanced containment for countries with vulnerable agriculture
Exposure / Infection Routes	**Exposure:** ▸ Cutaneous (plant surface): Direct contact ▸ Injection (internal plant tissues): Not a known route of exposure **Host/Reservoir:** Soil, water, citrus plants **Vector:** Not applicable
Geographic Distribution	Eastern Europe, Middle East, Asia, Africa
EU Control List Entry	Not applicable
Applicable AG Footnotes	None

PWF1.2. Notable Features

Phoma tracheiphila (also known as *Deuterophoma tracheiphila*) is a fungal plant pathogen of citrus trees, with lemon trees most susceptible to infection. The fungus produces specialised spores that are effectively transmitted by rain, irrigation waters, wind, insects, birds, or inadvertently by humans. *P. tracheiphila* causes three forms of disease that vary based on entry site within the plant. The most common disease manifestation is known as mal secco, where spores settle and germinate on uninfected host leaves. The fungus invades the leaf through the stomata or open wounds. *P. tracheiphila* colonises the internal plant tissue, which produces a gum-like material to block water transport within the plant. Typical symptoms of mal secco include chlorosis (yellowing of the leaves), leaf wilt, red colouration of the xylem, and dieback of sprouts and branches. The disease progresses downward from the site of infection. When the main trunk and roots become infected, the host plant dies. In addition to mal secco, two additional forms of the disease exist: mal fulminante, likely caused by root infection and marked by rapid death of the host plant, and mal nero, a chronic infection that causes browning of the hard wood. There is no effective treatment for the disease once a plant is infected.

PWF1.3. Packaging

The shipping practices for plant pathogens are not addressed in current international guidelines. Additional information on the shipment of plant pathogens can be found in the Introduction to Pathogens and Toxins.

PWF1.4. Typical Applications

Basic agricultural disease research and development, epidemiology, and global surveillance.

PWF2. *Moniliophthora roreri* (*Monilia roreri*)

PWF2.1. Basic Description

Identifier/Property	Description
Type	Fungus
Associated Disease	Frosty pod rot disease, monilia pod rot, quevedo disease
Other Names	Not applicable
Key WMD Characteristic(s)	▸ Environmentally stable spores ▸ Potential for socioeconomic harm ▸ Potential to damage the environment ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 3; subject to enhanced containment for countries with vulnerable agriculture
Exposure / Infection Routes	**Exposure:** ▸ Cutaneous (plant surface): Direct contact ▸ Injection (internal plant tissues): Not a known route of exposure **Host/Reservoir:** Soil, wind, cocoa pods **Vector:** Not applicable
Geographic Distribution	South America, Central America
EU Control List Entry	Not applicable
Applicable AG Footnotes	None

PWF2.2. Notable Features

First reported in 1917, *Moniliophthora roreri* (also known as *Monilia roreri*) is a fungal pathogen of cocoa in parts of Latin America. Infection begins when the fungus colonises and penetrates the exterior coating of the cocoa pod. Initially, symptoms include dark spotting on the pod surface followed by a characteristic white powder that appears on the pod. This white substance is actually the spore-forming structure of the fungus, as seen in Figure PWF2.A. These spores are easily transmitted by wind and water for distribution to other cocoa plants. Currently, the disease is confined to Columbia, Ecuador, Venezuela, Peru, Nicaragua, Guatemala, Belize, and Mexico. Many fear that spread of the disease could decimate cocoa production in Bolivia and Brazil. There is no effective treatment for the disease once a plant is infected.

Figure PWF2.A. *Cocoa pods with frosty pod rod disease.*

PWF2.3. Packaging

The shipping practices for plant pathogens are not addressed in current international guidelines. Additional information on the shipment of plant pathogens can be found in the Introduction to Pathogens and Toxins.

PWF2.4. Typical Applications

Basic agricultural disease research and development, epidemiology, and global surveillance.

Viruses

PWV1. *Banana bunchy top virus*

PWV1.1. Basic Description

Identifier/Property	Description
Type	Virus: DNA
Associated Disease	Banana bunchy top
Other Names	BBTV
Key WMD Characteristic(s)	▸ Potential for socioeconomic harm ▸ Potential to damage the environment ▸ Limited post-exposure treatment
Containment and Handling	Biosafety Level 3; subject to enhanced containment for countries with vulnerable agriculture
Exposure / Infection Routes	**Exposure:** ▸ Cutaneous (plant surface): Direct contact ▸ Injection (internal plant tissues): Banana aphid bite **Host/Reservoir:** Soil, water, banana plants, plantain plants **Vector:** Banana aphids
Geographic Distribution	Tropics, Southeast Asia, Africa, United States (Hawaii only)
EU Control List Entry	Not applicable
Applicable AG Footnotes	None

PWV1.2. Notable Features

Banana bunchy top virus is a viral plant pathogen that targets all types of banana plants and plantains. Initial symptoms of the disease include the appearance of dot-dash lines also known as "morse code streaking" on the leaves of the plant. As the disease progresses, the virus stunts the growth of infected plants resulting in a bunchy appearance, discolouration of leaves, and deformation of fruit. Though the deformed fruit is edible, the disease eventually renders the plant sterile. The pathogen is transmitted either by an insect vector or through contamination of soil with infected plant material. Banana aphids predominantly are responsible for the spread of the virus. Though complete eradication has proven unsuccessful, vector control programs have produced positive results. There is no effective treatment for the disease once a plant is infected.

PWV1.3. Packaging

The shipping practices for plant pathogens are not addressed in current international guidelines. Additional information on the shipment of plant pathogens can be found in the Introduction to Pathogens and Toxins.

PWV1.4. Typical Applications

Basic agricultural disease research and development, epidemiology, and global surveillance.

Control List of Dual-Use Biological Equipment and Related Technology and Software

The following sections provide basic descriptions and information on the notable features, packaging, and typical applications of items on the Australia Group Control List of Dual-Use Biological Equipment. Each section also includes an illustrative "Global Production" listing, which lists countries that are home to the headquarters of equipment producers. Those producers may have subsidiaries in other countries, but those subsidiary locations are not included in these lists. The text in the blue boxes at the beginning of each equipment section provides the AG control language as of its February 2020 revision.[64] Following the items on the Control List of Dual-Use Biological Equipment are brief sections on equipment recommended by the AG for inclusion in Awareness Raising Guidelines, and sections describing Related Technology and Software that should be subject to export control.

Harmonized System (HS) codes are not provided for items on this control list. The World Customs Organization's Strategic Trade Control Enforcement (STCE) Implementation Guide provides commentary on the applicability of various HS headings and subheadings to dual-use biological equipment.[65]

The complete AG control language as of February 2020 is found in Appendix C. See the Glossary for definitions of technical terms used in the Handbook.

[64] The current AG control language can be found online at https://www.dfat.gov.au/publications/minisite/theaustraliagroupnet/site/en/dual_biological.html.

[65] World Customs Organization, Strategic Trade Control Enforcement Implementation Guide, http://www.wcoomd.org/en/topics/enforcement-and-compliance/instruments-and-tools/guidelines/wco-strategic-trade-control-enforcement-implementation-guide.aspx. Available in English, Spanish, Russian, Arabic, and French.

This page intentionally left blank.

I. Equipment

1. Containment Facilities and Related Equipment

a) Complete containment facilities that meet the criteria for P3 or P4 (BL3, BL4, L3, L4) containment as specified in the WHO Laboratory Biosafety Manual (3rd edition, Geneva, 2004)

b) Equipment designed for fixed installation in containment facilities specified in a., as follows:

i. Double-door pass-through decontamination autoclaves;

ii. Breathing air suit decontamination showers;

iii. Mechanical-seal or inflatable-seal walkthrough doors.

1.1. Basic Description

Global Production

- Australia
- Canada
- Germany
- Singapore
- Switzerland
- United States

Containment facilities for working with hazardous biological agents help ensure the safety of workers, the environment, and the surrounding community. The World Health Organization's (WHO's) *Laboratory Biosafety Manual* provides criteria for working at various levels of containment, depending on the risk posed by a particular agent.[66] The WHO classifies infectious agents into four Risk Groups and specifies the respective facilities appropriate for safely working with them. These specifications are the four Biosafety Levels. The design of Biosafety Level 3 (containment) and Biosafety Level 4 (maximum containment) facilities allows for safe work with the most dangerous pathogens (Risk Groups 3 and 4, respectively). Biosafety Level 3 and Biosafety Level 4 are the facilities of most concern for nonproliferation export controls. These facilities may be referred to by a number of abbreviations, including **L** (Level), **P** (Pathogen or Protection Level), **BL** (Biosafety Level), **CL** (Containment Level), and **BSL** (BioSafety Level). Table 1 provides a brief overview of the pathogen Risk Groups and their related facility requirements for safe handling.

Assignment of a specific pathogen to a Risk Group depends on a variety of factors, and this Risk Group combined with other considerations (e.g., the need to work with aerosolised pathogens) will lead to a determination of the necessary Biosafety Level and appropriate facility requirements. In other words, the Biosafety Level required will depend on a full risk assessment on the work to be done. For example, the United States' Centers for Disease Control and Prevention (CDC) recommends Biosafety Level 2 containment and facilities for working with the bacteria that causes anthrax if the work involves using clinical materials and diagnostic quantities of infectious cultures. In contrast, the CDC recommends operating at Biosafety Level 3 if the work involves production quantities or concentrations of cultures, or a high potential for the production of aerosols.[67]

Containment facilities at Biosafety Level 3 and Biosafety Level 4 often have the characteristics listed below, some of which have already been summarised in Table 1. The WHO *Laboratory Biosafety Manual* contains additional details. Please note that these items are in addition to the equipment specifically called out in the AG control language

- Isolation from the environment and general traffic
- Sealable rooms for decontamination
- Controlled ventilation system with airflow, and with High-Efficiency Particulate Air (HEPA) filtered exhaust
- Controlled access with double-door entry (self-closing, interlockable access doors)

[66] *Laboratory Biosafety Manual*, 3rd Edition, World Health Organization, http://www.who.int/csr/resources/publications/biosafety/WHO_CDS_CSR_LYO_2004_11/en/.

[67] *Biosafety in Microbiological and Biomedical Laboratories* (BMBL), 5th Edition, U.S. Centers for Disease Control and Prevention, Section VIII-A: Bacterial Agents, http://www.cdc.gov/biosafety/publications/bmbl5/index.htm.

- Airlocks, with showers for Biosafety Level 4 facilities
- Anteroom (potentially with showers) for Biosafety Level 3 facilities
- Effluent treatment and autoclaves
- Biological safety cabinets
- Personnel safety monitoring capability, such as windows, closed-circuit television, and two-way communication

Table 1. *Summary of WHO Risk Groups and Related Biosafety Laboratory Characteristics*[68,69]

Risk Group	Pathogen Characteristics	Related Biosafety Level	Laboratory Practices and Equipment
1	Unlikely to cause human or animal disease	1	Good microbiological techniques (GMT); open bench work
2	Can cause human or animal disease; unlikely to be a serious hazard to laboratory workers, the community, livestock, or the environment; laboratory exposures may cause serious infection, but effective treatment and preventive measures are available and the risk of spread of infection is limited	2	GMT plus protective clothing and biohazard signs; open bench plus biological safety cabinets (BSCs)* for potential aerosols
3	Usually causes serious human or animal disease but does not ordinarily spread from one infected individual to another; effective treatment and preventive measures are available†	3	As Level 2 plus special clothing, anteroom with changing facilities, controlled access, and directional air flow; BSCs and/or other primary devices for all activities
4	Usually causes serious human or animal disease and can be readily transmitted from one individual to another, directly or indirectly; effective treatment and preventive measures are usually not available†	4	As Level 3, plus airlock entry, decontamination shower on exit, and special waste disposal; Class III BSCs or positive pressure suits in conjunction with Class II BSCs, double-ended autoclave (through the wall), tethered air supply for positive pressure suits

*See Protective and Containment Equipment for information on controlled biological safety cabinets.

†For examples, see The American Biological Safety Association's Risk Group Database (https://my.absa.org/Riskgroups).

1.2. Notable Features

Permanent biocontainment facilities, even those designed to contain the most dangerous pathogens, may look like ordinary buildings from the exterior.[70] For example, Figure 1.A (left) shows an exterior view of a Biosafety Level 3 laboratory and Figure 1.B (left) shows an exterior of a Biosafety Level 4 laboratory. Both are relatively indistinguishable as biological facilities. The large, specialised air handling and ventilation facilities located above the Biosafety Level 3 research facility in Figure 1.A (the gray-coloured section on the top of the building) may be covered by other construction and would only be recognised by someone skilled in the construction of these facilities.

[68] *Laboratory Biosafety Manual*, 3rd Edition, World Health Organization, pp. 1–2, http://www.who.int/csr/resources/publications/biosafety/WHO_CDS_CSR_LYO_2004_11/en/.

[69] *Biosafety in Microbiological and Biomedical Laboratories* (BMBL), 5th Edition, Centers for Disease Control and Prevention, Section III: Principles of Biosafety, http://www.cdc.gov/biosafety/publications/bmbl5/index.htm.

[70] See an online BSL-4 Lab Tour of the National Emerging Infectious Diseases Laboratory https://vimeo.com/59246199.

Rather, the interior of the facility, and the associated equipment moved into it, will distinguish it as a containment or maximum containment laboratory. Figures 1.A (right) and 1.B (centre, right) show examples of the interiors of Biosafety Level 3 and Biosafety Level 4 laboratories, respectively. The features of these rooms should match the characteristics noted in the previous section and in the WHO manual. For example, when compared to Biosafety Level 1 and Biosafety Level 2 laboratories, a prominent feature of Biosafety Level 3 containment facilities is an anteroom or airlock room with shower/changing/decontamination facilities. The anteroom is integral to the the decontamination of personnel and the regulation of airflow. Biosafety Level 3 laboratories will also feature in-room autoclave access. Prominent features of Biosafety Level 4 maximum containment facilities with suit laboratories would be enhanced shower/changing room/ decontamination facilities, including breathing air suit decontamination showers together with provisions for tethered air, as evidenced in Figure 1.B. (centre, right) and Figure 1.E.

Figure 1.A. *Biosafety Level 3 containment facilities. Left: exterior view. Right and inset: interior views.*

Additional equipment needed for both levels of controlled biocontainment facilities can include laboratory furniture made of non-fabric material for easy decontamination, Class II or Class III biological safety cabinets, positive-pressure protective suits, HEPA filters and associated ventilation equipment, double-door pass-through decontamination autoclaves and mechanical-seal or inflatable-seal walkthrough doors. Of note, the surfaces of these laboratories will likely have water-resistant, easy-to-clean walls with all gaps sealed, as well as air ducting systems allowing gaseous decontamination. Requirements for the interior walls could necessitate the use of special paints.

Figure 1.B. *Biosafety Level 4 maximum containment facilities. Left: exterior view. Centre, right: interior views.*

Prefabricated and modular biocontainment facilities are also available. Figure 1.C shows two examples of modular Biosafety Level 3 facilities, which look like vehicle trailers or shipping containers. One supplier claims that minimum on-site construction and installation are required, and that the unit is completely

furnished with rooms, air-conditioning, electricity, machinery, and air-flow control.[71] Mobile maximum biocontainment Biosafety Level 4 facilities have also been designed.[72] All mobile containment facilities have legitimate peaceful uses and greatly facilitate rapid response to a disease outbreak or biological weapons attack.

Figure 1.C. *Mobile (left) and modular (right) Biosafety Level 3 containment laboratories. The side wall in the right image has been removed for display purposes only.*

The Australia Group lists both complete P3 and P4 containment facilities as well equipment designed for fixed installation in these containment facilities. The specific equipment listed are double-door pass-through decontamination autoclaves, breathing air suit decontamination showers, and mechanical-seal or inflatable-seal walkthrough doors. Double-door pass-through decontamination autoclaves prominently include two doors and the ability to pass sterilized items directly through the autoclave (Figure 1.D). With a few exceptions, double door autoclaves are manufactured almost exclusively for Biosafety Level 3 and Biosafety Level 4 facilities and are designed to sterilize items contaminated with Risk Group 3 and Risk Group 4 pathogens. To accomplish this mission safely, these autoclaves also feature the ability to seal to the wall separating the containment area from the non-containment area, and the ability to ensure the complete decontamination of all liquid and steam effluents through filtration and reboiling.

[71] Biosafety Level 3 (P3) Laboratory, Techcomp Limited, no longer available online.

[72] For example, see this article on using a mobile BSL-4 facility for conducting autopsies in the event of a disease outbreak: P. Chui, et al. "Mobile Biosafety Level-4 Autopsy Facility – An Innovative Solution," no longer available online.

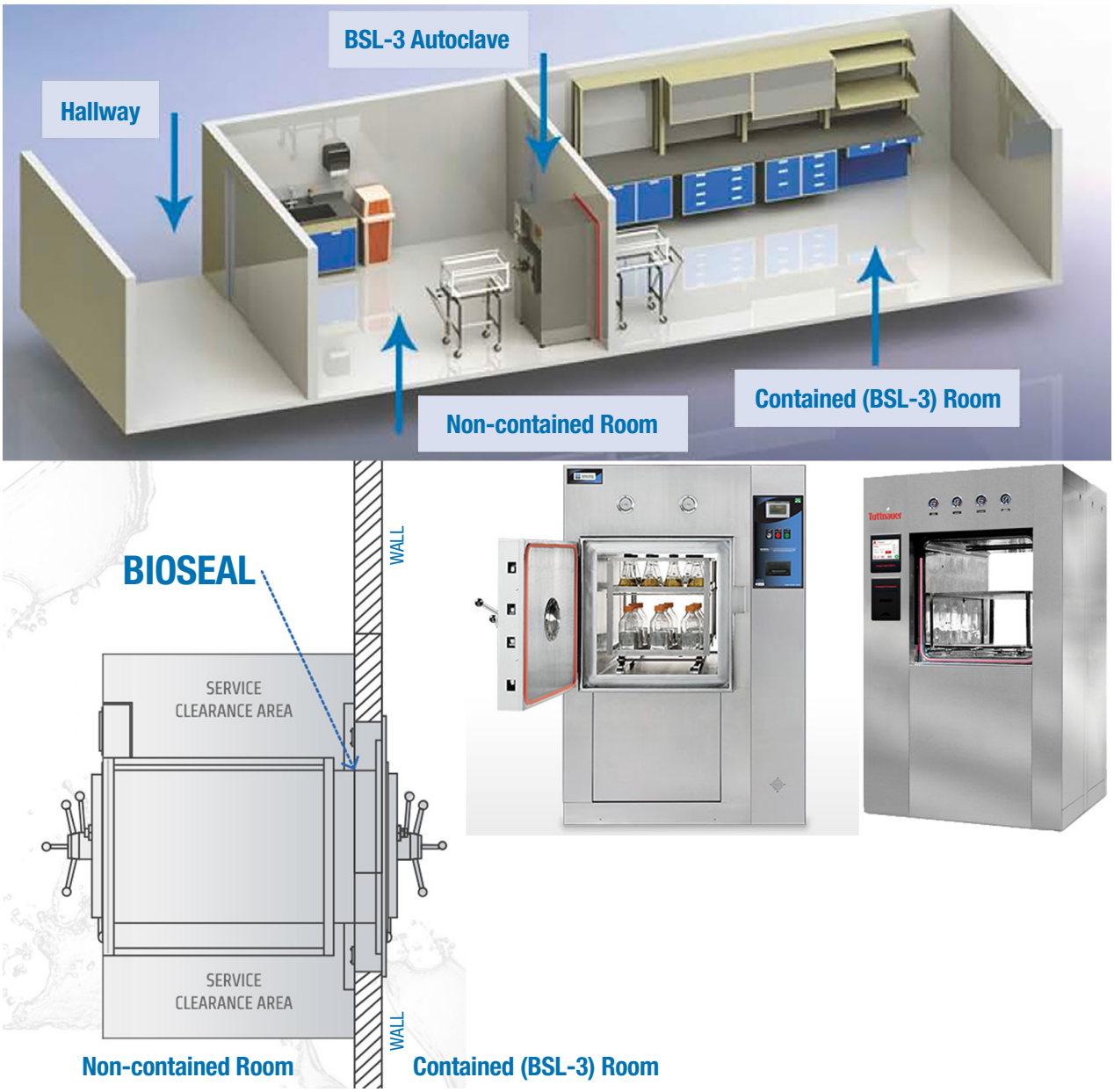

Figure 1.D. *Double door pass through decontamination autoclaves. The top schematic shows the location of the autoclave relative to the contained room and the non-contained room. The diagram on the bottom left shows a close up of the placement of the autoclave in the wall and the seal with the wall.*

Breathing air suit decontamination showers are found only in Biosafety Level 4 facilities. They provide a means to ensure that a worker's positive pressure protective suit is decontaminated prior to the worker removing the suit. As their name implies, these decontamination showers feature tethered air supplies (Figure 1.E). Mechanical-seal or inflatable-seal walkthrough doors are found in both for Biosafety Level 3 and Biosafety Level 4 facilities. Of important note, these doors may also be found in any non-biological containment facility that requires controlled air flow (e.g. an industrial "clean room"). The doors can completely seal, blocking all airflow between adjacent rooms (Figure 1.F, top). While mechanical seal doors achieve this seal by application of mechanical pressure against flexible gaskets, inflatable seal doors include a special tubular gasket that is inflated and deflated as necessary. When the gasket is inflated, it increases in volume and seals the door to the door frame. Because of the requirement for pressurized air, inflatable seal doors will almost universally incorporate a gauge that can monitor air pressure between rooms and a gauge that can monitor air pressure within the door gasket itself (Figure 1.F, bottom centre).

Figure 1.E. *Two views of a breathing air suit decontamination shower.*

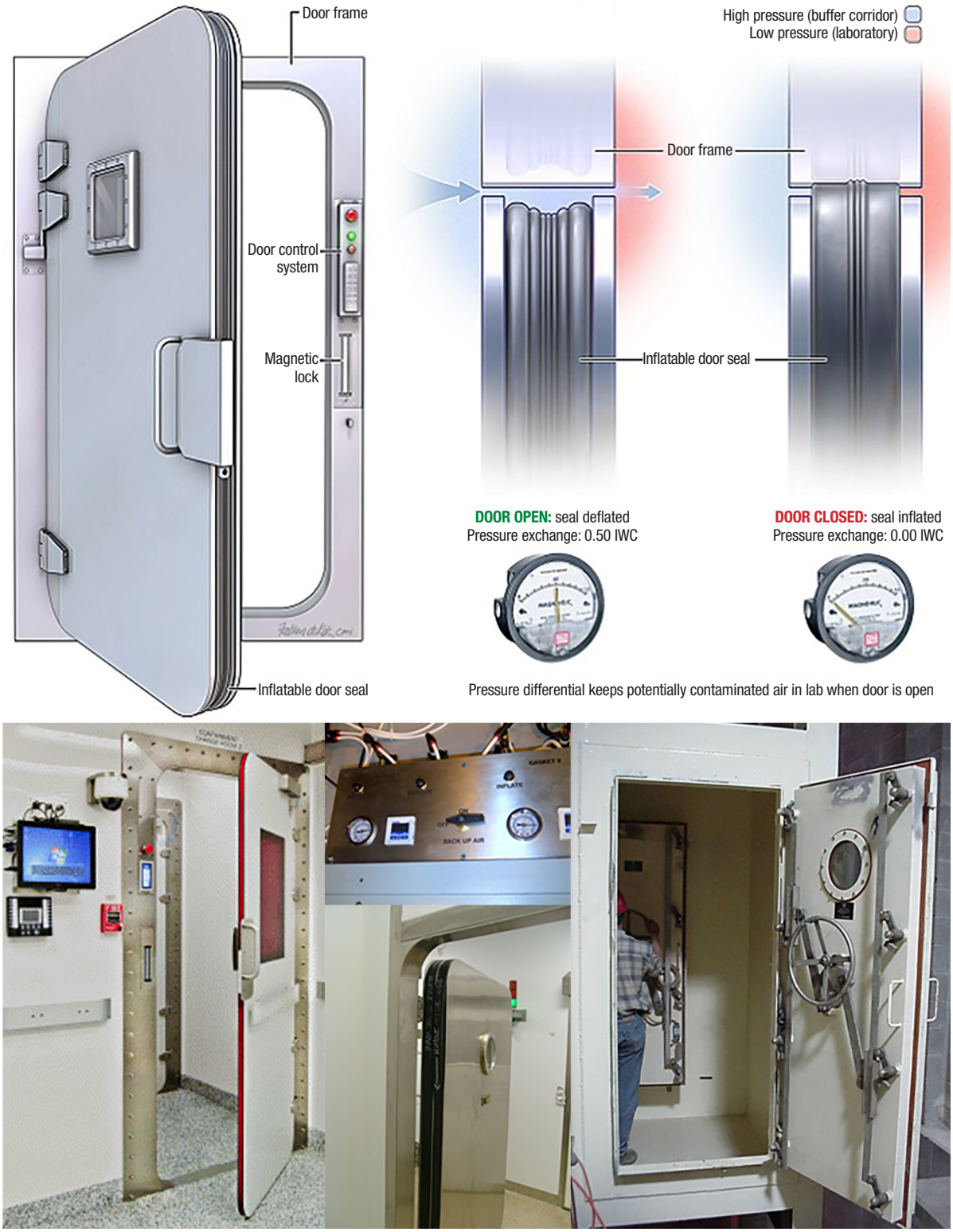

Figure 1.F. *Mechanical-seal or inflatable-seal walkthrough doors. The top schematic describes how the door seal inflates to block the flow of air between rooms of a containment facility. The bottom images show examples of inflatable seal doors (left, centre) and mechanical seal doors (right). Note the red (left) and black (centre) colors of the inflatable sealing gasket.*

1.3. Packaging

Construction for permanent containment facilities would occur on-site. Associated equipment for the laboratories would be packaged as appropriate to specific items. Double-door pass-through autoclaves and mechanical-seal or inflatable-seal walkthrough doors would likely ship on large pallets. Breathing air suit decontamination showers might ship as a single unit resembling a small room or ship in pieces for assembly on-site. For examples of packaging for other controlled items relevant to biocontainment facilities, see protective and containment equipment and fan-HEPA filter units. Modular, prefabricated laboratories might be delivered in shipping containers or permanently mounted to large semi trucks.

1.4. Typical Applications

Countries throughout the world have legitimate uses for Biosafety Level 3 and Biosafety Level 4 facilities for research, either with Risk Group 3 and Risk Group 4 agents or with large volumes of Risk Group 2 agents posing a high risk of aerosol spread. Such facilities allow for research supporting the development of vaccines, treatments, and diagnostics for infectious diseases. These facilities also can support the diagnosis of suspected illnesses caused by these high-risk agents,[73] and the development of detection methods.

[73] For example, see this article on using a mobile BSL-4 facility for conducting autopsies in the event of a disease outbreak: P. Chong, et al. “Mobile Biosafety Level-4 Autopsy Facility – An Innovative Solution,” no longer available online.

2. Fermenters

Fermenters capable of cultivation of microorganisms or of live cells for the production of viruses or toxins, without the propagation of aerosols, having a total internal volume of 20 litres or greater.

Components designed for such fermenters, as follows:

a) cultivation chambers designed to be sterilized or disinfected in situ;

b) cultivation chamber holding devices; or

c) process control units capable of simultaneously monitoring and controlling two or more fermentation system parameters (e.g. temperature, pH, nutrients, agitation, dissolved oxygen, air flow, foam control).

Note 1 – Fermenters include bioreactors (including single-use (disposable) bioreactors), chemostats and continuous-flow systems.

Note 2 – Cultivation chamber holding devices include single-use cultivation chambers with rigid walls.

2.1. Basic Description

Fermenters are vessel systems used to grow microorganisms. They range from relatively simple apparati to complex, computer-controlled systems that provide ideal growth conditions for the cultivation of microorganisms. In order to meet control specifications, fermenters must have a total internal volume of at least 20 litres and be designed to prevent the propagation of aerosols.

Controlled items in this entry also include bioreactors, chemostats, and continuous-flow systems. The term "bioreactor" is the most general of these. A bioreactor can be defined as "an apparatus used to carry out any kind of bioprocess."[74] Fermenters and chemostats are examples of bioreactors. For example, a fermenter is "a bioreactor which enables optimal fermentation conditions to be maintained, allowing addition of nutrients, removal of products and insertion of measuring and/or control probes as well as other necessary equipment (e.g., for heating, cooling, aeration, agitation, sterilisation, etc.) under sterile conditions,"[75] while a chemostat is "a bioreactor in which constant growth conditions for microorganisms are maintained over prolonged periods of time by supplying the reactor with a continuous input of nutrients and continuous removal of medium."[76] A continuous-flow system, often called a continuous-flow stirred tank reactor (or CSTR), is another name for a chemostat arrangement. Bioreactor systems can be found in both reusable and single-use designs.[77]

Global Production

- Austria
- Bulgaria
- Canada
- China
- Denmark
- France
- Germany
- India
- Iran
- Italy
- Japan
- Republic of Korea
- Latvia
- Malaysia
- The Netherlands
- Spain
- Sweden
- Switzerland
- United Kingdom
- United States

2.2. Notable Features

At the most basic level, a fermenter system includes a cultivation chamber (typically a cylindrical vessel) in which the growth takes place, sensors for monitoring growth conditions, and a (computerised) process control system. Fermenter cultivation chambers can range in volume from less

[74] IUPAC Gold Book definition of a bioreactor: http://goldbook.iupac.org/B00662.html.

[75] IUPAC Gold Book definition of a fermenter: http://goldbook.iupac.org/F02338.html.

[76] IUPAC Gold Book definition of a chemostat: http://goldbook.iupac.org/C01053.html.

[77] "Markets Expand for Single-Use Bioreactors" https://www.genengnews.com/magazine/288/markets-expand-for-single-use-bioreactors/.

than a litre to thousands of litres and are commonly constructed of glass and/or stainless steel. In addition, many manufacturers now produce pre-sterilised, disposable plastic bags and rigid plastic chambers that can be used as cultivation chambers, when mated to appropriate fermenter components such as a cultivation chamber holding device and a process control unit. Fermenters often have one cultivation chamber per computer control system, but may have multiple chambers connected to a central control unit.

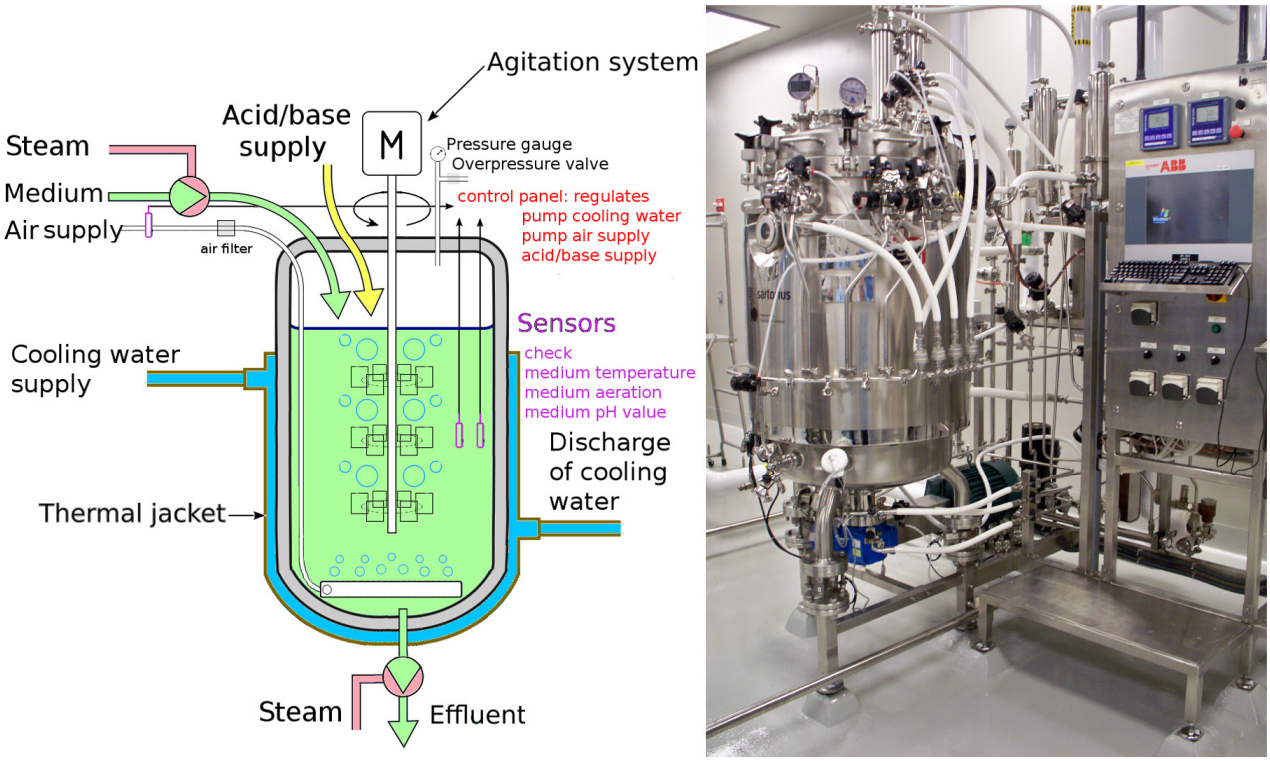

Figure 2.A. *Schematic of a fermenter cultivation chamber (left) and a complete reusable bioreactor system (right).*

Figure 2.A shows a schematic of a fermenter cultivation chamber, alongside a photograph of a complete reusable bioreactor system. These systems have a cylindrical vessel, often with a height-to-diameter ratio of approximately 2:1. The bottom of the chamber may be hemispherical or conical. The chamber will have numerous inlet and outlet ports for a variety of functions: addition of nutrients; draining/removal of materials; monitoring of growth conditions; control of pH, temperature, and oxygen content; mixing of chamber contents; venting of waste gases; and input of steam for sterilisation. Fermenter cultivation chambers often have a viewport or a narrow window on the side of the chamber. The system will frequently have computer process controls either attached to the cultivation chamber or freestanding beside it. Fermenter systems are often designed for *in situ* disinfection or steam sterilisation. The capability for *in situ* disinfection or steam sterilisation is not a requirement when disposable cultivation chambers are used.

Fermenters are available in laboratory, pilot, and industrial sizes. All share the same basic features, with some variations due to scale. Figure 2.B shows fermenters of different sizes. Note that a fermenter with a total internal volume at the lower limit of the control specifications (20 litres) is considered a pilot-scale or large laboratory-scale device. Larger production (industrial) scale fermenters may more closely resemble chemical reaction vessels.[78] Sub-20-litre capacity fermenters appear in the Awareness Raising Guidelines of the biological equipment control list. It is noteworthy that a system of smaller fermenters can be operated in parallel or in series and be able to produce an amount of product that is equal to or greater than the amount produced by a larger fermenter. This possibility is reflected in the AG's "special emphasis on aggregate orders or designs for use in combined systems" in the small fermenter awareness raising entry.

[78] Chemical reaction vessels appear on the AG's Control List of Chemical Manufacturing Facilities and Equipment and Related Technology and Software.

Figure 2.B. *Fermenters with different capacities: 15–30 litre laboratory/pilot scale (left); 90-litre pilot scale (centre); 7000 litre production scale (right).*

The AG control also includes fermenters with disposable cultivation chambers. Three basic designs of single-use (disposable) fermenters are currently available. Two feature a pre-sterilised plastic chamber or bag placed in a chamber holding device, accompanied by a (computerised) process control unit. The chamber holding device supports the plastic bag, supports a means of agitation, and organises the various probes necessary for control of various parameters (e.g., temperature, dissolved O_2, dissolved CO_2). One type of disposable fermenter, shown in Figure 2.C, has a platform that holds the bag and provides agitation through a rocking motion. The second type looks similar to the stirred tank reactor design of reusable fermenters (see Figure 2.A and Figure 2.B) and is shown in Figure 2.D. It has an open cylindrical holding device in which the bag sits. This holder supports the bag, and an agitator inserted into the bag mixes the solution. A third design features a free standing, rigid wall plastic cultivation chamber attached to a process control unit. In this design, the rigid chamber doubles as the cultivation chamber holding device. Figure 2.D shows three types of stirred tank reactor-style cultivation chamber holding devices: those which are solid cylinders, those with doors that open to allow access to the disposable plastic cultivation chamber, and those where the rigid walled cultivation chamber also serves as the cultivation chamber holding device.

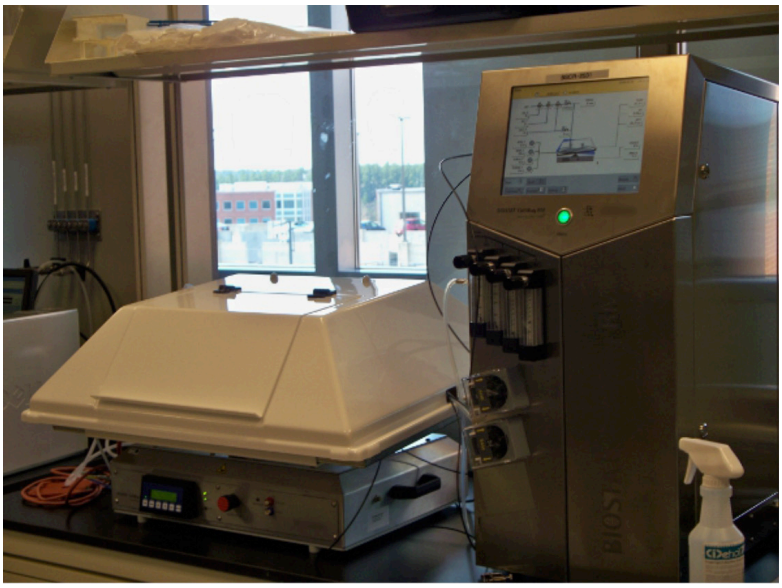

Figure 2.C. *20-litre laboratory/pilot scale rocker-type disposable fermenter.*

Figure 2.D. *Stirred tank reactor-type disposable fermenters. Left: A stirred tank reactor with the cultivation chamber inflated. Right: A different cultivation chamber holding device with the cultivation chamber deflated.*

2.3. Packaging

The cultivation chamber and the process control unit may be packaged separately. Components will most likely be wrapped in plastic and all ports of the cultivation chamber will be sealed to keep the interior of the chamber clean during shipping. Large fermenters will be mounted on pallets or in boxes for transport. Smaller units may be self-contained and packaged as a single unit. Figure 2.E shows a 1000-litre fermenter with a stainless steel cultivation chamber packed for transport on pallets along with its control unit and steam generator.

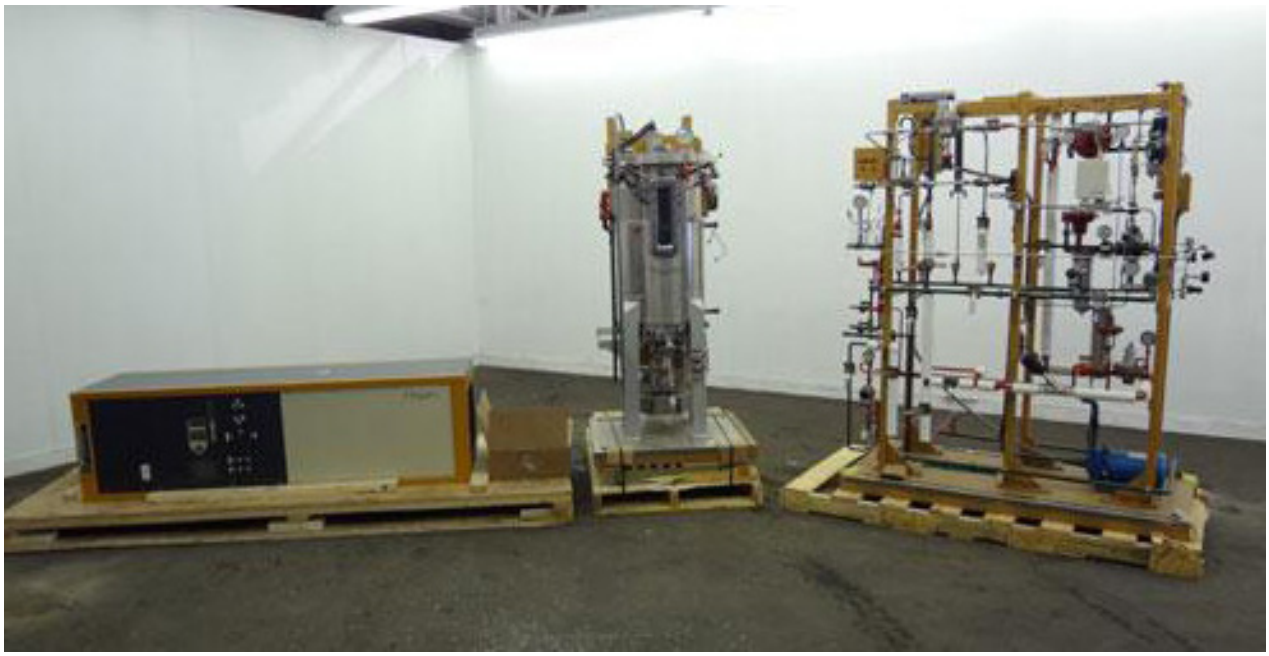

Figure 2.E. *A 1000-litre fermenter packed for transit together with its control unit (left) and steam generation apparatus (right).*

2.4. Typical Applications

Fermenters/bioreactors have a variety of commercial uses in numerous industry sectors. These include the production of microorganisms for industrial use and other consumer products. The pharmaceutical industry uses them to produce medications and vaccines; for example, insulin and interferon. The food and beverage industry also uses fermenters for the production of beer, wine, yogurt, and substances such as Vegemite and Marmite. Fermenters are also used to produce metabolic products (e.g., ethanol, citric acid, and vitamins), biopesticides and feed additives for agriculture, and enzymes for industrial use. Other applications include bioremediation and municipal and industrial wastewater treatment.

This page intentionally left blank.

3. Centrifugal Separators

Centrifugal separators capable of the continuous separation of pathogenic microorganisms, without the propagation of aerosols, and having all the following characteristics:

a) one or more sealing joints within the steam containment area;

b) a flow rate greater than 100 litres per hour;

c) components of polished stainless steel or titanium;

d) capable of in-situ steam sterilisation in a closed state.

Technical note: Centrifugal separators include decanters.

3.1. Basic Description

Following growth, microorganisms or the toxins they produce must be separated from both the nutrients in the media and waste products produced during growth. In theory, the components of a mixture will naturally separate by the force of gravity – heavier particles will come to rest at the bottom of the container while lighter particles will move to the top of the solution. A centrifugal separator accelerates this natural process by using the centrifugal force generated by high-speed rotation. The material requiring separation enters a chamber ("bowl") of the centrifuge, where it undergoes high-speed rotation. The centrifugal force separates components according to their density (e.g., liquids separate from other liquids and/or solids). Denser (heavier) materials collect on the sides of the centrifuge bowl, while less dense (lighter) materials remain in the inner portion of the bowl.[79]

Global Production

- Austria
- China
- Denmark
- France
- Germany
- Italy
- Japan
- Spain
- Sweden
- Switzerland
- United Kingdom
- United States

AG control specifications for centrifugal separators require that they have at least one sealing joint in the steam containment area, be capable of continuous operation at a flow rate of greater than 100 litres per hour, have titanium or polished stainless steel components, and be capable of *in situ* steam sterilisation in a closed state. Depending on their design, centrifugal separators might also be referred to as "disk stack centrifuges." Furthermore, this control list entry also includes decanters, which are similar to traditional (vertical bowl) centrifugal separators, but have a horizontal spinning bowl and incorporate a scroll or screw conveyor for moving separated solids out of the unit. Both designs are discussed in this section.

[79] For a more detailed overview of centrifugal separator working principles and a survey of applications, see "Alfa Laval – disc stack centrifuge technology," Alfa Laval: http://www.alfalaval.com/globalassets/documents/industries/pulp-and-paper/pchs00022en_lowres.pdf.

3.2. Notable Features

Centrifugal separators

Centrifugal separators designed for continuous operation are often of a "disk stack" design. These devices feature a prominent conical metal bowl with at least three connections – one feed inlet and two outlets. Both outlets may be on the upper portion of the bowl, or the second discharge outlet also may be located near the lower portion of the unit. In addition, there may be a third discharge port/vessel on the side for the removal of solids (so-called "three-phase separation" for two liquids and a solid). The inside of the metal bowl contains not only the spinning part of the centrifuge, but also a stack of disks to assist the separation. A motor connects to the unit to provide power for spinning. Figure 3.A shows a schematic of a three-phase separation disk stack centrifuge, while Figure 3.B shows photographs of centrifugal separators. The separator will be mounted together with its control unit or have a separate unit for controlling the separation process.

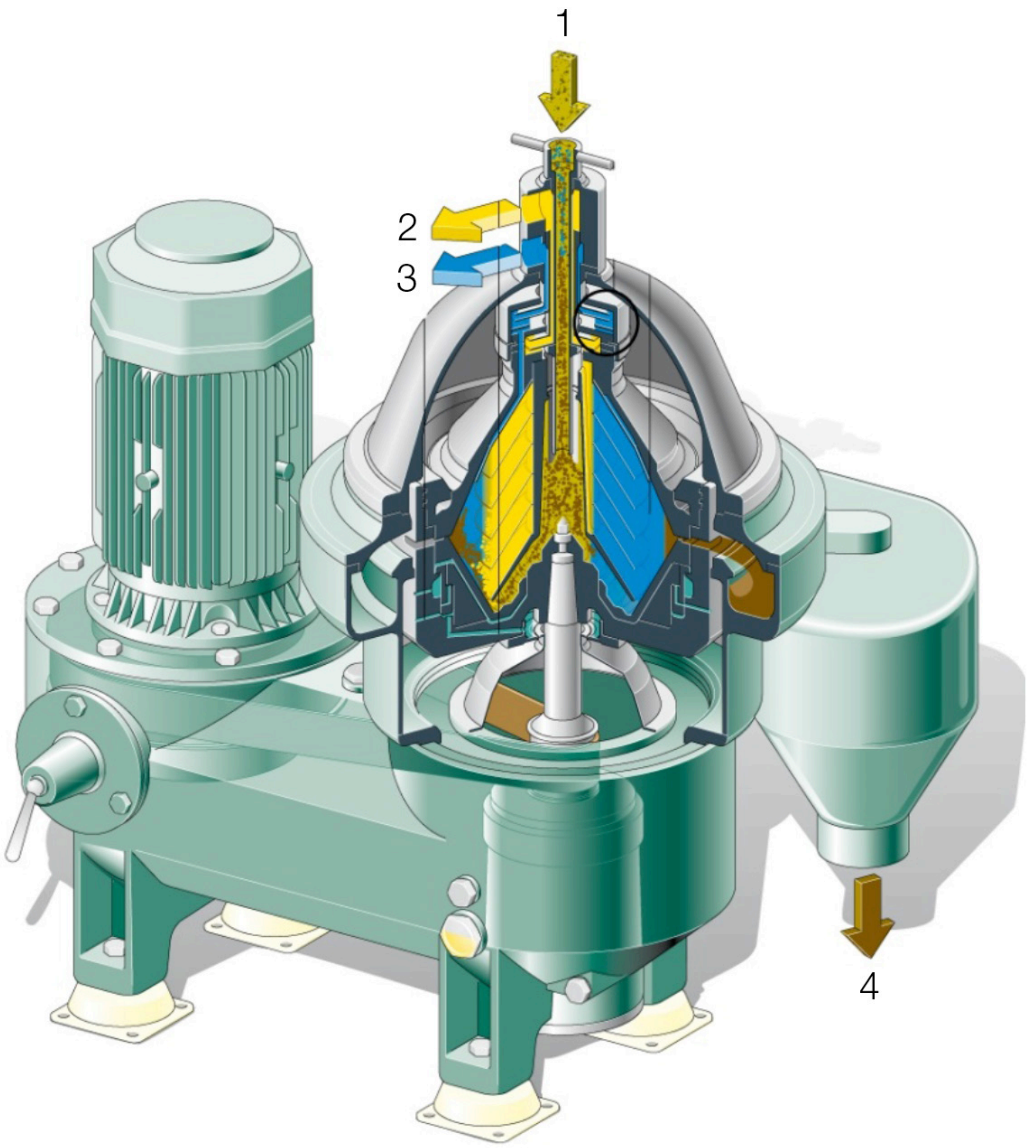

Figure 3.A. *Schematic of a disk stack centrifuge for three-phase separation. (1) Feed stock to be separated, (2) light liquid phase discharge, (3) heavy liquid phase discharge, (4) solids discharge.*

Figure 3.B. *Centrifugal separators.*

Decanter centrifuges

Decanter centrifuges are conceptually similar to centrifugal separators,[80] but rather different in appearance. Decanters have a horizontal spinning metal bowl encased in another metal housing. The bowl has the shape of a tapered cylinder, with the inlet and the solids outlet on the tapered end. The other end of the bowl contains one or more liquid outlets. A scroll or screw conveyor within the bowl rotates at a different speed than the bowl and removes separated solids for discharge. As a result, a decanter centrifuge may have two visible motors. The diagram in Figure 3.C depicts the operation of a decanter centrifuge, while Figure 3.D shows photographs of such devices.

[80] See http://www.lenntech.com/Centrifugation.htm for a comparison of centrifugal separators and decanters.

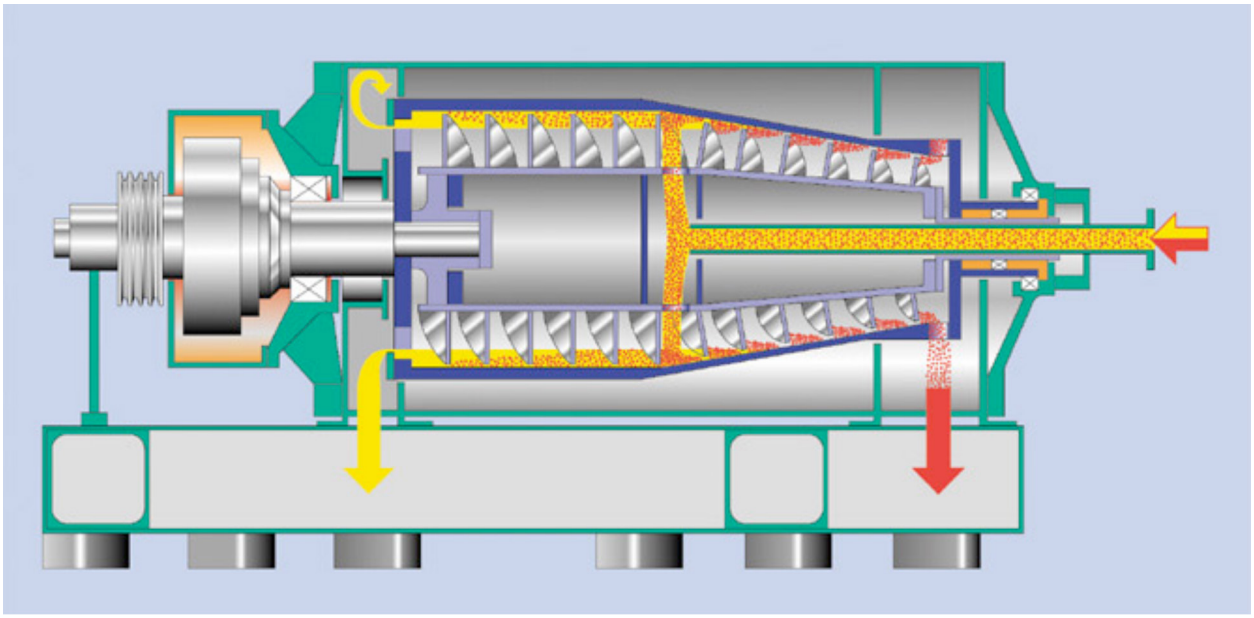

Figure 3.C. *Schematic of a decanter centrifuge showing solid (red) and liquid (yellow) discharges.*

Figure 3.D. *Decanter centrifuges.*

3.3. Packaging

Controlled centrifuges are heavy items and likely to be packaged on pallets. Decanters may ship with the spin bowl separated from its metal housing. Figure 3.E shows centrifugal separators, decanters, and their components mounted to pallets. One decanter manufacturer notes that their palletised complete units have the rotating assemblies raised on transportation brackets to protect ball bearings during shipping.[81]

[81] Derrick Corporation, DE-1000 SB product literature; no longer available online.

Figure 3.E. *Separators, decanters, and their components packaged for shipping.*

3.4. Typical Applications

Numerous industrial sectors require separation of liquid and solid components from mixtures. Centrifugal separators and decanters can accomplish such separations and thus are, like all other controlled biological equipment, highly dual-use items. At the most basic level, they can clarify liquids, separate mixtures of liquids, concentrate solutions (e.g., remove water from solids), and recover solids.[82] In general, centrifugal separators are used when solid concentrations are relatively low and particle sizes are small, while decanter centrifuges are employed for greater solid concentrations and particle sizes.[83,84] However, one producer does note use of decanters for dewatering very fine solids.[85] Table 3 summarises examples of uses in a variety of industries. The suitability of a particular centrifugal separator or decanter centrifuge for a specific end use will depend on the characteristics of the mixture of interest.

[82] Seital Separator, http://www.spxflow.com/en/seital/.

[83] "Alfa Laval – disc stack centrifuge technology," Alfa Laval, http://www.alfalaval.com/globalassets/documents/industries/pulp-and-paper/pchs00022en_lowres.pdf. See also "Decanters," GEA Centrifuges and Separation, https://www.gea.com/en/productgroups/centrifuges-separation_equipment/decanter-centrifuge/index.jsp.

[84] "Decanters," GEA Centrifuges and Separation, https://www.gea.com/en/productgroups/centrifuges-separation_equipment/decanter-centrifuge/index.jsp.

[85] Siebtechnik, Products/Decanter Centrifuge, https://www.siebtechnik-tema.net/decanter-centrifuge/.

Table 3. *Applications of centrifugal separators and/or decanters in different industry sectors.*[86]

Sector	Sample applications
Beverages	Clarification of beer, wine, and fruit and vegetable juices; citrus processing; recovery of starches and proteins; clarification of coffee and tea extracts; production of instant coffee
Dairy industry	Skimming: milk and whey clarification; removal of bacteria; cream concentration; production/recovery of butter, cream cheese, whey fines, cheese fines, etc.
Energy/environment	Purification of wastewater; thickening and dewatering of sludge; fuel oil processing; purification of industrial fluids; marine industry applications; treatment of diesel oil
Life sciences and the chemical industry	Vaccine production; separation of drugs from cell cultures; cell separation; production of enzymes and hormones; solvent recovery and clarification; production of plastics (PVC, HDPE, etc.); segregation of fine pigments and catalysts; production of oil additives; separation of medicines and essential oils
Oils and fats	Edible oil processing/clarification; oleochemistry (e.g., soaps); biofuels; recovery of animal byproducts
Other processing industries	Treatment of lubricants and cleaning liquids; treatment/dewatering of lubricants and hydraulic oils; processing of spent oils/emulsions; mineral processing

[86] See GEA Centrifuges and Separation: https://www.gea.com/en/productgroups/centrifuges-separation_equipment/index.jsp. See also Flottweg AG Separation Technology: http://www.flottweg.de/usa/centrifuges/separator/disc-stack-separator-.html (separators): http://www.flottweg.de/usa/centrifuges/decanter/industrial-centrifuges.html (decanters); and "Alfa Laval – decanter centrifuge technology," http://www.alfalaval.com/globalassets/documents/industries/pulp-and-paper/pcd00002en.pdf.

4. Cross (Tangential) Flow Filtration Equipment

Cross (tangential) flow filtration equipment capable of separation of microorganisms, viruses, toxins or cell cultures having all the following characteristics:

a) a total filtration area equal to or greater than 1 square metre; and

b) having any of the following characteristics:

   i. capable of being sterilized or disinfected in-situ; or

   ii. using disposable or single-use filtration components.

(Note – This control excludes reverse osmosis and hemodialysis equipment, as specified by the manufacturer.)

Cross (tangential) flow filtration components (eg modules, elements, cassettes, cartridges, units or plates) with filtration area equal to or greater than 0.2 square metres for each component and designed for use in cross (tangential) flow filtration equipment as specified above.

Technical note: In this control, 'sterilized' denotes the elimination of all viable microbes from the equipment through the use of either physical (eg steam) or chemical agents. 'Disinfected' denotes the destruction of potential microbial infectivity in the equipment through the use of chemical agents with a germicidal effect. 'Disinfection' and 'sterilization' are distinct from 'sanitization', the latter referring to cleaning procedures designed to lower the microbial content of equipment without necessarily achieving elimination of all microbial infectivity or viability.

4.1. Basic Description

Cross-flow filtration, also known as tangential-flow filtration, is a separation technique that can be used for the purification of microorganisms or toxins. Figure 4.A compares the cross-flow filtration process with the traditional approach to filtration. In traditional ("normal" or "dead end") filtration, the material to be filtered passes through the filter material perpendicularly. In cross-flow filtration, by contrast, the material to be filtered passes tangentially across the filter surface, reducing the fouling and clogging of the filter. Generally, AG-controlled cross-flow filtration equipment and components achieve minimal fouling of the filter by operating at a high cross-flow speed (1–6 m/s) tangentially to the membrane. Other terms often used in connection with cross-flow filtration are microfiltration, ultrafiltration, nanofiltration, and reverse osmosis. These names refer to the size range of particles that can be separated and are listed above from the largest to smallest pore size of the membranes. Importantly, the AG control language explicitly excludes reverse osmosis equipment and haemodialysis equipment.[87]

Global Production

- China
- France
- Germany
- India
- Italy
- Japan
- Poland
- Spain
- Sweden
- Switzerland
- United Kingdom
- United States

[87] Reverse osmosis refers to the process of removing water from a solution of dissolved solids. For example, see http://www.nmfrc.org/pdf/ro.htm.

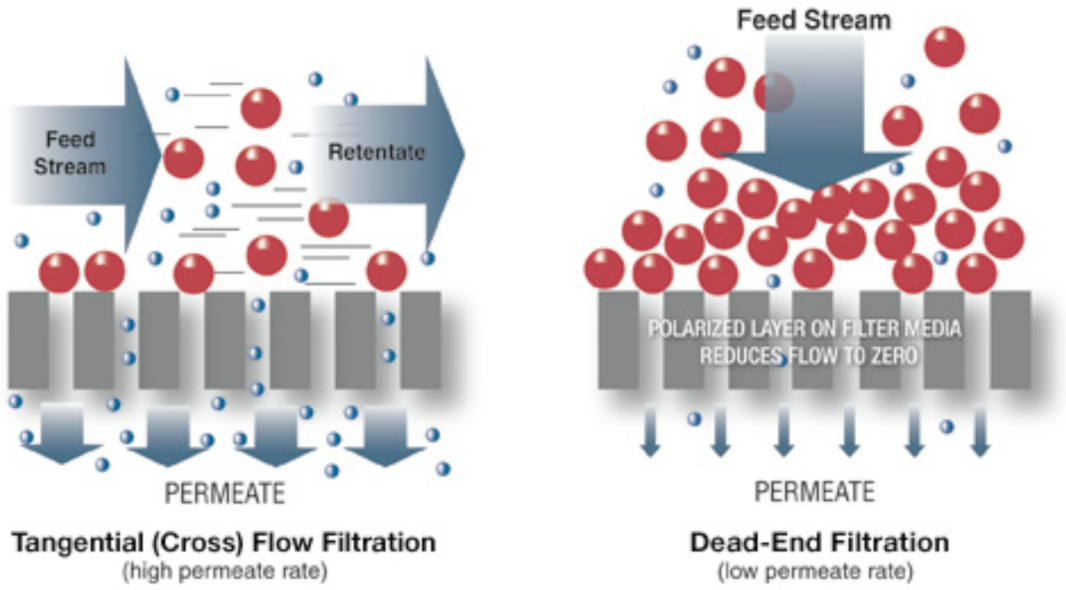

Figure 4.A. *Cross-flow vs. normal (dead-end) filtration.*

4.2. Notable Features

Cross-flow filtration equipment has a few basic components: a pump for moving materials through the system; one or more cross-flow filtration cassettes in holders/housings; and a retentate control valve with feed and retentate pressure sensors for controlling and monitoring the filtration process. Generally, there will also be some sort of feed vessel into which the retentate (the material that does not permeate the filter) is returned for recycling through the system. Some systems also incorporate feed and filtrate flow metres and other sensors (e.g., temperature, pH, UV absorbance, conductivity, and/or filtrate pressure) depending on process needs.[88] Figure 4.B shows a schematic diagram of a basic cross-flow filtration system. The presence of control valves, pressure sensors, and flow metres is particularly noteworthy because AG-controlled cross-flow filtration generally requires equipment and components to withstand transmembrane pressures (pressure across the filtration membrane) of 200 kPa or greater.

The appearance of cross-flow filtration equipment varies greatly depending upon the scale of the respective operation. In general, however, the equipment should have the physical features as described above: a pump, one or more canisters or plate-like cassette holders, and piping, metres, and control panels for process control and monitoring. Figure 4.C shows some examples of cross-flow filtration systems at different scales. Importantly, because filtration cartridges can yield substantial surface areas in a relatively small unit, pilot-scale cross-flow filtration systems that appear small can be capable of meeting the total filtration area specification of the AG control list entry.

Cross-flow filters can be composed of a variety of different materials. In addition, filtration cartridges are available in several shapes. The three basic filter designs are hollow fibre filters, spiral wound filters, and cassettes (or flat plates).[89] In general, hollow fibre filters and spiral-wound filters are cylindrical, while cassettes are rectangular in shape. The filters can be organic membranes/plastics, ceramics/minerals, or even stainless steel. Figures 4.D–4.F show a variety of different filters and their housings. Note that, especially in the case of hollow fibre filters, a filter unit in its housing may somewhat resemble a shell and tube heat exchanger. However, a complete unit should have the filters visible on-end, distinguishing it from

[88] "Clarification and Recovery of Recombinant Proteins using a Cascade Tangential Flow Filtration (TFF) System," Millipore Application Note; no longer available online. In addition, please see https://www.merckmillipore.com/INTERSHOP/web/WFS/Merck-CN-Site/zh_CN/-/CNY/ShowDocument-File?ProductSKU=MM_NF-C613&DocumentId=201306.9516.ProNet&DocumentUID=5320911&DocumentType=TI&Language=EN&Country=NF&Origin=PDP.

[89] For details on the specific design features of these filter systems, see https://www.cytivalifesciences.com/en/us/shop/bioprocessing-filtration/tangential-flow-filtration.

a simple heat exchanger tube bundle (see Figure 4.D). In some cases (particularly larger units), flat plate cassette filters in their holders may resemble a plate and frame heat exchanger as well (see Figure 4.F).[90]

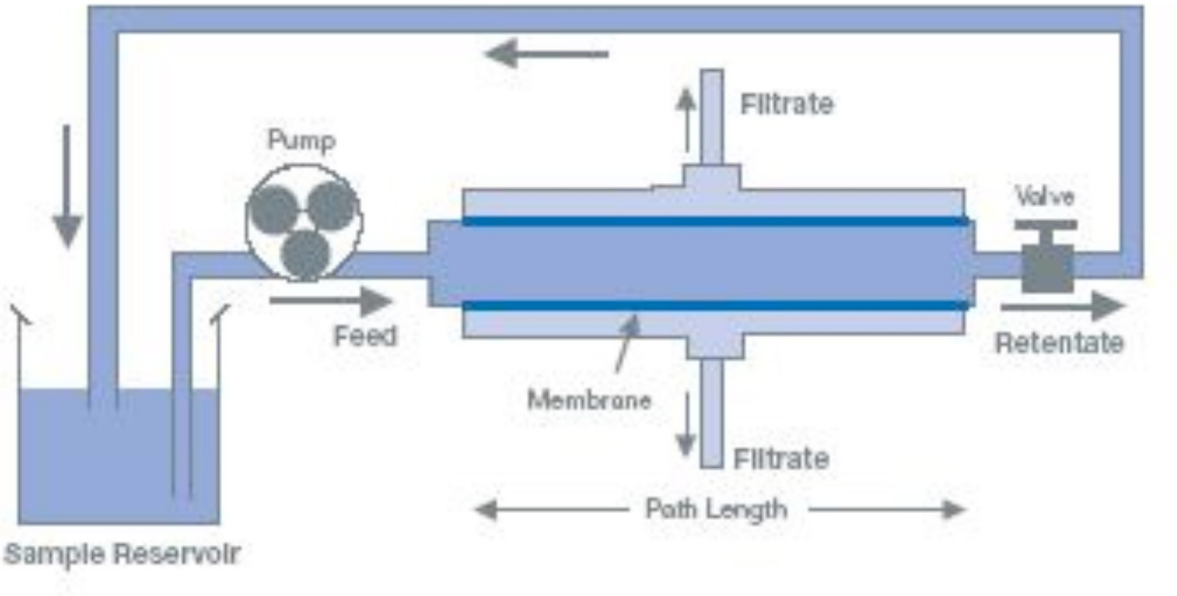

Figure 4.B. *Schematic diagram of a basic cross-flow filtration system.*

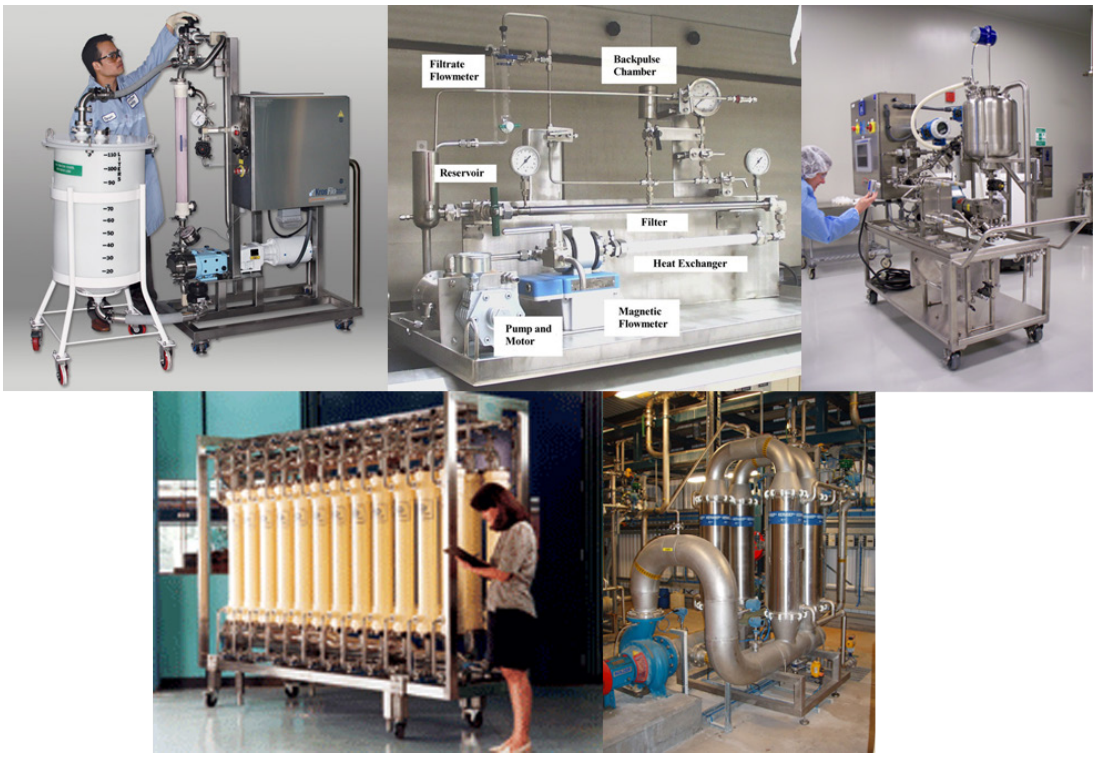

Figure 4.C. *Complete cross-flow filtration systems at different process scales. Top row: laboratory/pilot scale. Bottom row: industrial scale.*

[90] Heat exchangers are included on the Australia Group Control List of Dual-Use Chemical Manufacturing Facilities and Equipment.

Figure 4.D. *Hollow fibre filters and housings.*

Figure 4.E. *Spiral-wound filter.*

Figure 4.F. *Flat plate cassette filters and housings.*

4.3. Packaging

Packaging will vary greatly depending upon the scale of the filtration system. Industrial-scale units will be large and heavy and likely packaged in separate parts on pallets. Small laboratory-scale units likely ship as a single unit. The filtration cassettes will be packed in cartons or boxes.

4.4. Typical Applications

The pharmaceutical, water treatment, dairy, food, beer and wine, marine, chemical, and petrochemical industries all have legitimate uses for cross-flow filtration systems. For example, many pharmaceuticals are produced in bacteria. Harvesting the pharmaceutical product requires separation from the growth media and the bacteria. In the production of beer and wine, the fermented product is typically filtered using cross-flow filtration to significantly reduce the microbial content. Additional applications include a variety of biological/biopharmaceutical processing uses such as:[91,92,93,94]

- Purification and separation of proteins (blood plasma factors, monoclonal antibodies, etc.), peptides, polysaccharides, oligonucleotides, and viruses;
- Clarification of wine and fruit juices;
- Beer dealcoholisation;[95]
- Recycling of paints and lacquers and filtration of dyestuffs;[96]
- Water purification, including waste water;
- Separation of fuel oil;
- Industrial laundry;[97]
- Catalyst stream recovery; and
- Solvent purification/reclamation.

[91] Crossflow Microfiltration Helps Wineries Reduce Costs," Koch Membrane Systems, https://www.kochmembrane.com/KochMembraneSolutions/media/case-studies/Markets%20-%20Beverages/wine-microfiltration-cs.pdf.

[92] "Kerasep®-Bio Ceramic Membranes," Novasep, https://www.novasep.com/home/products-services/fermentation-products-and-chemicals-intermediates/products/kerasep-mineral-membranes-for-industrial-cross-flow-filtration.html.

[93] Tangenx Technology Corporation, https://www.repligen.com/products/downstream-solutions/tangenx/.

[94] Ceramic Filtration Applications, Mantec Technical Ceramics, http://mantecfiltration.com/chemical-pharmaceutical/ and http://mantecfiltration.com/case-studies/.

[95] "Beer Dealcoholization System," Alfa Laval, https://www.alfalaval.us/products/separation/membranes/membrane-filtration-systems/lowal-de-alcoholizer/.

[96] Applications, Atech Innovations GMBH, http://www.atech-innovations.com/.

[97] Fluid Filtration, Hilliard Hilco Division, https://www.hilliardcorp.com/hilco-filter-equipment/.

Filter materials and process designs vary according to application requirements.[98] For example, one company's application guide discusses membrane materials of choice for various biological processing applications.[99] Figure 4.G displays a chart for biological materials relating the size of filter pores with substances that can permeate them. This demonstrates that viruses are amenable to ultrafiltration, while bacterial separations lie in the realm of microfiltration. Also notable is that disposable or "single-use" systems are gaining traction in some applications.[100]

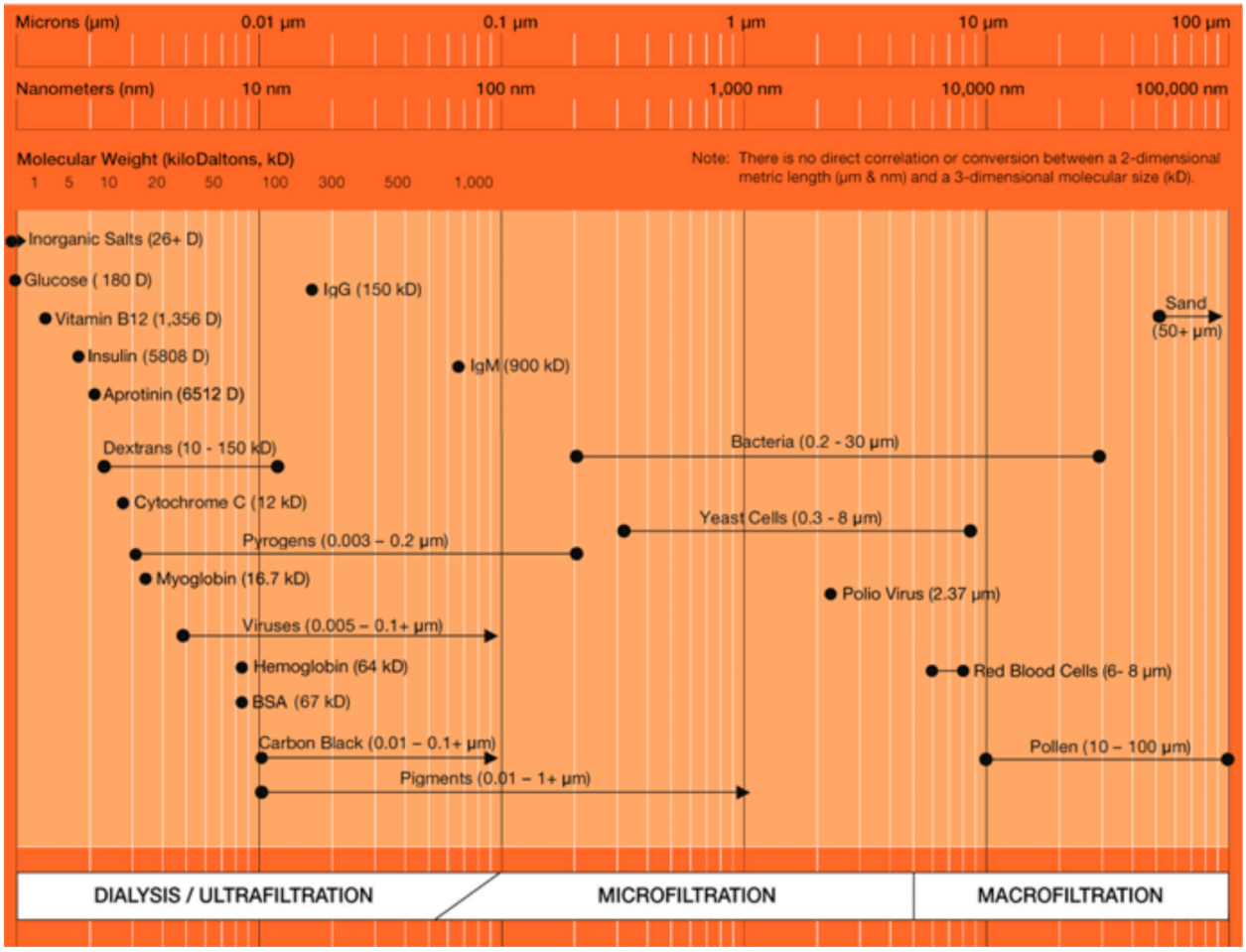

Figure 4.G. *Filter pore sizes for different biological and chemical substances.*[101]

[98] For example, see the aforementioned references from Novasep.

[99] "Application Guide based on Membrane Type", SpectrumLabs.com, https://www.alfalaval.com/products/separation/membranes/what-is-membrane-filtration/.

[100] "Tangential Flow Filtration Explores New Niches," http://www.pharmamanufacturing.com/articles/2008/111.html?page=3.

[101] Spectrum Laboratories, Inc., https://www.repligen.com/resources/knowledge-base/references/mabselectsure-1.

5. Freeze-Drying Equipment

Steam, gas or vapour sterilisable freeze-drying equipment with a condenser capacity of 10 kg of ice or greater in 24 hours and less than 1000 kg of ice in 24 hours.

5.1. Basic Description

Freeze-drying (also known as lyophilisation) is a dehydration process used to stabilise most any perishable material in order to increase its shelf life and reduce its sensitivity to environmental stresses.[102] This process works by freezing the material and then reducing the surrounding pressure by vacuum to allow the ice in the material to sublimate. If required, the dried material may be subsequently milled to produce a powder. Substances that are not damaged by freezing can usually be lyophilised. Many microorganisms and proteins survive lyophilisation well, especially if they are frozen in excipient solutions designed to protect them during the freezing process. Lyophilisation is a long-standing preservation method for vaccines, pharmaceuticals, and blood fractions.[103]

Global Production

- Brazil
- France
- Germany
- Republic of Korea
- New Zealand
- United Kingdom
- United States

5.2. Notable Features

Freeze-drying equipment, also known as lyophilisers, has two basic configurations: manifold design and chamber design. Many smaller laboratory-scale units have manifolds that attach to the unit either vertically or horizontally. Bottles attach to the manifolds and hold the substances to be freeze-dried. Larger pilot- and industrial-scale freeze-dryers are more likely to be chamber style, with trays that hold the material to be lyophilised. The tray units are often removable from the system. Freeze-dryers will have a refrigeration unit, a way to remove ice, a vacuum pump or port for vacuum hookup, and sterilisation capacity in forms such as an attachment for steam sterilisation, a built-in steam generator, an attachment for vapourous hydrogen peroxoide sterilization, or a portable vapourous hydrogen peroxide generator. Figures 5.A–5.C display various lyophilisers and their components. Figures 5.A and 5.C show manifold-style and chamber-style freeze-dryers, respectively, while Figure 5.B shows a hybrid design with both a manifold and chamber for the material to be dried. The control panels in Figures 5.A and 5.B show indicators and controls for temperature and vacuum – along with switches for "freeze" and "condenser" in Figure 5.B – suggestive of their use in a freeze-drying application.

[102] See also "Freeze Drying / Lyophilisation Info Online," http://freezedryinginfo.com/.

[103] "Lyophilisation: Freeze-Drying, A Downstream Process;" no longer available online. Technical descriptions of lyophilisation principles can be found at http://www.freezedryinginfo.com/Process.html.

Figure 5.A. *Laboratory-scale manifold design. Left: complete floor unit. Right: view of panel indicators and controls.*

Figure 5.B. *Multiple views of a combination manifold and tray freeze-drying unit.*

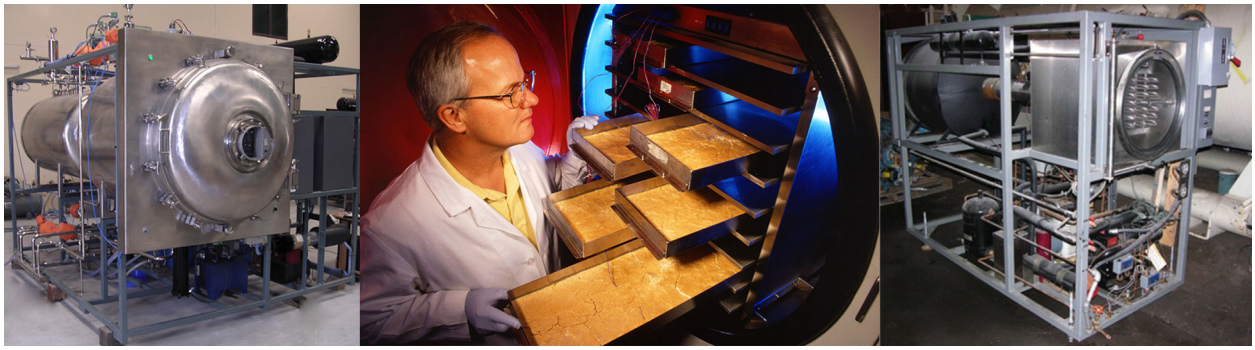

Figure 5.C. *Tray-style freeze-drying units. Note: the internal tray assembly is often removable.*

5.3. Packaging

Large freeze-drying units could be packaged on pallets. Tray assemblies, vacuum pumps, refrigeration units, and steam- or vapour-generating units might be packaged separately.

5.4. Typical Applications

Many industries use freeze-drying, particularly the food and pharmaceutical sectors. In the food industry, lyophilisation helps preserve fruits, vegetables, meats, and instant coffee.[104] For pharmaceuticals and diagnostic products, freeze-drying helps protect temperature-sensitive products such as vaccines, blood plasma, enzymes, nucleic acids, and antibodies for storage. However, preservation is not the only benefit. Freeze-drying also reduces the weight, space, and packaging materials needed, making transport of freeze-dried products cheaper than their hydrated counterparts.[105] Other applications of freeze-drying include the salvage of water-damaged books and documents,[106] preservation of flowers, and the processing and preservation (taxidermy) of animals.[107]

[104] For examples of food products that can be freeze dried, see: https://www.gea.com/en/productgroups/dryers_particle-processing-systems/freeze-dryers/index.jsp and https://www.cuddonfreezedry.com/freeze-dried-food/.

[105] "General Principles of Freeze Drying (The Lyophilisation Process)," American Lyophiliser, Inc., http://www.freezedrying.com/freeze_drying_principles.html.

[106] "Vacuum freeze-drying, a method used to salvage water-damaged archival and library materials," UNESCO; http://unesdoc.unesco.org/images/0007/000750/075091eo.pdf.

[107] Freeze Dry Co., Inc., http://www.freezedryco.com/.

This page intentionally left blank.

6. Spray-Drying Equipment

Spray-drying equipment capable of drying toxins or pathogenic microorganisms having all of the following characteristics:

a) a water evaporation capacity of ≥ 0.4 kg/h and ≤ 400 kg/h;

b) the ability to generate a typical mean product particle size of ≤ 10 micrometers with existing fittings or by minimal modification of the spray-dryer with atomization nozzles enabling generation of the required particle size; and

c) capable of being sterilized or disinfected in situ.

6.1. Basic Description

Global Production

- Denmark
- Germany
- India
- Japan
- Switzerland
- United Kingdom
- United States

Spray-drying is a dehydration process used to increase the shelf life of perishable material, from food products to microorganisms and proteins. In addition to preservation, spray-drying can impart other advantageous properties to a material, such as increased solubility of the resulting fine powder. Spray-drying accomplishes similar goals to freeze-drying, but is much more economical and is different in several ways. The spray-drying process works by atomising a liquid feedstock and immediately evaporating the liquid from the atomised particles via contact with a drying gas of a higher temperature (Figure 6.A). Thus, spray-drying produces high-quality powders of uniform diameters directly from a liquid feedstock. In addition, spray-drying is a continuous process, as opposed to batch operation of freeze-drying equipment. Particle sizes generated by spray-drying can range from several hundred nanometres to several hundred micrometres in diameter. Spray dryers that can generate particles of ≤10 μm are controlled because these particles can easily enter the lungs.

While spray-drying dates back over 100 years for non-biological commercial products, advances in the technology in recent years have enabled some spray dryer models to routinely and reliably preserve temperature-sensitive biological materials.

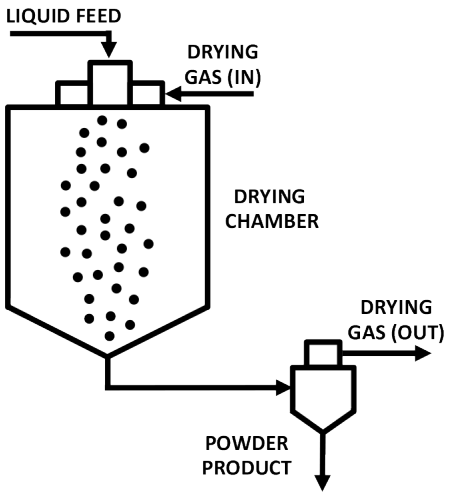

Figure 6.A. *Schematic illustrating the process of spray-drying: atomise a liquid feed; contact atomised particles with hot drying gas; collect dry powder product.*

6.2. Notable Features

Spray dryers are commercially available in a range of sizes based on their production capacity. However, all spray dryers share some common physical features. Key components of spray dryers include: a large cylindrical drying chamber, tapered at the bottom; smaller cylindrical chambers for collection of particles; a heating system with a blower motor to create the hot drying air; and tubing to carry liquid feed, hot drying air, and powdered product. Most often, spray dryers will be constructed of stainless steel, but glass is a popular material for smaller spray dryers (Figure 6.B). Tubing may be stainless steel, glass, or plastic. A spray dryer capable of *in situ* steam sterilisation will have chambers, tubing, and connections of stainless steel and will be rated to withstand the high pressure required. However, construction to withstand high pressure is not required for disinfection *in situ*, which also can be done with germicidal chemicals. Due to the additional costs associated with high-pressure-rated designs, it is more common for spray dryers to be constructed to run cleaning or scrubbing solutions that will disinfect the equipment *in situ*.

The size of a spray dryer is related to its maximum water evaporation capacity (kg H_2O/hr), which in turn is a measure of its powder production capacity. Controlled spray dryers range from those small enough to fit on a benchtop to those whose components fill an average-sized room. Larger spray dryers (upward of 1200 kg/hr) are available and would generally occupy several rooms or whole buildings, but these usually would not fall within the range of the AG's control specification (≥0.4 and ≤400 kg/hr). The maximum water evaporation capacity is often cited in the manufacturer's technical product literature and occasionally included along with the serial number on the nameplate of the spray dryer.

The particle sizes generated by a spray dryer are not visually apparent from the unit. However, the type of atomisation nozzle in the spray dryer can be a clue to its capabilities and should be noted in the equipment's product literature; more detailed technical specifications may provide particle size ranges as well. There are four types of atomisation nozzles currently used by spray dryers, but controlled spray dryers are likely to use one of only two designs: a multi-fluid nozzle or an ultrasonic nozzle (Figure 6.C). Both use atomisation techniques (compressed air and high-frequency vibration, respectively) that are capable of producing particles ≤10 µm. These techniques also are gentle enough to atomise biological materials without damaging their structure or viability. Technical limitations prevent rotary atomisers (using fast rotational speed) or pressure nozzles (using high feedstock pressure) from generating particles smaller than 20 µm. In addition, the high rotational speed and high pressure used by these nozzles are much more likely to damage biological materials than the other two designs.[108]

Figure 6.B. *Controlled spray dryers. These spray dryers have water evaporation capacities of ~1 kg/hr.*

[108]Personal communication with a spray dryer manufacturer

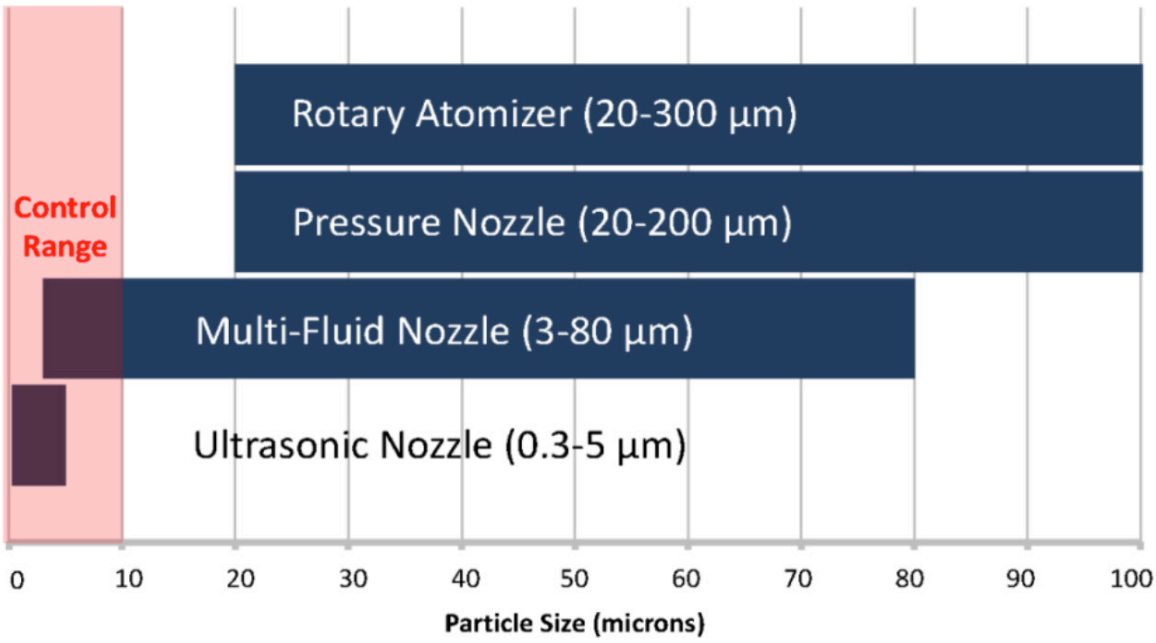

Figure 6.C. *Multi-fluid (two-fluid, four-fluid) and ultrasonic nozzles are more capable of producing the controlled particle size.*

6.3. Packaging

Packaging will vary greatly depending on the size of the spray dryer. Smaller models may ship as one piece with appropriate shrink-wrap to prevent damage to individual components. Larger units, particularly room-size models, will ship in separate pieces (i.e., the drying chamber, the control unit, the heater, the collection chamber[s], and any tubing may be packaged separately) (Figure 6.D). Units that are less likely to be controlled may have drying chambers so large as to necessitate shipping on flat-bed tractor trailer trucks.

As noted in Section 6.1, spray drying is a technique approximately 100 years old. While spray dryers purchased new are more likely to be able to preserve viable biological material, there are many models on the resale market that were manufactured in the last 10+ years and meet criteria for control.

Figure 6.D. *Spray dryer removed from shipping crate and shrink wrap following delivery. Top three images: the drying chamber, heater, and control unit. Bottom three images: the fine particulate system. This shipment also featured a third crate containing 8–10 cardboard boxes of parts.*

6.4. Typical Applications

Controlled spray-drying equipment is most likely to be used in pharmaceutical applications, and the most recent growth in spray-drying use overall has come from this industry.[109] The surge in interest from the pharmaceutical industry arises from the ability of spray-drying to increase the solubility – and therefore effectiveness – of active pharmaceutical ingredients (APIs). Spray-drying can also increase the stability of an API for improved shelf life. Preservation by spray-drying can preserve protein-, cell-, and viral-based therapies.

Spray-drying has been used heavily by the food, ceramics, and chemical industries for decades to make various powders, including coffee, milk, pigments, ceramics, metals, and chemicals. However, spray-drying equipment used for these products is significantly less likely to meet the AG control specifications, given the much different operating conditions and particle size requirements of these industries.

[109]E. Greb (2009) "Is Spray Drying a Viable Alternative to Lyophilisation?" Pharmtech.com, http://www.pharmtech.com/spray-drying-viable-alternative-lyophilization.

7. Protective and Containment Equipment

Protective and containment equipment as follows:

a) protective full or half suits, or hoods dependent upon a tethered external air supply and operating under positive pressure;

Technical note: This does not control suits designed to be worn with self-contained breathing apparatus.

b) biocontainment chambers, isolators, or biological safety cabinets having all of the following characteristics, for normal operation:

i. fully enclosed workspace where the operator is separated from the work by a physical barrier;

ii. able to operate at negative pressure;

iii. means to safely manipulate items in the workspace;

iv. supply and exhaust air to and from the workspace is HEPA filtered.

Note 1 – this control includes class III biosafety cabinets, as described in the latest edition of the WHO Laboratory Biosafety Manual or constructed in accordance with national standards, regulations or guidance.

Note 2 – this control does not include isolators specially designed for barrier nursing or transportation of infected patients.

7.1. Basic Description

Protective and containment equipment is used to keep workers safe while handling infectious agents. This equipment serves as a primary barrier between workers and these agents, with secondary barriers provided by the features of the physical workspace and the design of the overall containment facility in which the work is done. In many cases, containment equipment also protects biological material from contamination.

Global Production

- Canada
- China
- France
- India
- Singapore
- Sweden
- United Kingdom
- United States

7.2. Notable Features

Protective clothing

Controlled suits and hoods have attachments for tethered air and will operate under positive pressure. Suits will be either full or half design with overlapping and sealed seams. Hoods that operate using tethered air are also available. Figure 7.A shows examples of full suits covered in this control list entry.

Figure 7.A. *Examples of full suits with tethered air supplies.See also Figure 1.B for a picture of personnel in full suits.*

Biological safety cabinets

A biological safety cabinet or biosafety cabinet (BSC) is an enclosed space that controls ventilation and the environment for work with infectious agents or toxins. BSCs reduce the risk of airborne infection by physically containing the workspace used. They accomplish this goal through the use of directional airflow, HEPA filtration of supply and/or exhaust air, and a physical barrier such as a plastic or glass shield. Three kinds of BSCs (Class I, II and III) meet various research and clinical containment needs. Distinguishing features include their construction, airflow velocities and patterns, and exhaust systems.[110] Only Class III BSCs appear in the AG biological equipment control list. Figure 7.B displays Class I, II, and III BSCs. The most obvious distinguishing feature of the Class III BSC is the sealed front face with gloves for manipulating materials inside the cabinet. The WHO's *Laboratory Biosafety Manual* contains helpful descriptions and diagrams of Class I, II, and III BSC operating criteria.[111]

Figure 7.B. *Comparison (left to right) of Class I, II, and III biological safety cabinets.*

[110]See Esco Technologies, Inc., "A Guide to Biosafety & Biological Safety Cabinets," http://escoglobal.com/resources/pdf/biosafety-booklet.pdf; see also http://www.bakerco.com/intro-to-biological-safety-cabinets.html for a description of different class designs.

[111]See Chapter 10, "Biological Safety Cabinets," in *Laboratory Biosafety Manual*, Third Edition. (2004) World Health Organization. http://www.who.int/csr/resources/publications/biosafety/Biosafety7.pdf. See also Appendix A "Primary Containment for Biohazards" in *Biosafety in Microbiological and Biomedical Laboratories*, Fifth Edition. (2009) U.S. Department of Health and Human Services, https://www.cdc.gov/labs/pdf/CDC-BiosafetyMicrobiologicalBiomedicalLaboratories-2009-P.PDF.

Class III BSCs[112] (Figure 7.C) are fully enclosed, sealed, and "gas tight." Invariably, these cabinets feature physical barrier separation between the operator and the workspace. Class III BSCs also may be referred to as "Class III glove boxes" because the operator works with gloves (a means to manipulate items safely in the workspace) sealed into the front of the cabinet by removable gaskets. Supply air is HEPA-filtered and exhaust air is double HEPA-filtered. The air is not recirculated. Double HEPA filtration occurs by using two HEPA filters in series. Airflow is maintained by an exhaust system dedicated to the cabinet, which keeps the interior of the cabinet at negative pressure relative to the room in which the cabinet is housed. While operational parameters for gas-tightness and negative pressure can vary between manufacturers and depending on the specific application of the BSC, the WHO *Laboratory Biosafety Manual* references that a Class III BSC should be able to maintain its workspace at a negative pressure of 124.5 Pa. Liquid disinfectant tanks and pass-through boxes (sterilisable and equipped with HEPA-filtered exhaust) are used to transfer materials into and out of the cabinet. The Class III BSC may be connected to a double-door autoclave to decontaminate materials entering or exiting the cabinet. Invariably, these cabinets feature physical barrier separation between the operator and the workspace.

It is important to note that AG controls apply to chambers and cabinets that have Class III BSC performance standards listed above but may be labeled as: "flexible isolators," "dry boxes," "anaerobic chambers," "glove boxes," or "laminar flow hoods." Design specifications must be checked carefully for such units to assess whether those performance standards are met. For example, Class I and Class II BSCs may be labeled "laminar flow hoods" and possess the ability to HEPA filter supply and exhaust air, but they will feature neither a fully enclosed workspace with physical barrier separation, nor the means to operate with the workspace at negative pressure, nor sealed gloves to safely manipulate items in the workspace.

[112]See Chapter 10 (pp. 55–56) "Biological Safety Cabinets" in *Laboratory Biosafety Manual*, Third Edition. (2004) World Health Organization, http://www.who.int/csr/resources/publications/biosafety/Biosafety7.pdf.

Figure 7.C. *Class III biological safety cabinets. Top left: mobile Class III BSC. Top right: Class III BSC with small pass-through box (transfer hatch). Bottom left: multiple-user Class III BSC with dunk tank. Bottom right: extra-large Class III BSC.*

7.3. Packaging

Tethered air suits and hoods will likely be contained in sealed bags and may have warnings to protect from heat. Class III biological safety cabinets are large pieces of equipment that will be shipped on pallets. Units will likely ship in one piece.

7.4. Typical Applications

Legitimate research with dangerous agents and toxins utilises tethered-air suits and hoods and Class III BSCs. Class III BSCs are suitable for work with microorganisms from all four Biosafety Levels. However, these cabinets probably will be reserved for use with the most dangerous pathogens since lower class BSCs are suitable for work with less harmful materials.[113] The pharmaceutical and food industries, aerobiology studies, hazard response/receipt operations, and mammalian tissue culture work all employ controlled protective equipment.

[113]See http://www.who.int/csr/resources/publications/biosafety/Biosafety7.pdf and https://www.cdc.gov/labs/pdf/CDC-BiosafetyMicrobiologicalBiomedicalLaboratories-2009-P.PDF.

8. Aerosol Inhalation Equipment

Aerosol inhalation equipment designed for aerosol challenge testing with microorganisms, viruses or toxins as follows:

a) Whole-body exposure chambers having a capacity of 1 cubic metre or greater.

b) Nose-only exposure apparatus utilising directed aerosol flow and having capacity for exposure of 12 or more rodents, or 2 or more animals other than rodents; and, closed animal restraint tubes designed for use with such apparatus.

8.1. Basic Description

Aerosol inhalation equipment is also known as (aerosol) inhalation exposure systems. Two basic designs exist: "whole-body" systems that expose the entire animal to aerosolised material; and "nose-only" systems that expose animals to reagents through inhalation only. Both whole-body and nose-only systems can be "designed for aerosol challenge testing with microorganisms, viruses, or toxins."

Global Production

- Canada
- France
- Germany
- India
- United Kingdom
- United States

8.2. Notable Features

Whole-Body Chambers

Whole-body units have metal, plastic, or glass chambers that enclose the entire animal. Piping for the agent either connects to each chamber so that the entire chamber fills with the agent, or the agent is sent into an airtight outer cabinet, which encloses all animal cages. Some small whole-body systems can operate in a biological safety cabinet. Whole-body systems may look similar to storage racks for animals, but some designs look like single animal cages. Figure 8.A shows variations in whole-body chamber designs with integral containment systems, while Figure 8.B shows a set of chambers that would require additional containment measures for safer operation.

Figure 8.A. *Whole-body aerosol inhalation chambers with integral containment systems. Note the connections for sensors and sampling on the side of the chamber in the second photograph from the right. The chamber on the far right contains a basket that can hold multiple mice for whole-body exposure.*

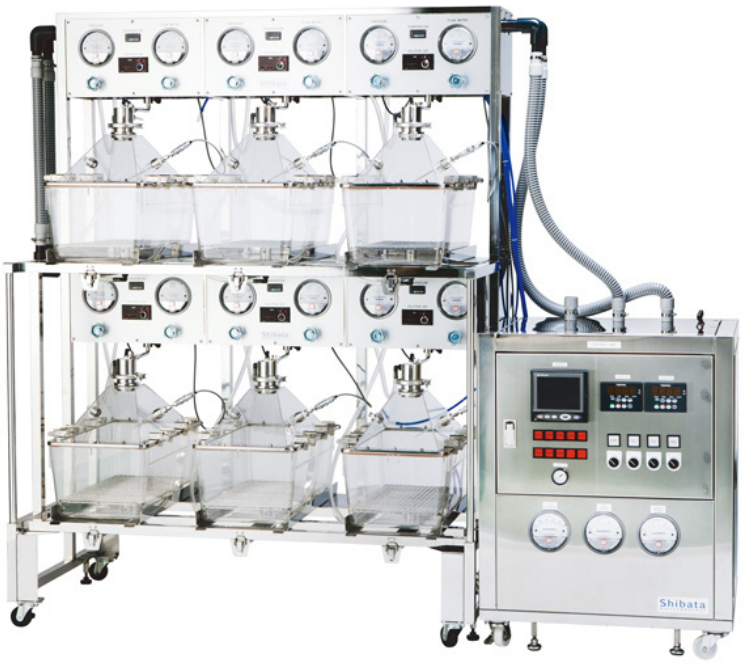

Figure 8.B. *Whole-body aerosol inhalation chambers without additional containment.*

Nose-Only Apparati

Nose-only units have a cylindrical design, with piping for the agent extending axially through the central cylinder (plenum) and ports for animal chambers on the periphery (Figure 8.C). Cylinders may be modular (stackable) for increasing the exposure capacity of the units and are most frequently constructed of polished stainless steel. Each port on the cylinder attaches to individual animal restraint tubes composed of glass or plastic. Each animal tube has an area that attracts the animal's nose and a plug or "pusher" for securing the animal in position (i.e., with its nose in the front opening to force inhalation of aerosols; Figure 8.D). Nose-only animal restraint tubes come in sizes to accommodate small mice up to larger rabbits.

Figure 8.C. *Nose-only aerosol inhalation apparatus resident within a Class III Biological Safety Cabinet. Note that the central plenum in the apparatus shown consists of three stackable tiers.*

Figure 8.D. *Close up views of one tier of a stackable central plenum and closed rodent restraint tubes. Note the polished metal used to construct the plenum as well as the multiple O-ring (orange) seals. A toy mouse is included for size comparison purposes.*

8.3. Packaging

Whole-body units containing a single airtight outer chamber (Figure 8.A) will likely ship in one piece, although baskets or racks to hold animals may be packaged separately. In whole-body units containing multiple airtight chambers (Figure 8.B), the chambers might be packaged separately. For nose-only units, the circular plenum will likely be packaged separately from the individual animal restraint tubes.

8.4. Typical Applications

Toxicology assessments (chemicals and particulates), vaccine development, clinical medicine (e.g., gene therapy by inhalation), biodefence activities (countermeasures),[114] and pathogen research all use aerosol inhalation equipment. In vaccine research, investigators will or will not vaccinate test animals prior to exposure to an aerosolised agent. In this manner, scientists can determine whether a vaccine confers protection to exposed animals or if pharmaceutical preparations serve as effective treatments for exposed but unvaccinated animals. When working with highly dangerous materials such as pathogenic microorganisms, toxins, or lethal chemicals, researchers will tend to use very small quantities of material and employ extensive biological safety measures such as protective suits or Class III biological safety cabinets to ensure their personal protection.

[114]United States Army Medical Research Institute of Infectious Diseases, http://www.usamriid.army.mil/aboutpage.htm.

9. Spraying or Fogging Systems and Components

Spraying or fogging systems and components therefore, as follows:

a) Complete spraying or fogging systems, specially designed or modified for fitting to aircraft, lighter than air vehicles or UAVs, capable of delivering, from a liquid suspension, an initial droplet "VMD" of less than 50 microns at a flow rate of greater than two litres per minute.

b) Spray booms or arrays of aerosol generating units, specially designed or modified for fitting to aircraft, lighter than air vehicles or UAVs, capable of delivering, from a liquid suspension, an initial droplet "VMD" of less than 50 microns at a flow rate of greater than two litres per minute.

c) Aerosol generating units specially designed for fitting to systems that fulfil all the criteria specified in paragraphs 9.a and 9.b.

Technical notes: Aerosol generating units are devices specially designed or modified for fitting to aircraft such as nozzles, rotary drum atomisers and similar devices.

This entry does not control spraying or fogging systems and components as specified in paragraph 9 above that are demonstrated not to be capable of delivering biological agents in the form of infectious aerosols.

Pending definition of international standards, the following guidelines should be followed:

Droplet size for spray equipment or nozzles specially designed for use on aircraft or UAVs should be measured using either of the following methods:

a. *Doppler laser method*

b. *Forward laser diffraction method*

9.1. Basic Description

Global Production

- Australia
- United Kingdom
- United States

Spraying or fogging equipment delivers aerosolised solutions over large areas. These systems may or may not be mountable to aircraft, but only spraying or fogging equipment that can be mounted on aircraft is controlled. This equipment can distribute pesticides to control insect populations or other agricultural chemicals to promote plant health. It can also disperse aerosolised biological pathogens and toxins. The optimum aerosol droplet size for respiration is considered to be 10 microns (μm) in diameter, but because droplets decrease in size after discharge from a spray nozzle (due to evaporation), droplets that start out 50 μm in diameter can be reduced to respirable sizes before they settle and contact humans, animals, or plants. The AG recommends that aircraft mountable spraying or fogging systems be subject to control if they are capable of delivering an initial droplet diameter of less than 50 μm at a flow rate of greater than 2 litres per minute. The control entry includes spray booms or arrays of aerosol generating units that both fulfill the above criteria and are designed or modified to fit to aircraft, lighter than air vehicles, or UAVs. The control entry also includes individual aerosol generating units designed for fitting to larger systems that fulfill the above criteria.

The potential aircraft used for mounting such equipment include "crop duster" type airplanes, helicopters, UAVs, or even blimps (e.g., lighter than air vehicles). Terminology used in connection with sprayers includes controlled droplet application (CDA), aerial atomisers or sprayers, rotary atomisers, and spray pods.

9.2. Notable Features

Spraying and fogging equipment will contain various parts, including tanks/reservoirs, pump(s), mounts for the sprayers, and individual spray nozzles or atomisers. Mounting arrangements for aerial systems include both spray booms and spray pods. Pods can attach to standard structural components of aircraft, eliminating the need for additional structural modifications.[115]

Spray nozzles can use a variety of mechanisms to generate different size droplets. Many nozzles, particularly rotary atomisers, adjust droplet size easily. Major types of nozzles include rotary, twin-fluid air-assist, air-blast, electrostatic, and hydraulic.[116] Sonic nozzles are also available, but are not common for agricultural spraying according to one manufacturer.[117] An informal survey of commercially available nozzles suggests that, of these types, rotary atomisers are particularly suitable for achieving droplet sizes below 50 µm. Rotary atomisers feature characteristic wire gauze cages and droplet generation either driven by wind speed during flight or driven directly by electricity. Electrically driven atomisers have a motor attached to each nozzle, while wind-driven atomisers have propellers or fan blades.

Other atomiser types capable of very small droplet sizes also exist. These include hollow cone nozzles backed by high-pressure pumps, as well as twin-fluid designs.[118] Therefore, additional nozzle designs may achieve control specifications, and technical parameters of a given nozzle will need to be consulted as part of a control status determination.

9.3. Packaging

These systems may be packaged as individual parts. Boom assemblies will be large, but spray attachments and nozzles are small and could be individually wrapped and packaged.

9.4. Typical Applications

Common uses of spraying and fogging equipment include pest control for agriculture and public health. However, different applications within these areas have different desirable spray characteristics, namely with respect to droplet sizes. As noted by one manufacturer:

> For most spray applications there are particular spray droplet sizes which will be most effective in hitting the target and achieving the desired biological result. In pesticide application, for example, different pests present different targets depending on their size, location and behavior, thus different spray droplet sizes will be best for different applications.[119]

Small droplets are more susceptible to drift than larger ones, leading many agricultural spraying applications to use droplets in the 200-400 µm range. Smaller droplets may be used when conducting "drift spraying" or when spraying in a closed building.[120] Table 9 shows optimal droplet sizes (according to one manufacturer) for different agricultural spraying targets. However, not all suppliers agree on optimal droplet sizes.[8.]

[115]Micronair self contained spray pod system, http://www.micron.co.uk/product/micronair_self_contained_spray_pod_system.

[116]There is some, but not complete, overlap with the technology used in spray dryer atomisers.

[117]Proceedings of the North American Conference on Pesticide Spray Drift Management (1998). See A. J. Hewett, "The Importance of Nozzle Selection and Droplet Size Control in Spray Applications," for a detailed discussion of nozzle design, p 75.

[118]J.S. Clayton and T.P.Y. Sander, "Aerial application for control of public health pests," *Aspects of Applied Biology* 66 (2002), http://www.micron.co.uk/files/aerialcontrol_2002.pdf.

[119]Micron Sprayers, Ltd. "Why CDA?" http://www.micron.co.uk/why_cda.

[120]Curtis Dyna-Fog, Ltd., "Fogging vs. Spraying," http://www.encap-it.com/fogging-vs.-spraying.html.

Table 9. *Crop protection targets and their optimum droplet sizes.*[121,122]

Target	Optimum size range of spray droplets
Flying insects	10–50 µm
Insects on surfaces	30–150 µm
Plant diseases	30–150 µm
Weeds	100–300 µm

Insect control applications therefore appear to require the small droplet sizes produced by controlled spraying systems and their components. In these cases, small droplets that drift and stay airborne (rather than deposit on/near the ground as in agricultural applications) are advantageous for pest control.[123] However, such pest control campaigns that seek ultra-low volume dissemination methods can result in the use of systems that have flow rates at or below that dictated by control specifications.

[121] Micron Sprayers, Ltd. "Why CDA?" http://yorktonaircraft.com/.

[122] Another supplier claims somewhat different desired droplet sizes - Forestry Applications: 85–100 microns; Insect Control: 100–300 microns; Fungicide Control: 150–300 microns; Herbicide Control: 450–800 microns; see http://yorktonaircraft.com/.

[123] J.S. Clayton and T.P.Y. Sander, "Aerial application for control of public health pests," *Aspects of Applied Biology* 66 (2002), http://www.micron.co.uk/files/aerialcontrol_2002.pdf.

This page intentionally left blank.

10. Nucleic Acid Assemblers and Synthesizers

Nucleic acid assemblers and synthesizers, which are partly or entirely automated, and designed to generate continuous nucleic acids greater than 1.5 kilobases in length with error rates less than 5% in a single run.

10.1. Basic Description

Global Production

- United States

Nucleic acid synthesizers chemically produce (synthesize) continuous nucleic acid polymers, also known as DNA and RNA. Chemically synthesized nucleic acids are necessary for almost all synthetic biology applications, such as applications that modidify genes or genomes. Nucleic acid polymers usually contain naturally occurring monomers (a.k.a. bases) adenine (A), thymine (T), guanine (G), and cytosine (C) for DNA[124], or adenine (A), uracil (U), guanine (G), and cytosine (C) for RNA[125]. Unnatural[126] bases may also be used. Automated DNA synthesis equipment has been in use since the 1980s. However, these original machines and many of their successors still in use today are not capable of meeting the specifications listed in the control language. These machines are typically capable of synthesizing continuous nucleic acids of between only 20-200 bases (0.02-0.2 kilobases) with error rates less than 5%.

All DNA synthesis is not perfect and carries a corresponding rate at which the chemistry includes an incorrect monomer. Figure 10.A provides a graphical illustration of how an error occurs and how error rate is calculated. Of important note, advances in technology of this equipment may continue to improve (lower) the error rate.

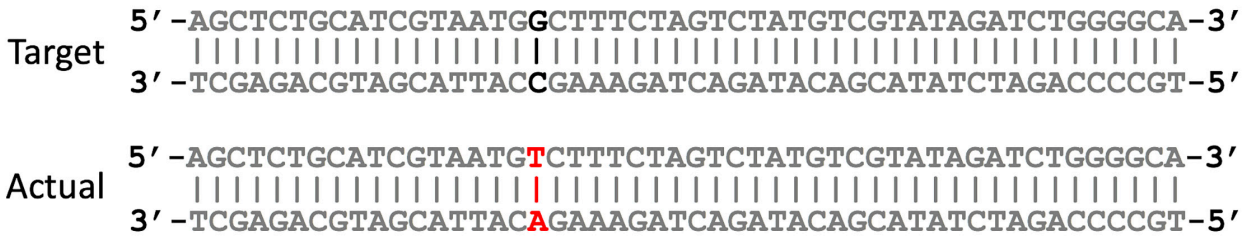

Figure 10.A. *The error rate of DNA synthesis. When compared to the "target" desired sequence, the "actual" synthesized sequence contains one error (G → T). The error rate of this 50 base synthesis reaction would be 1/50 or 2%. In this schematic of double standed DNA, the vertical lines illustrate pairing between bases of the complementary double strands.*

Nucleic acid assemblers are a recent advance in DNA synthesis technology that can produce much longer continuous polymers of DNA. Often this equipment starts not with monomers but 50-200 base (0.05 – 0.2 kilobase) polymers known as oligonucleotides and assembles them into longer (>1.5 kilobase) continuous polymers using a proprietary assembly protocol. These oligonucleotides may be synthesized in situ on the nucleic acid assembler or they may be synthesized using different equipment. Figure 10.B provides a basic illustration of DNA assembly. Nucleic acid assemblers are highly automated and may feature advanced networking capabilities to communicate with the equipment manufacturer, review order information, as well as screen orders for potential relevance to known pathogens or toxins. Advances in technology of this equipment will likely continue to improve the length of DNA polymer that may be produced.

[124] https://www.genome.gov/25520880/deoxyribonucleic-acid-dna-fact-sheet/

[125] https://www.genome.gov/glossary/index.cfm?id=180

[126] Zhang et al. 2017. "A semi-synthetic organism that stores and retrieves increased genetic information" *Nature*. 551:644-647. doi: 10.1038/nature24659. https://www.ncbi.nlm.nih.gov/pubmed/29189780 The development of unnatural bases is increasing in specialized synthetic biology research areas, but the vast majority of nucleic acid synthesis remains focused on DNA polymers using naturally occurring DNA bases.

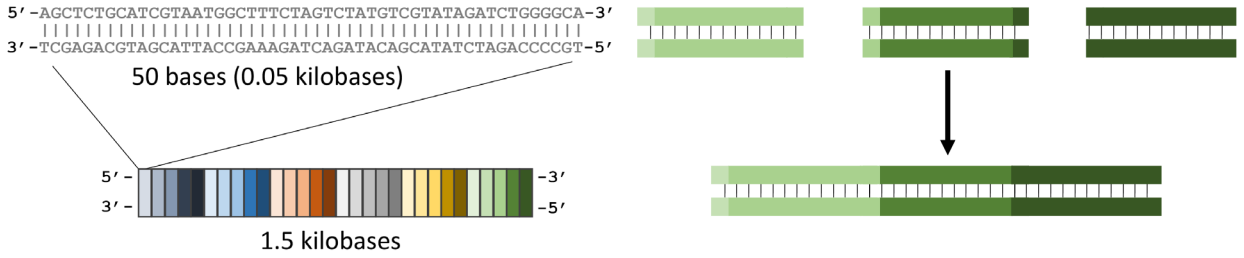

Figure 10.B. *DNA assembly. At least 30, 50 base oligonucleotides would be needed to construct a 1.5 kilobase DNA molecule (left). Oligonucleotides are assembled into a larger DNA molecule and the basis of their overlapping, identical end sequences (right).*

10.2. Notable Features

Figure 10.C shows an example of equipment that mets the specifications outlined in the control languge. Typically, this equipment will be capable of DNA assembly with DNA synthesis occurring separately on a synthesizer that does not meet the control specification for continuous length. The assemblers are typically small enough to fit on a laboratory workbench. To an unfamiliar eye, a DNA assembler may appear to be a large, relatively nondescript box (Figure 10.C, top left), perhaps similar to other common laboratory equipment. The greatest area of distinction is located within the automated workspace (Figure 10.C, bottom) which focusses on microlitre scale fluid handling and temperature control. Small-scale fluid handling procedures permit the assembly of multiple DNA polymers in one production run. Typically, samples are processed in small 96 reaction well or 384 reaction well plastic plates and fluids are transferred using small plastic tips specially designed for these plates. Chilling and heating units also known as thermocyclers help regulate temperature changes necessary for denaturing and reannealing cycles, which are temperature controlled processes that cycle DNA in between its single stranded form and its double stranded form. A robotic arm or other robotic transfer mechanism typically moves the reaction plates around the automated workspace. For comparison, Figure 10.D shows an example of equipment capable of DNA synthesis only that cannot produce continuous nucleic acids longer than 200 bases (0.2 kilobases). Note the work space is markedly different than in Figure 10.C, with bottles of required reagents featured prominently.

Partly or entirely automated assemblers and synthesizers are listed for control. This language excludes the numerous nucleic acid (primarily DNA) assembly “kits” sold ubiquitously throughout the synthetic biology community unless the kit is packaged with partial automation. Typically, these DNA assembly kits consist of all necessary and proprietary reagents to assemble continuous DNA polymers of greater than 1.5 kilobases with error rates of less than 5%, but at a scale and rate far slower than automated assembly equipment.

10.3. Packaging

Nucleic acid assemblers and synthesizers may be packaged for shipment with additional padding to protect their delicate instrumentation from damage during shipment, but otherwise packing will be unremarkable. This equipment will likely ship on a single shipping pallet.

10.4. Typical Applications

The ability to synthesize long high quality (low percentage error) DNA is a critical node in all synthetic biology and most applications in molecular biology. These applications could range from synthesis of genes or genomes to the synthesis of DNA and RNA molecules required to direct editing of DNA using the CRISPR-Cas technique[127]. A highly non-exhaustive list of pharmaceutical and biotechnology research applications that benefit from large amounts of high quality synthesized and assembled DNA include: protein production, custom antibody generation, and cell metabolic engineering. Material produced by nucleic acid synthesizers and assemblers may or may not be subject to control under the Genetic Elements and Genetically-modified Organisms entry on the List of Human and Animal Pathogens and Toxins for Export Control.

[127] https://ghr.nlm.nih.gov/primer/genomicresearch/genomeediting

Figure 10.C. *Different views of a DNA assembler. Exterior with the workspace area closed (top left), exterior with the workspace area open (top right), interior workspace with different areas labeled (bottom).*

Figure 10.D. *A used DNA synthesizer. This equipment is capable of DNA synthesis only (not assembly). It cannot produce continuous nucleic acids longer than 200 bases (0.2 kilobases).*

This page intentionally left blank.

Items for Inclusion In Awareness Raising Guidelines

These sections provide basic descriptions and notable features of the Items for Inclusion in the Awareness Raising Guidelines of the Control List of Dual-Use Biological Equipment. Section numbers match the AG Awareness Raising Guidelines entry numbers, and the text in the blue box at the beginning of each section provides language for each entry as of the control list's February 2020 revision.[128]

[128]The current AG list may be found at https://www.dfat.gov.au/publications/minisite/theaustraliagroupnet/site/en/dual_biological.html.

This page intentionally left blank.

Experts propose that the following items be included in awareness raising guidelines to industry:

ARG1. Encapsulation Equipment and Technology

Equipment and technology (not specified elsewhere in the control list of Dual-use Biological Equipment and Related Technology and Software) for the encapsulation of live pathogenic microorganisms, viruses and toxins, with a typical mean product particle size of 10 µm or less.

Basic Description and Notable Features

Encapsulation refers to the "packaging" of an active substance inside a nanometre to several millimetre-sized capsule (Figure ARG 1.A), allowing release at a later time by breach of the capsule wall.[129] The capsule wall may be broken by a variety of methods (e.g., rupture, dissolution, diffusion, melting, ablation, or biodegradation) depending on the specific formulation and conditions.[130] The encapsulated substance may be referred to as the active substance, core, internal phase, or fill of a capsule, while the encapsulating material is often called the shell or wall. Depending on their average diameter, capsules also may be called nanoparticles, nanospheres, microparticles, or microspheres. Encapsulation shields the active material from its environment – which is convenient for long-term viability and storage – and offers the possibility for controlled or targeted (local) release of the substance. Common reasons for encapsulating biological materials include improving probiotics, vaccines (bacterial-, viral-, or protein-based), and biopesticides. Encapsulation is employed in numerous areas, including the pharmaceutical, food, cosmetic, paint, adhesive, printing, textile, and agriculture industries; however, it is also of concern for application to live pathogenic microorganisms, viruses, and toxins.

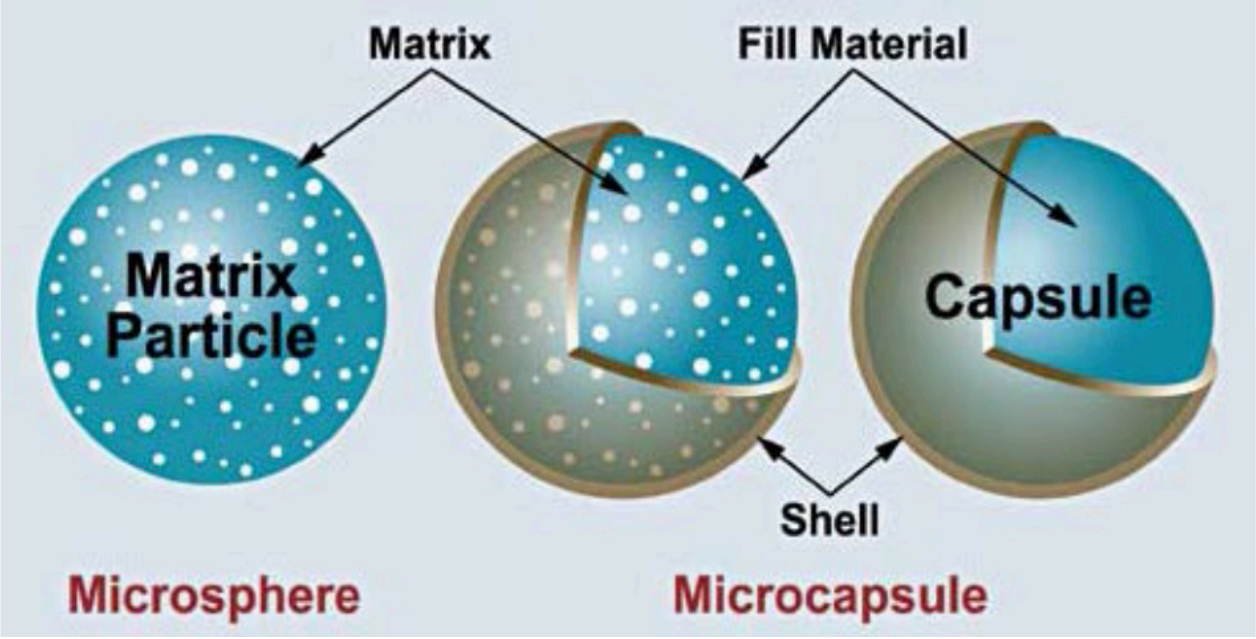

Figure ARG 1.A. *Microcapsule structure showing the shell enclosing the fill material.*

[129]Definition from Lipo Technologies Inc.: http://www.lipotechnologies.com/.

[130]J. Franjione and N. Vasishtha, "The Art and Science of Microencapsulation," no longer available online.

The AG proposes that equipment and technology for the encapsulation of live pathogenic microorganisms, viruses, and toxins, with a typical mean product particle size of 10 µm or less be included in awareness raising guidelines for industry. Particles of less than 10 µm in diameter are of greatest BW concern because they can be inhaled easily. Numerous methods of encapsulation are practiced, and several are capable of generating micro- or nanocapsules of biological materials in the range of 10 µm or less. Examples include emulsification followed by solvent removal by evaporation or extraction, phase separation (coacervation), interfacial polycondensation, and spray drying or spray chilling. Figure ARG1.B provides a conceptual illustration of many of these encapsulation processes.

With the exception of spray drying or chilling, most encapsulation methods that can generate particles of biological materials in the range of 10 µm or less require little specialised equipment; most commercial microencapsulators based on extrusion methods are not yet able to produce sub-10-µm biological particles. Because spray-drying equipment capable of attaining these particle sizes for such biological materials (and meeting other requirements) are controlled, the awareness raising entry specifies that it refers to only equipment and technology not specified elsewhere in the Control List of Dual-use Biological Equipment and Related Technology and Software (i.e., spray-drying equipment meeting the control specifications remains subject to controls when used for encapsulation).

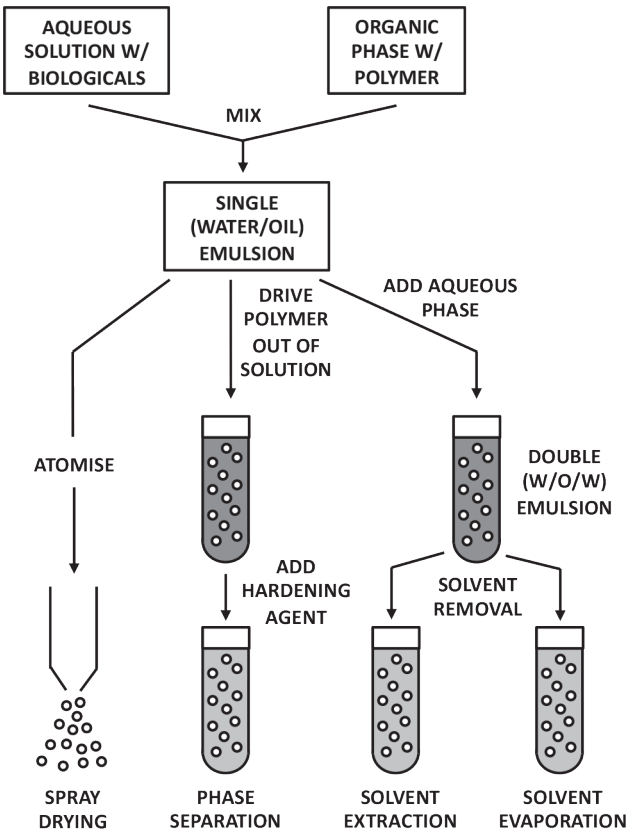

Figure ARG1.B. *Conceptual illustration of selected microencapsulation methods: spray drying, phase separation, and (double) emulsion with solvent removal by evaporation or extraction.*

Micro- and nanoencapsulation are both complex arts, involving a wide range of potential encapsulants and variables that impact the success of the process for a given biological material. When considering a transfer of encapsulation equipment or technology that is capable of generating micro- or nanocapsules of biological materials in the range of 10 µm or less, a thorough assessment of potential proliferation risk should be conducted.

ARG2. Small Fermenters

Fermenters of less than 20 litre capacity with special emphasis on aggregate orders or designs for use in combined systems.

Basic Description and Notable Features

Fermenters under this Awareness Raising entry are smaller capacity versions of the fermenters controlled under Item 2. This entry calls for special attention to orders of multiple fermenters or those designed for use in combined systems. Small fermenters may be *in situ* sterilisable or autoclavable. They also may contain disposable culture chambers paired with reusable chamber holders and control units. Small fermenters share most of the physical features of their larger counterparts: a glass or stainless steel vessel accompanied by a control unit which can vary in its level of sophistication. Other accessories also may be attached. Figure ARG2.A shows pictures of several small fermenters, including multi-fermenter and disposable designs. See fermenters control entry for more details about fermenter system components.

Figure ARG2.A. *Small fermenters.*

This page intentionally left blank.

ARG3. Clean-Air Rooms and Fan-HEPA Filter Units

Conventional or turbulent air-flow clean-air rooms and self-contained fan-HEPA filter units that may be used for P3 or P4 (BL3, BL4, L3, L4) containment facilities.

Basic Description and Notable Features

A clean-air room, also known as a "clean room," is a controlled-environment space that has a very low level of pollutants and particulates. Clean rooms have a wide range of applications, from dust elimination in electronics/semiconductor applications to biocontainment.

HEPA is an abbreviation for High Efficiency Particulate Air and is the name commonly applied to air filters used in biocontainment facilities and equipment. While HEPA is the commonly applied name, there are actually two filters used in biocontainment applications: HEPA, which is rated to remove at least 99.97% of airborne particles 0.3 µm in diameter, and ULPA (Ultra Low Particulate Air), which is rated to remove at least 99.999% of airborne particles 0.12 µm in diameter.[131] Both filter types may exceed the minimum standards to be considered "HEPA" filters.

HEPA filter units and their supporting equipment can come in various designs and sizes. However, *self-contained* fan-HEPA filter units are listed in the Awareness Raising Guidelines because (as manufacturers state) these units can be used "to convert an existing space into a cleanroom without additional ductwork or air handling equipment."[132] Fan-HEPA filter systems are highly portable and can transform an existing, contained space into a "clean room" or control airflow from room to room without major refitting. These systems are frequently employed in hospital settings to create infection control zones, based on the airborne infectivity of pathogens. Fan-HEPA filter units may also be referred to as "fan/filter modules" or "fan filter units." They differ from ducted HEPA filtration systems known as "terminal diffusers" because the latter does not integrate the fan and the HEPA filter in the same unit.

Self-contained fan-HEPA filter units are typically comprised of a HEPA filter module and a fan/motor assembly inside a housing, with a protective grill covering the air inlet and a HEPA filter covering the air outlet. They also may incorporate pre-filters on the air inlet. There are three general types (Figure ARG3.A) of fan-HEPA filter units (1) those that can be mounted in the ceiling (2) those that can be wheeled from room to room, and (3) those that are miniaturised for personal protective equipment. Units designed to be ceiling mounted often come in dimensions of 2 feet × 2 feet, 2 feet × 3 feet, or 2 feet × 4 feet to match standard dimensions of ceiling tiles, with nominal 10-inch or 12-inch "input collars."[133] Some units on wheels are notable for their ability to create a "negative pressure" room, which is desirable for biocontainment. This is achieved by exhausting a certain percentage of filtered air to the outside environment, causing outside air to flow into the room. These mobile units may have the ability to attach additional duct work.

[131] U.S. Department of Energy, "Nuclear Air Cleaning Handbook," https://www.standards.doe.gov/standards-documents/1100/1169-bhdbk-2003-pt1/@@images/file.

[132] AAF International, manufacturer of FM2-LE self-contained fan-HEPA filter units, https://www.aafintl.com/en/commercial/browse-products/commercial/hepa-ulpa-modules.

[133] See http://www.cleanroomspecialists.com/products/documents/MicroSoundFilter.pdf.

Another notable feature of a fan-HEPA filter unit is the mechanism used to create a leak-proof seal between the HEPA filter and the fan unit. This design involves clamps (see top left of Figure ARG 3.A) to apply pressure and usually a silicone gel which embeds securely around a "knife edge" of the HEPA filter (Figure ARG 3.B).

Figure ARG 3.A. *Self-contained, fan-HEPA filter units. Top left: a unit with an air inlet visible and the HEPA filter hidden from view. Note the clamps to secure the HEPA filter to the fan unit and the hooks for hanging the unit from the ceiling. Top right: the HEPA outlet side of a similar unit installed in a ceiling. Bottom: battery-powered personal fan-HEPA filter units can be worn during work in P3/L3/BL3/BSL3 containment facilities. In this unit, the fan and HEPA filter are small. Filtered air is blown into the clear facemask.*

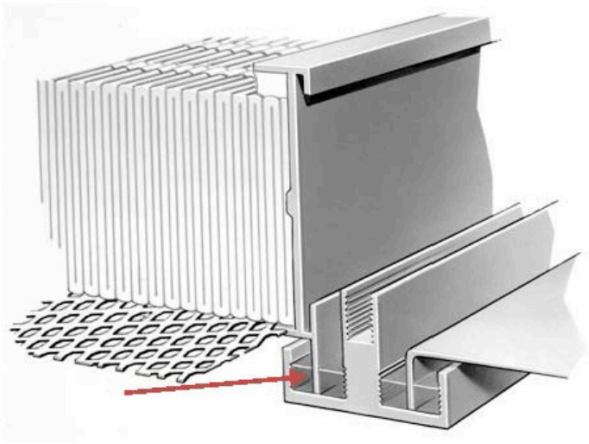

Figure ARG 3.B. *Schematic showing how the "knife edge" of a HEPA filter is embedded into a silicone gel (red arrow) to form a leak-proof seal in a fan-HEPA filter unit.*

II. Related Technology

Technology, including licenses, directly associated with

- AG-controlled pathogens and toxins; or
- AG-controlled dual-use biological equipment items

to the extent permitted by national legislation.

This includes

a) transfer of 'technology' ('technical data') by any means, including electronic media, fax or telephone;

b) transfer of 'technology' in the form of 'technical assistance'.

Controls on 'technology' do not apply to information 'in the public domain' or to 'basic scientific research' or the minimum necessary information for patent application.

The approval for export of any AG-controlled item of dual-use equipment also authorises the export to the same end-user of the minimum 'technology' required for the installation, operation, maintenance, or repair of that item.

II.1. Basic Description

Control of knowledge that would enable a BW program is a challenging, but extremely important, task. The AG's Control List of Dual-Use Biological Equipment prescribes controls on technology directly associated with not only AG-controlled dual-use equipment, but also AG-controlled pathogens and toxins. In the context of the list, technology is defined as "specific information necessary for the 'development', 'production' or 'use' of a product. The information takes the form of 'technical data' or 'technical assistance'." All terms within single quotation marks are further defined in the AG list; see the Glossary for those definitions.

There are notable exemptions from control for certain types of technology. First, such controls do not apply to information in the public domain – according to the AG's definition, this means "technology or software that has been made available without restrictions upon its further dissemination."[134] Controls also do not apply to basic scientific research, defined by the AG as "experimental or theoretical work undertaken principally to acquire new knowledge of the fundamental principles of phenomena or observable facts, not primarily directed towards a specific practical aim or objective." The minimum information necessary to apply for patents is also exempted. The AG further specifies that approved exports of dual-use equipment bring with them an authorisation to transfer the minimum technology necessary for the installation, operation, maintenance, or repair of the item transferred.

II.2. Examples of Related Technology

Controlled technologies related to agents, toxins, and equipment of BW concern could take many forms, with some examples noted below. In some circumstances, information may be available in the published scientific literature about growth conditions for controlled pathogens and production conditions for toxins because work is conducted with these materials for public health or other legitimate purposes. However, it is likely that information available in published scientific literature will be suitable for laboratory-scale (small-scale) production only. Publically available information is not controlled and may only provide a basis for crude production, but other information will be required to produce high-quality BW in significant quantities. Transfer of controlled technologies of types such as those below therefore must be scrutinised carefully, particularly with regard to the end users of the information and their intentions for using it.

[134]The AG further notes that "copyright restrictions do not remove technology or software from being in the public domain."

- ***Purification Techniques (Strain-Specific Details):*** While many pathogens and toxins exist naturally, information on highly pure seed stocks or strain-specific details related to an agent will often will often be excluded from the public domain by culture repositories, vaccine producers, or biotechnology companies. This information may be protected because of security concerns and/or trade secrets. Since the effectiveness of a BW depends in part on the purity and the specific strain of the agent used, application of this knowledge would overcome a major hurdle in acquiring BW.
- ***Production Plans:*** Production of a pathogen with a certain purity is fairly easy in a small-scale laboratory setting. However, the same degree of control is not possible during industrial-scale production. Vaccine producers and biotechnology companies develop detailed process flows, incorporating specific equipment, precise media and growth conditions, and rigourous purification and preservation protocols. Knowledge of industrial production plans would be desirable to a BW production program interested in ensuring a high degree of purity and consistency in large-scale production of BW.
- ***Synthetic Biology:*** Chemical synthesis of DNA can be used to assemble genomes or genetic elements encoding pathogens and toxins, depending on the size of the DNA molecule desired and available time and resources. DNA synthesis machines are widely available around the world and techniques used to assemble the DNA fragments generated by these machines are often in the public domain. However, as technology advances, biotechnology companies have developed specialised reagents, reaction procedures, and equipment to assemble synthetic DNA on an industrial scale. Many of these technologies are not available in the public domain and are protected as trade secrets.
- ***Development Technology for Biological Equipment:*** Like controlled technology related to pathogens and toxins, controlled technology of this type could take several forms. Equipment-related technology could be resident in blueprints, diagrams, models, tables, formulae, engineering designs, photographs, specification manuals, procedures, instructions, books, or reports. The information can therefore be transferred orally or physically, including through the use of computer devices and networks. It is important to note that controlled development technology for equipment that is no longer state-of-the-art may still be relevant to proliferators seeking a BW production capability.

III. Software

Controls on 'software' transfer only apply where specifically indicated in sections I and II above, and do not apply to 'software' which is either:

1. Generally available to the public by being:
   a. Sold from stock at retail selling points without restriction, by means of:
      i. Over-the-counter transactions;
      ii. Mail order transactions;
      iii. Electronic transactions; or
      iv. Telephone call transactions; and
   b. Designed for installation by the user without further substantial support by the supplier; or
2. 'In the public domain'.

III.1. Basic Description

The AG defines software as "a collection of one or more 'programs' or 'microprograms' fixed in any tangible medium of expression." The AG definition of a program is "a sequence of instructions to carry out a process in, or convertible into, a form executable by an electronic computer." Likewise, a microprogram is defined as "a sequence of elementary instructions maintained in a special storage, the execution of which is initiated by the introduction of its reference instruction into an instruction register." Controls on software do not apply to the two instances outlined in the control list (i.e., in the public domain or generally available to the public as defined by the AG). At present, there is no equipment entry in the AG's Control List of Dual-Use Biological Equipment that specifically indicates controls on software.

This page intentionally left blank.

Appendix A:
List of Human and Animal Pathogens and Toxins for Export Control

February 2020

Core List[1]

Viruses	
1.	*African horse sickness virus*
2.	*African swine fever virus*
3.	*Andes virus*
4.	*Avian influenza virus*[2]
5.	*Bluetongue virus*
6.	*Chapare virus*
7.	*Chikungunya virus*
8.	*Choclo virus*
9.	*Classical swine fever virus (Hog cholera virus)*
10.	*Crimean-Congo hemorrhagic fever virus*
11.	*Dobrava-Belgrade virus*
12.	*Eastern equine encephalitis virus*
13.	*Ebolavirus: all members of the Ebolavirus genus*
14.	*Foot-and-mouth disease virus*
15.	*Goatpox virus*
16.	*Guanarito virus*
17.	*Hantaan virus*
18.	*Hendra virus (Equine morbillivirus)*
19.	*Japanese encephalitis virus*
20.	*Junin virus*
21.	*Kyasanur Forest disease virus*
22.	*Laguna Negra virus*
23.	*Lassa virus*
24.	*Louping ill virus*
25.	*Lujo virus*
26.	*Lumpy skin disease virus*
27.	*Lymphocytic choriomeningitis virus*
28.	*Machupo virus*
29.	*Marburgvirus: all members of the Marburgvirus genus*
30.	*Middle East respiratory syndrome-related coronavirus (MERS-CoV)*

31.	*Monkeypox virus*
32.	*Murray Valley encephalitis virus*
33.	*Newcastle disease virus*
34.	*Nipah virus*
35.	*Omsk hemorrhagic fever virus*
36.	*Oropouche virus*
37.	*Peste-des-petits-ruminants virus*
38.	*Porcine Teschovirus*
39.	*Powassan virus*
40.	*Rabies virus and other members of the Lyssavirus genus*
41.	*Reconstructed 1918 influenza virus*
42.	*Rift Valley fever virus*
43.	*Rinderpest virus*
44.	*Rocio virus*
45.	*Sabia virus*
46.	*Seoul virus*
47.	*Severe acute respiratory syndrome-related coronavirus (SARS-related coronavirus)*
48.	*Sheeppox virus*
49.	*Sin Nombre virus*
50.	*St. Louis encephalitis virus*
51.	*Suid herpesvirus 1 (Pseudorabies virus; Aujeszky's disease)*
52.	*Swine vesicular disease virus*
53.	*Tick-borne encephalitis virus (Far Eastern subtype)*
54.	*Variola virus*
55.	*Venezuelan equine encephalitis virus*
56.	*Vesicular stomatitis virus*
57.	*Western equine encephalitis virus*
58.	*Yellow fever virus*

Bacteria	
B1	*Bacillus anthracis*
B2	*Brucella abortus*
B3	*Brucella melitensis*
B4	*Brucella suis*
B5	*Burkholderia mallei* (*Pseudomonas mallei*)
B6	*Burkholderia pseudomallei* (*Pseudomonas pseudomallei*)
B7	*Chlamydia psittaci (Chlamydophila psittaci)*

B8	*Clostridium argentinense* (formerly known as *Clostridium botulinum* Type G), botulinum neurotoxin producing strains
B9	*Clostridium baratii,* botulinum neurotoxin producing strains
B10	*Clostridium botulinum*
B11	*Clostridium butyricum,* botulinum neurotoxin producing strains
B12	Clostridium perfringens, epsilon toxin producing types[3]
B13	*Coxiella burnetii*
B14	*Francisella tularensis*
B15	*Mycoplasma capricolum* subspecies *capripneumoniae* ("strain F38")
B16	*Mycoplasma mycoides* subspecies *mycoides* SC (small colony)
B17	*Rickettsia prowazekii*
B18	*Salmonella enterica* subspecies *enterica* serovar *Typhi (Salmonella typhi)*
B19	Shiga toxin producing Escherichia coli (STEC) of serogroups O26, O45, O103, O104, O111, O121, O145, O157, and other shiga toxin producing serogroups[4]
B20	*Shigella dysenteriae*
B21	*Vibrio cholerae*
B22	*Yersinia pestis*

Toxins as follows and subunits thereof:[5]	
T1	Abrin
T2	Aflatoxins
T3	Botulinum toxins[6]
T4	Cholera toxin
T5	*Clostridium perfringens* alpha, beta 1, beta 2, epsilon and iota toxins
T6	Conotoxins[6]
T7	Diacetoxyscirpenol
T8	HT-2 toxin
T9	Microcystins (Cyanoginosins)
T10	Modeccin
T11	Ricin
T12	Saxitoxin
T13	Shiga toxins (shiga-like toxins, verotoxins, and verocytotoxins)
T14	*Staphylococcus aureus* enterotoxins, hemolysin alpha toxin, and toxic shock syndrome toxin (formerly known as Staphylococcus enterotoxin F)
T15	T-2 toxin
T16	Tetrodotoxin
T17	Viscumin (Viscum album lectin 1)
T18	Volkensin

Fungi	
F1	*Coccidioides immitis*
F2	*Coccidioides posadasii*

Genetic Elements and Genetically-modified Organisms

Any genetically-modified organism[1] which contains, or genetic element[2] that codes for:

G1. any gene or genes specific to any listed virus; or

G2. any gene or genes specific to any listed bacterium[3] or fungus, and which

a. in itself or through its transcribed or translated products represents a significant hazard to human, animal or plant health, or

b. could endow or enhance pathogenicity[4]; or

G3. any listed toxins or their sub-units.

Technical note:

1. Genetically-modified organisms include organisms in which the nucleic acid sequences have been created or altered by deliberate molecular manipulation.

2. Genetic elements include, inter alia: chromosomes, genomes, plasmids, transposons, vectors, and inactivated organisms containing recoverable nucleic acid fragments, whether genetically modified or unmodified, or chemically synthesized in whole or in part. For the purposes of the genetic elements control, nucleic acids from an inactivated organism, virus, or sample are considered 'recoverable' if the inactivation and preparation of the material is intended or known to facilitate isolation, purification, amplification, detection, or identification of nucleic acids.

3. These controls do not apply to nucleic acid sequences of shiga toxin producing *Escherichia coli* of serogroups O26, O45, O103, O104, O111, O121, O145, O157, and other shiga toxin producing serogroups, other than those genetic elements coding for shiga toxin, or for its subunits.

4. 'Endow or enhance pathogenicity' is defined as when the insertion or integration of the nucleic acid sequence or sequences is/are likely to enable or increase a recipient organism's ability to be used to deliberately cause disease or death. This might include alterations to, inter alia: virulence, transmissibility, stability, route of infection, host range, reproducibility, ability to evade or suppress host immunity, resistance to medical countermeasures, or detectability.

Warning List[1]

Bacteria	
WB1	Clostridium tetani[7]
WB2	*Legionella pneumophila*
WB3	*Yersinia pseudotuberculosis*
WB4	Other strains of Clostridium species that produce botulinum neurotoxin[8]
WB5	*Bacillus cereus biovar anthracis*

Fungi	
WF1	*Fusarium langsethiae*
WF2	*Fusarium sporotrichioides*

[1] An agent/pathogen is covered by this list except when it is in the form of a vaccine. A vaccine is a medicinal product in a pharmaceutical formulation licensed by, or having marketing or clinical trial authorisation from, the regulatory authorities of either the country of manufacture or of use, which is intended to stimulate a protective immunological response in humans or animals in order to prevent disease in those to whom or to which it is administered.

Biological agents and pathogens are controlled when they are an isolated live culture of a pathogen agent, or a preparation of a toxin agent which has been isolated or extracted from any source, or material including living material which has been deliberately inoculated or contaminated with the agent. Isolated live cultures of a pathogen agent include live cultures in dormant form or in dried preparations, whether the agent is natural, enhanced or modified.

[2] This includes only those Avian influenza viruses of high pathogenicity as defined by the World Organization for Animal Health (OIE), the European Union (EU), or competent national regulatory bodies.

[3] It is understood that limiting this control to epsilon toxin-producing strains of *Clostridium perfringens* therefore exempts from control the transfer of other *Clostridium perfringens* strains to be used as positive control cultures for food testing and quality control.

[4] Shiga toxin producing *Escherichia coli* (STEC) includes *inter alia* enterohaemorrhagic *E. coli* (EHEC), verotoxin producing *E. coli* (VTEC) or verocytotoxin producing *E. coli* (VTEC).

[5] Excluding immunotoxins

[6] Excluding botulinum toxins and conotoxins in product form meeting all of the following criteria:

- are pharmaceutical formulations designed for testing and human administration in the treatment of medical conditions;
- are pre-packaged for distribution as clinical or medical products; and
- are authorised by a state authority to be marketed as clinical or medical products.

[7] The Australia Group recognizes that this organism is ubiquitous, but, as it has been acquired in the past as part of biological warfare programs, it is worthy of special caution.

[8] It is the intent of Australia Group members to add to the control list strains of species of *Clostridium* identified as producing botulinum neurotoxin.

This page intentionally left blank.

Appendix B:
List of Plant Pathogens for Export Control

February 2020

Core List

Bacteria	
PB1	*Xanthomonas albilineans*
PB2	*Xanthomonas axonopodis* pv. *citri* (*Xanthomonas campestris* pv. *citri A*) [*Xanthomonas campestris* pv. *citri*]
PB3	*Xanthomonas oryzae* pv. *oryzae* (*Pseudomonas campestris* pv. *oryzae*)
PB4	*Clavibacter michiganensis* subsp. *sepedonicus* (*Corynebacterium michiganensis* subsp. *sepedonicum* or *Corynebacterium sepedonicum*)
PB5	*Ralstonia solanacearum,* race 3, biovar 2

Fungi	
PF1	*Colletotrichum kahawae* (*Colletotrichum coffeanum* var. *virulans*)
PF2	*Cochliobolus miyabeanus* (*Helminthosporium oryzae*)
PF3	*Microcyclus ulei* (syn. *Dothidella ulei*)
PF4	*Puccinia graminis* ssp. *graminis* var. *graminis*/*Puccinia graminis* ssp. *graminis* var. *stakmanii* (*Puccinia graminis* [syn. *Puccinia graminis* f. sp. *tritici*])
PF5	*Puccinia striiformis* (syn. *Puccinia glumarum*)
PF6	*Magnaporthe oryzae* (*Pyricularia oryzae*)
PF7	*Peronosclerospora philippinensis* (*Peronosclerospora sacchari*)
PF8	*Sclerophthora rayssiae* var. *zeae*
PF9	*Synchytrium endobioticum*
PF10	*Tilletia indica*
PF11	*Thecaphora solani*

Viruses	
PV1	*Andean potato latent virus* (Potato Andean latent tymovirus)
PV2	*Potato spindle tuber viroid*

Genetic Elements and Genetically-modified Organisms

Any genetically-modified organism[1] which contains, or genetic element[2] that codes for:

PG1. any gene or genes specific to any listed virus; or

PG2. any gene or genes specific to any listed bacterium or fungus, and which

a. in itself or through its transcribed or translated products represents a significant hazard to human, animal or plant health, or

b. could endow or enhance pathogenicity[3].

Technical note:

1. Genetically-modified organisms include organisms in which the nucleic acid sequences have been created or altered by deliberate molecular manipulation.

2. Genetic elements include, inter alia: chromosomes, genomes, plasmids, transposons, vectors, and inactivated organisms containing recoverable nucleic acid fragments, whether genetically modified or unmodified, or chemically synthesized in whole or in part. For the purposes of the genetic elements control, nucleic acids from an inactivated organism, virus, or sample are considered 'recoverable' if the inactivation and preparation of the material is intended or known to facilitate isolation, purification, amplification, detection, or identification of nucleic acids.

3. 'Endow or enhance pathogenicity' is defined as when the insertion or integration of the nucleic acid sequence or sequences is/are likely to enable or increase a recipient organism's ability to be used to deliberately cause disease or death. This might include alterations to, inter alia: virulence, transmissibility, stability, route of infection, host range, reproducibility, ability to evade or suppress host immunity, resistance to countermeasures, or detectability.

Items for Inclusion in Awareness Raising Guidelines

Bacteria	
PWB1	*Xylella fastidiosa*

Fungi	
PWF1	*Phoma tracheiphila* (*Deuterophoma tracheiphila*)
PWF2	*Moniliophthora roreri* (*Monilia roreri*)

Viruses	
PWV1	*Banana bunchy top virus*

Genetic Elements and Genetically-modified Organisms:	
PWG1	Genetic elements that contain nucleic acid sequences associated with the pathogenicity of any of the microorganisms in the Awareness Raising Guidelines.
PWG2	Genetically-modified organisms that contain nucleic acid sequences associated with the pathogenicity of any of the microorganisms in the Awareness Raising Guidelines.

Technical note:

Genetically-modified organisms includes organisms in which the genetic material (nucleic acid sequences) has been altered in a way that does not occur naturally by mating and/or natural recombination, and encompasses those produced artificially in whole or in part.

Genetic elements include inter alia chromosomes, genomes, plasmids, transposons, and vectors whether genetically modified or unmodified, or chemically synthesized in whole or in part.

Nucleic acid sequences associated with the pathogenicity of any of the microorganisms in the list means any sequence specific to the relevant listed microorganism:

- that in itself or through its transcribed or translated products represents a significant hazard to human, animal or plant health; or
- that is known to enhance the ability of a listed microorganism, or any other organism into which it may be inserted or otherwise integrated, to cause serious harm to human, animal or plant health.

This page intentionally left blank.

Appendix C:
Control List of Dual-Use Biological Equipment and Related Technology and Software

February 2020

I. Equipment

1. Containment Facilities and Related Equipment as follows

a) Complete containment facilities that meet the criteria for P3 or P4 (BL3, BL4, L3, L4) containment as specified in the WHO Laboratory Biosafety Manual (3rd edition, Geneva, 2004)

b) Equipment designed for fixed installation in containment facilities specified in a., as follows:

i. Double-door pass-through decontamination autoclaves;

ii. Breathing air suit decontamination showers;

iii. Mechanical-seal or inflatable-seal walkthrough doors.

2. Fermenters

Fermenters capable of cultivation of microorganisms or of live cells for the production of viruses or toxins, without the propagation of aerosols, having a total internal volume of 20 litres or greater.

Components designed for such fermenters, as follows:

a) cultivation chambers designed to be sterilized or disinfected in situ;

b) cultivation chamber holding devices; or

c) process control units capable of simultaneously monitoring and controlling two or more fermentation system parameters (e.g. temperature, pH, nutrients, agitation, dissolved oxygen, air flow, foam control).

Note 1 - Fermenters include bioreactors (including single-use (disposable) bioreactors), chemostats and continuous-flow systems.

Note 2 - Cultivation chamber holding devices include single-use cultivation chambers with rigid walls.

3. Centrifugal Separators

Centrifugal separators capable of the continuous separation of pathogenic microorganisms, without the propagation of aerosols, and having all the following characteristics:

a) one or more sealing joints within the steam containment area;

b) a flow rate greater than 100 litres per hour;

c) components of polished stainless steel or titanium;

d) capable of in-situ steam sterilisation in a closed state.

Technical note: Centrifugal separators include decanters.

4. Cross (tangential) Flow Filtration Equipment

Cross (tangential) flow filtration equipment capable of separation of microorganisms, viruses, toxins or cell cultures having all the following characteristics:

a) a total filtration area equal to or greater than 1 square metre; and

b) having any of the following characteristics:

i. capable of being sterilized or disinfected in-situ; or

ii. using disposable or single-use filtration components.

(Note – This control excludes reverse osmosis and hemodialysis equipment, as specified by the manufacturer.)

Cross (tangential) flow filtration components (eg modules, elements, cassettes, cartridges, units or plates) with filtration area equal to or greater than 0.2 square metres for each component and designed for use in cross (tangential) flow filtration equipment as specified above.

Technical note: In this control, 'sterilized' denotes the elimination of all viable microbes from the equipment through the use of either physical (eg steam) or chemical agents. 'Disinfected' denotes the destruction of potential microbial infectivity in the equipment through the use of chemical agents with a germicidal effect. 'Disinfection' and 'sterilization' are distinct from 'sanitization', the latter referring to cleaning procedures designed to lower the microbial content of equipment without necessarily achieving elimination of all microbial infectivity or viability.

5. Freeze-drying Equipment

Steam, gas or vapour sterilisable freeze-drying equipment with a condenser capacity of 10 kg of ice or greater in 24 hours and less than 1000 kg of ice in 24 hours.

6. Spray-drying Equipment

Spray drying equipment capable of drying toxins or pathogenic microorganisms having all of the following characteristics:

a) a water evaporation capacity of ≥ 0.4 kg/h and ≤ 400 kg/h

b) the ability to generate a typical mean product particle size of ≤10 micrometers with existing fittings or by minimal modification of the spray-dryer with atomization nozzles enabling generation of the required particle size; and

c) capable of being sterilized or disinfected in situ.

7. Protective and containment equipment as follows:

a) protective full or half suits, or hoods dependent upon a tethered external air supply and operating under positive pressure;

Technical note: This does not control suits designed to be worn with self-contained breathing apparatus.

b) biocontainment chambers, isolators, or biological safety cabinets having all of the following characteristics, for normal operation:

i. fully enclosed workspace where the operator is separated from the work by a physical barrier;

ii. able to operate at negative pressure;

iii. means to safely manipulate items in the workspace;

iv. supply and exhaust air to and from the workspace is HEPA filtered.

Note 1 - this control includes class III biosafety cabinets, as described in the latest edition of the WHO Laboratory Biosafety Manual or constructed in accordance with national standards, regulations or guidance.

Note 2 - this control does not include isolators specially designed for barrier nursing or transportation of infected patients.

8. Aerosol inhalation equipment

Aerosol inhalation equipment designed for aerosol challenge testing with microorganisms, viruses or toxins as follows:

a) Whole-body exposure chambers having a capacity of 1 cubic metre or greater.

b) Nose-only exposure apparatus utilising directed aerosol flow and having capacity for exposure of 12 or more rodents, or 2 or more animals other than rodents; and, closed animal restraint tubes designed for use with such apparatus.

9. Spraying or fogging systems and components therefor, as follows:

a) Complete spraying or fogging systems, specially designed or modified for fitting to aircraft, lighter than air vehicles or UAVs, capable of delivering, from a liquid suspension, an initial droplet "VMD" of less than 50 microns at a flow rate of greater than two litres per minute.

b) Spray booms or arrays of aerosol generating units, specially designed or modified for fitting to aircraft, lighter than air vehicles or UAVs, capable of delivering, from a liquid suspension, an initial droplet "VMD" of less than 50 microns at a flow rate of greater than two litres per minute.

c) Aerosol generating units specially designed for fitting to systems that fulfil all the criteria specified in paragraphs 9.a and 9.b.

Technical Notes:
Aerosol generating units are devices specially designed or modified for fitting to aircraft such as nozzles, rotary drum atomisers and similar devices.

This entry does not control spraying or fogging systems and components as specified in paragraph 9 above that are demonstrated not to be capable of delivering biological agents in the form of infectious aerosols.

Pending definition of international standards, the following guidelines should be followed:

Droplet size for spray equipment or nozzles specially designed for use on aircraft or UAVs should be measured using either of the following methods:

a) Doppler laser method

b) Forward laser diffraction method

10. Nucleic Acid Assemblers and Synthesizers

Nucleic acid assemblers and synthesizers, which are partly or entirely automated, and designed to generate continuous nucleic acids greater than 1.5 kilobases in length with error rates less than 5% in a single run.

Items for inclusion in Awareness Raising Guidelines

Experts propose that the following items be included in awareness raising guidelines to industry:

1. Equipment and technology (not specified elsewhere in the control list of Dual-use Biological Equipment and Related Technology and Software) for the encapsulation of live pathogenic microorganisms, viruses and toxins, with a typical mean product particle size of 10 μm or less.
2. Fermenters of less than 20 litre capacity with special emphasis on aggregate orders or designs for use in combined systems.
3. Conventional or turbulent air-flow clean-air rooms and self-contained fan-HEPA filter units that may be used for P3 or P4 (BL3, BL4, L3, L4) containment facilities.

II. Related Technology

Technology, including licenses, directly associated with

- AG-controlled pathogens and toxins; or
- AG-controlled dual-use biological equipment items to the extent permitted by national legislation.

This includes

a) transfer of 'technology' ('technical data') by any means, including electronic media, fax or telephone;

b) transfer of 'technology' in the form of 'technical assistance'.

Controls on 'technology' do not apply to information 'in the public domain' or to 'basic scientific research' or the minimum necessary information for patent application.

The approval for export of any AG-controlled item of dual-use equipment also authorises the export to the same end-user of the minimum 'technology' required for the installation, operation, maintenance, or repair of that item.

III. Software

Controls on 'software' transfer only apply where specifically indicated in sections I and II above, and do not apply to 'software' which is either:

1. Generally available to the public by being:

   a) Sold from stock at retail selling points without restriction, by means of:

      i. Over-the-counter transactions;

      ii. Mail order transactions;

      iii. Electronic transactions; or

      iv. Telephone call transactions; and

   b) Designed for installation by the user without further substantial support by the supplier; or

2. 'In the public domain.'

Definition of Terms

'Basic scientific research'
Experimental or theoretical work undertaken principally to acquire new knowledge of the fundamental principles of phenomena or observable facts, not primarily directed towards a specific practical aim or objective.

'Development'
'Development' is related to all stages before 'production' such as:

- assembly of prototypes,
- configuration design,
- design,
- design analysis,
- design concepts,
- design data,

- design research,
- integration design,
- layouts,
- pilot production schemes, and
- process or transforming design data into a product.

'Export'
An actual shipment or transmission of AG-controlled items out of the country. This includes transmission of 'technology' by electronic media, fax or telephone.

'In the public domain'
'In the public domain', as it applies herein, means 'technology' or 'software' that has been made available without restrictions upon its further dissemination. (Copyright restrictions do not remove 'technology' or 'software' from being 'in the public domain').

'Lighter than air vehicles'
Balloons and airships that rely on hot air or on lighter-than-air gases such as helium or hydrogen for their lift.

'Microprogram'
A sequence of elementary instructions maintained in a special storage, the execution of which is initiated by the introduction of its reference instruction into an instruction register.

'Production'
'Production' means all production phases such as:

- construction,
- production engineering,
- manufacture,
- integration,
- assembly (mounting),
- inspection,
- testing, and
- quality assurance.

'Program'
A sequence of instructions to carry out a process in, or convertible into, a form executable by an electronic computer.

'Software'
A collection of one or more 'programs' or 'microprograms' fixed in any tangible medium of expression.

'Technical assistance'
May take forms, such as: instruction, skills, training, working knowledge, consulting services. 'Technical assistance' includes oral forms of assistance. 'Technical assistance' may involve transfer of 'technical data.'

'Technical data'
May take forms such as blueprints, plans, diagrams, models, formulae, tables, engineering designs and specifications, manuals and instructions written or recorded on other media or devices such as disk, tape, read-only memories.

'Technology'
Specific information necessary for the 'development,' 'production,' or 'use' of a product. The information takes the form of 'technical data' or 'technical assistance.'

'UAVs'
Unmanned Aerial Vehicles.

'Use'
Operation, installation, (including on-site installation), maintenance, (checking), repair, overhaul or refurbishing.

'VMD'
Volume Median Diameter *(note: for water-based systems, VMD equates to MMD – the Mass Median Diameter)*.

Appendix D:
Biological Pathogens and Toxins Descriptions: Definitions and Resources

In this Handbook, each biological agent and toxin on the List of Human and Animal Pathogens and Toxins and List of Plant Pathogens is described in four subsections: (1) Basic Description; (2) Notable Features; (3) Packaging; and (4) Typical Applications. This appendix provides definitions of terms included in the Basic Description sub-section. Additional resources are provided in the Bibliography.

Note: The authors do not endorse or in any way attest to the accuracy of the sources referenced herein.

x. AG pathogen or toxin name (where x is the pathogen or toxin number on the control list of origin)

x.1. Basic Description

The basic description is devoted to a table of identifiers and properties of the pathogen or toxin compiled from various public health agencies, published scientific literature, and toxin-producing companies. The table includes information on the biological properties of the specific pathogen or toxin in addition to key attributes of disease(s) caused by the pathogen or toxin. Each virus, bacteria, and fungi has a table of identifiers and properties, with the following format:

Identifier/Property	Description
Type	Virus, Bacteria, or Fungi
Associated Disease	
Other Names	
Key WMD Characteristic(s)	
Containment and Handling	
Exposure/Infection Routes	
Geographic Distribution	
Zoonotic	
Human Transmissibility	
EU Control List Entry	
Applicable AG Footnote(s)	

Due to the unique properties of toxins, the table for toxins differs slightly from those of the virus, bacteria, and fungi entries. Each toxin has a table of identifiers and properties, with the following format:

Identifier/Property	Description
Type	Toxin
Other Names	
Associated Disease	
Produced By (Scientific Name)	
Key WMD Characteristic(s)	
Containment and Handling	
Exposure Routes	
Endemic Range	
CAS#	
EU Control List Entry	
Applicable AG Footnote(s)	

The sections below provide an explanation of each field in the tables for pathogens and toxins.

Type

The type describes whether the control list entry is a virus, bacterium, fungus, or toxin. For viral and bacterial pathogens, additional defining characteristics are included that have potential bearing on pathogenicity: for virus, DNA or RNA is specified, and for bacteria, Gram stain negative or Gram stain positive is specified.

Associated Disease

The associated disease is the illness or clinical manifestation(s) of symptoms that occur as a direct result of infection with the pathogen or exposure to the toxin. For example, the associated disease for *Variola virus* is smallpox.

Other Names

The other names field includes any additional scientific or common names that are used to identify a pathogen or toxin. It is common for a pathogen to have additional or historical names as classification, and taxonomy distinctions change due to new scientific discoveries. This section also includes common abbreviations. For example, *Andes virus* is also reported in scientific and public health literature as ANDV.

Key WMD Characteristic(s)

This field includes properties of the pathogen or toxin and the disease it manifests that may be of concern with regard to potential proliferation. The characteristics cited in this field are described below:

- Mortality rate: This statistic describes the potential rate of death for all humans that are exposed to the pathogen.
- Potential or effective aerosol: An effective aerosol means that the pathogen currently has the natural ability to be transmitted via inhalation exposure. A potential aerosol means that the pathogen could gain the ability to transmit via inhalation exposure through reasonable manipulation in a laboratory environment. Potential aerosols do not have the natural ability to transmit via inhalation exposure.
- Environmentally stable (spores): A pathogen that is environmentally stable is likely to persist in the environment for longer periods of time than other pathogens. This is particularly true for spores (e.g., *Bacillus anthracis* spores can stay viable in the soil for decades).

- Potential for socioeconomic harm: This characteristic is included when the pathogen has the ability to cause considerable damage to key agricultural or crop supplies. For example, animals infected with *Foot-and-mouth disease virus* cannot be exported. This can decimate or severely hinder a country's cattle industry, causing considerable economic damage and impacts on the food supply.
- Potential to damage the environment: This characteristic is included when a pathogen is able to survive in water sources used for human consumption causing sustained damage to the environment. For example, a common exposure route for *Shigella dysenteriae* is contaminated water.
- Treatment options: Many pathogens and toxins on the AG Common Control Lists lack an effective vaccine or antitoxin. Others have extremely limited post-exposure treatment. For example, there is a vaccine for *Venezuelan equine encephalitis virus* that is widely used to immunise livestock but only administered in humans for military and at-risk personnel. Once exposed, treatment of infected humans is limited to supportive care.

Containment and Handling

This field includes the biosafety level recommended when handling the controlled pathogen or toxin for legitimate reasons in a laboratory environment. Biosafety levels range from Biosafety Level 1 to Biosafety Level 4, with the level of containment and protective measures increasing from 1 to 4. Biosafety Levels included in the AG Common Control Handbook for human pathogens represent the highest biosafety level used for containment and handling by most AG member countries. However, biosafety levels may vary among member states due to the lack of international standard. *Importantly, the Biosafety Level required will depend on a full risk assessment on the work to be done.* Further information, including physical descriptions of containment facilities and protective and containment equipment may be found in the AG control list entries on Containment Facilities and Related Equipment and Protective and Containment Equipment, respectively.

Exposure/Infection Routes

An exposure or infection route describes the pathway used to move a pathogen from its natural reservoir into the host to manifest disease. The four possible exposure routes (cutaneous, inhalation, gastrointestinal, and injection) are discussed in the Introduction to Pathogens and Toxins. An exposure route is annotated as "not a known route of exposure" if it is not known to be an effective *natural* route of transmitting infectious pathogens in a manner than manifests disease. In certain cases, an exposure route is annotated as "not a likely route of exposure" if the route of exposure could manifest disease but is highly unlikely to occur naturally. For example, *Yersinia pestis* is not likely to transmit via gastrointestinal exposure because it would require consumption of the flea vector containing the bacteria. However, if a person were to consume fleas infected with *Yersinia pestis*, disease symptoms would likely manifest. In addition to the exposure route, the host, reservoir, and/or vector are included as applicable.

Geographic Distribution

The geographic distribution field states the location(s) where disease outbreaks caused by a controlled pathogen have occurred. Though certain geographic locations could potentially support disease outbreaks (i.e., they have a susceptible host and vector population), the information included in the Handbook includes only geographic locations where known outbreaks have occurred or are occurring.

Zoonotic

A pathogen is zoonotic if it has the ability to manifest disease in both humans and animals.

Human Transmissibility

Many pathogens are capable of manifesting disease in humans but lack the ability to be effectively transmitted directly from human to human. Those pathogens that do have the ability to pass from human to human will be listed in the table as "Yes" with annotation for the route of exposure (manual and/or aerosolisation). Those pathogens not considered to have human-to-human transmissibility will be listed in the table as "Not transmissible."

EU Control List Entry

Control List numbers from the European Union's Dual-Use List.[135]

Applicable AG Footnote(s)

The AG Human and Animal Pathogens and Toxins Control List includes footnotes for certain pathogen or toxin entries. These footnotes include clarification on the spirit and intent of the AG when an infectious substance is included on the Core or Warning Lists. For example, footnote [5] states "excluding immunotoxins" and applies to every toxin entry. This means that although toxins are controlled by the AG, immunotoxins associated with each toxin are not.

The following sections are included in toxin entries only:

Produced By (Scientific Name)

This field includes the common and scientific name(s) for the organism(s) responsible for toxin production. Certain toxins are produced by only one organism (e.g., *Vibrio cholerae* produces cholera toxin), whereas other toxins may be produced by multiple organisms (e.g., multiple species of *Clostridium* are capable of producing botulinum toxins).

Endemic Range

The endemic range is the geographic location where the producing organism is found. Incidence of toxin exposure varies greatly depending on the specific toxin, and it is not always tied to endemic range of the producing organism. For example, tetrodotoxin is produced by bacteria that live in puffer fish. Exposure to humans occurs through eating contaminated puffer fish, not from swimming in the fish's natural habitat.

CAS#

Toxins are essentially chemical substances and therefore may be assigned a Chemical Abstracts Service Registry Number (CAS#) as they fall within the scope of the CAS Registry.[136] The CAS# is a registry number assigned by the Chemical Abstracts Service. It is the most commonly used, unique identifier for a chemical substance. It takes the form XXXXXXX-XX-X, where each X is a number 0–9. The first number in the code varies in its number of digits (from two to seven), but the second and third parts always have two digits and one digit, respectively. The last digit in the CAS# is determined from the numbers that precede it, so it can be used to check whether or not a CAS# is valid. A formula for determining the validity of a CAS# can be found on the Chemical Abstracts Service website.[137] It is important to note that not every controlled toxin may have an assigned CAS#. This may be due in part to the relatively fast pace of new toxin discovery or delay in registering a newly discovered toxin with the Chemical Abstracts Service. Lack of a CAS# does not indicate a lack of toxicity.

[135]As of the revision of this Handbook, the most recent version of the EU Dual-Use List is Commission Delegated Regulation (EU) No 2019/2199, available in multiple languages at https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32019R2199.

[136]More information on the CAS Registry can be found at http://www.cas.org/content/chemical-substances.

[137]Check Digit Verification of CAS Registry Numbers, http://www.cas.org/content/chemical-substances/checkdig.

Appendix E: Pathogen Taxonomy Information

Many of the pathogens on the AG Common Control Lists share common routes of transmission and/or disease manifestation due to genetic similarity. Below is a list of virus families, bacteria families, and fungi phyla that contain multiple pathogens on the AG Common Control Lists. The taxonomic information in this appendix is not comprehensive and represents those families and phyla with multiple pathogen species on either the Human and Animal Pathogens and Toxins Control List or Plant Pathogens Control List.

Viruses

Arenaviridae

The *Arenaviridae* family includes the *Arenavirus* genus. The AG Human and Animal Pathogens and Toxins Control List includes all eight species of the *Arenavirus* genus known to cause disease in humans: *Chapare virus, Guanarito virus, Junin virus, Lassa virus, Lujo virus, Lymphocytic choriomeningitis virus, Machupo virus,* and *Sabia virus*. Species of the *Arenavirus* genus are RNA viruses that are tied to a rodent reservoir and are geographically tied to either the Old World (Europe, Africa, Asia, and Australia) or the New World (North and South America). Although each *Arenavirus* species tends to be confined to a small geographic area, the rodent reservoir provides these viruses the easy ability to spread to new locations. These viruses also appear to cause no visible symptoms in the rodent but remain sustained in the population through generational infection (spread from mother to offspring during pregnancy) or adult biting or in-fighting. Once a human becomes infected they are generally not contagious, though there are documented cases of person-to-person transmission.

Bunyaviridae

The *Bunyaviridae* family has five different genera, four of which have viruses that appear on the AG Human and Animal Pathogens and Toxins Control List: *Nairovirus* (*Crimean-Congo hemorrhagic fever virus*), *Orthobunyavirus* (*Oropouche virus*), *Phlebovirus* (*Rift Valley fever virus*), and *Hantavirus* (*Andes virus, Choclo virus, Dobrava-Belgrade virus, Hantaan virus, Laguna Negra virus, Seoul virus,* and *Sin Nombre virus*). *Bunyaviridae* family viruses are RNA viruses that cause viral hemorrhagic fever (VHF) and/or pulmonary syndrome and may or may not have an arthropod (mosquito, tick, or sand-fly) vector. The pathogens listed for control by the AG manifest disease in humans and generally have arthropod vectors. The only exceptions are viruses of the *Hantavirus* genus; they are unique in that they are always tied to a rodent reservoir with no arthropod vector. Similar to *Arenaviridae* family viruses, the *Bunyaviridae* family viruses included in the AG Human and Animal Pathogens and Toxins Control List are closely tied to either the New World or Old World and manifest different types of VHF diseases in their hosts based on geographic distribution. Species of New World *Hantavirus* cause hantavirus cardiopulmonary syndrome (HCPS or HPS), which attacks the pulmonary and cardiovascular system. In contrast, species of Old World *Hantavirus* cause hemorrhagic fever with renal syndrome (HFRS), causing the usual symptoms associated with VHF plus renal failure. Transmission of any virus of the *Hantavirus* genus occurs via direct contact with rodents or aerosolised urine or feces.

Togaviridae

The *Togaviridae* family includes the Alphavirus genus. Four *Alphavirus* species are included in the AG Human and Animal Pathogens and Toxins Control List: *Chikungunya virus, Eastern equine encephalitis virus, Venezuelan equine encephalitis virus,* and *Western equine encephalitis virus.* Species of *Alphavirus* are spread via a mosquito vector to humans and animals. Disease manifestation can be either VHF, encephalitis, or arthralgia, depending on the specific virus.

Poxviridae

The *Poxviridae* family has a large number of genera, two of which have viruses on the AG Human and Animal Pathogens and Toxins Control List: *Orthopoxvirus* (*Monkeypox virus* and *Variola virus*) and *Capripoxvirus* (*Goatpox virus, Sheeppox virus,* and *Lumpy skin disease virus*). Unlike the other virus families on the AG Control Lists, *Poxviridae* family viruses have genomes composed of DNA and have slower rates of mutation

compared to RNA genome viruses. Due to genetic similarity, vaccination against one species of *Poxviridae* often provides cross-protection against disease manifestation or, at a minimum, protection against a fatal disease by another species. *Poxviridae* family viruses are home to some of the oldest described diseases in human history (e.g., *Variola virus*), and they infect almost every mammalian and avian species on the planet.

Flaviviridae

The *Flaviviridae* family has two genera with viruses on the AG Human and Animal Pathogens and Toxins Control List: *Pestivirus* (*Classical swine fever virus* [*Hog cholera virus*]) and *Flavivirus* (*Japanese encephalitis virus, Kyasanur Forest disease virus, Louping ill virus, Murray Valley encephalitis virus, Omsk hemorrhagic fever virus, Powassan virus, Rocio virus, St. Louis encephalitis virus, Tick-borne encephalitis virus,* and *Yellow Fever virus*). Viruses of the *Flavivirus* genus have the ability to infect humans, while viruses of the *Pestivirus* genus manifest disease in animals. Virus species within the *Flavivirus* genus require an arthropod vector and manifest as VHF, encephalitis, or arthralgia.

Filoviridae

The *Filoviridae* family has two genera with viruses on the AG Human and Animal Pathogens and Toxins Control List: *Ebolavirus* and *Marburgvirus.* Viruses from both genera manifest versions of extremely virulent VHF with very high mortality rates. The vector for these viruses is unknown, but it is believed that primates are the main reservoir.

Paramyxoviridae

The *Paramyxoviridae* family has three genera with viruses on the AG Human and Animal Pathogens and Toxins Control List: *Henipavirus* (*Hendra virus* and *Nipah virus*), *Avulavirus* (*Newcastle disease virus*), and *Morbillivirus* (*Peste-des-petits ruminants virus* and *Rinderpest virus*). Affecting both humans and animals, *Paramyxoviridae* family viruses manifest severe neurologic symptoms related to encephalitis in humans and can cause the same or VHF in animals depending on the virus. The reservoir for species of the *Henipavirus* genus is bats. The virus can spread directly from bats to the host or through an intermediary host such as a pig.

Reoviridae

The *Reoviridae* family includes the *Orbivirus* genus. The two species of *Orbivirus* included in the Human and Animal Pathogens and Toxins Control List (*Bluetongue virus* and *African horse sickness virus*) exclusively manifest disease in animals. Spread via an insect vector, the *Orbivirus* pathogens controlled by the AG are notorious for causing mortality rates of up to 90%.

Picornaviridae

The *Picornaviridae* family has three genera with viruses on the Human and Animal Pathogens and Toxins Control List: *Aphthovirus* (*Foot-and-mouth disease virus*), and *Enterovirus* (*Swine vesicular disease virus*), and *Teschovirus* (*Porcine teschovirus*). All AG-listed *Picornaviridare* family viruses exclusively manifest disease in animals. These viruses are particularly adept at persisting in the environment for long periods of time.

Rhabdoviridae

The *Rhabdoviridae* family has two genera with viruses on the Human and Animal Pathogens and Toxins Control List: *Lyssavirus* (*Rabies virus* and all other members of the genus) and *Vesiculovirus* (*Vesicular stomatitis virus*). Species of *Rhabdoviridae* family viruses controlled by the AG are known for the manifestation of disease in animals. However, some virus species are zoonotic and capable of causing disease in humans (e.g., *Vesicular stomatitis virus* and certain species of the *Lyssavirus* genus).

Coronaviridae

The *Coronaviridae* family includes two subfamilies with a six genera, there are two viruses included in the AG Human and Animal Pathogens and Toxins Control List: *Severe acute respiratory syndrome-related coronavirus and Middle East respiratory syndrome-related coronavirus. Coronaviridae* viruses are RNA viruses that cause respiratory and gastrointestinal diseases in mammals and birds.

Bacteria

Brucellaceae

The *Brucellaceae* family of bacteria includes the genus *Brucella,* which has three species on the AG Human and Animal Pathogens and Toxins Control List: *Brucella abortus, Brucella melitensis,* and *Brucella suis*. These bacteria are non-spore forming, intracellular parasites and, as noted above, their lifecycle is dependent on replication within a host cell. All three pathogens cause a disease called brucellosis. This disease has several manifestations dependent on where the bacteria take up residence in the host. In humans, symptoms can include generic flu-like symptoms in addition to gastrointestinal stress (anorexia, nausea, vomiting, diarrhea, constipation), generic respiratory symptoms (cough), and drenching night sweats. In livestock, symptoms include abortion and inflammation of the genitalia.

Clostridiaceae

The *Clostridiaceae* family of bacteria is very large, containing 15 separate genera and 152 unique species. For the purposes of AG controls, there are five species on the Human and Animal Pathogens and Toxins Control List: *Clostridium botulinum, Clostridium argentinense, Clostridium baratii, Clostridium butyricum,* and *Clostridium perfringens*. In addition, *Clostridium tetani* and other strains of *Clostridium species* that produce botulinum neurotoxin are on the Human and Animal Pathogens and Toxins Warning List. All controlled species belong to the genus *Clostridium* and cause botulinum poisoning. These bacteria have the ability to sporulate and create neurotoxins when the spores germinate. As such, they can be extremely resistant to environmental degradation and can potently poison their hosts. *Clostridium* species can produce one or multiple types of neurotoxins (e.g., botulinum and epsilon). Botulinum toxin is known for causing irreversible paralysis in patients. Although the disease can affect animals through consumption of spores in the environment, it is most commonly associated with disease in humans through the consumption of contaminated food products.

Burkholderiaceae

The *Burkholderiaceae* family of Gram stain negative bacteria do not have the ability to create spores. This family includes one genus, *Burkholderia,* that has two species on the AG Human and Animal Pathogens and Toxins Control List: *Burkholderia mallei* and *Burkholderia pseudomallei.* Both pathogens are zoonotic and thus have the ability to manifest disease in both humans and animals.

Enterobacteriaceae

The *Enterobacteriaceae* family of Gram stain negative bacteria contains certain species capable of manifesting disease. There are four species on the Human and Animal Pathogens and Toxins Control List (*Salmonella enterica* subspecies *enterica* serovar *Typhi, Shigella dysenteriae, Yersinia pestis,* and shiga toxin producing *Escherichia coli* serogroups) and one species on the AG Human and Animal Pathogens and Toxins Warning List (*Yersinia pseudotuberculosis*). All members of the *Enterobacteriaceae* family replicate without the presence of oxygen, allowing them to reside in the intestines of humans and animals. It is common for these microorganisms to produce symptoms that are located in, but not limited to, the gastrointestinal system.

Mycoplasmataceae

The *Mycoplasmataceae* family includes the genus *Mycoplasma* of Gram stain negative bacteria. Two species from the *Mycoplasma* genus are on the AG Human and Animal Pathogens and Toxins Control List: *Mycoplasma mycoides* subspecies *mycoides SC* and *Mycoplasma capricolum* subspecies *capripneumoniae*. Both exclusively manifest disease in animals. *Mycoplasma* bacteria lack a cell wall, making them resistant to several common antibiotics (e.g., penicillin) that inhibit bacteria replication by hindering the ability of bacteria to make new cell walls.

Xanthomonadaceae

The *Xanthomonadaceae* family of plant bacteria includes the genus *Xanthomonas*. Species of *Xanthomonas* all have the ability to cause spots and blights in plants, and there are three pathogens from this genus on the AG Plant Pathogen Control List: *Xanthomonas albilineans, Xanthomonas axonopodis pv. citri,* and *Xanthomonas oryzae pv. oryzae*. These bacteria can be easily spread through manual means such as water or agricultural equipment. In addition to agricultural concern, members of the *Xanthomonas* genus are also used to produce xanthan gum, a substance with application in the cosmetic, food, and petroleum industries.

Fungi

Ascomycota

The *Ascomycota* phylum is the largest phylum of fungi with over 64,000 species. There are two species on the Human and Animal Pathogens and Toxins Control List (*Coccidioides immitis* and *Coccidioides posadasii*) and four species on the Plant Pathogens Control List (*Colletotrichum kahawae, Cochliobolus miyabeanus, Microcyclus ulei,* and *Magnaporthe oryzae*). In addition, two species appear on the Human and Animal Pathogens and Toxins Warning List: *Fusarium langsethiae* and *Fusarium sporotrichioides.* These are commonly referred to as sac fungi based on their appearance and have varying potential for harmful or beneficial effects on other organisms. *Ascomycota* includes species responsible for many pathogenic diseases but also species that produce helpful substances like antibiotics and baker's yeast.

Basidiomycota

The *Basidiomycota* phylum includes species commonly known as club fungi due to their large structures used during reproduction. Four species of *Basidiomycota* appear on the Plant Pathogens Control List: *Puccinia graminis ssp. graminis var. graminis, Puccinia striiformis, Tilletia indica,* and *Thecaphora solani.* Similar to *Ascomycota*, *Basidiomycota* contain both that are pathogenic to plants and humans, and species that are beneficial like additional types of yeast and edible mushrooms.

Oomycota

Two pathogens on the AG Plant Pathogen Control List (*Peronosclerospora philippinensis* and *Sclerophthora rayssiae* var. *zeae*) are actually categorised as protists, not fungi. Protists are considered a catch-all taxonomic kingdom for unicellular living organisms; they are too genetically different to be considered plants, animals, fungi, or bacteria. The two pathogens of concern for the AG Plant Pathogen Control List are of the genus *Oomycota*. Also known as water molds, these pathogens are considered fungus-like. *Oomycota* species look similar to fungi with the naked eye; however, they are genetically distinct, and the cell wall of water molds is made primarily of cellulose, not chitin.

Appendix F: Glossary

Note: This glossary contains terms found in this Handbook that may not be familiar to the reader and are not defined in the AG's own "Definition of Terms." Stated definitions derive from common knowledge and information gathered from both online dictionaries and Wikipedia.

Ablation
The removal of material from an object by an erosion-type process.

Absorption
The uptake of one phase into another, such as a gas into a liquid or a liquid into a solid.

Acetylcholinesterase
An enzyme that breaks down acetylcholine, a neurotransmitter needed for communication between nerve cells and their target organs but that normally is broken down after it transmits a signal. Nerve agents inhibit (i.e., prevent) activity of this enzyme; this in turn prevents the normal breakdown of acetylcholine, resulting in continuous stimulation of the target (e.g., muscles).

Active controls
A category of laboratory safety practices that require workers to actively do something for the controls to work (e.g., use of personal protective equipment).

Active pharmaceutical ingredient
The substance in a pharmaceutical drug or pesticide that is biologically active. Also known as active ingredient (AI) and active substance (in pesticide formations).

Actuation
In the context of this Handbook, actuation refers to the opening and closing of a valve (Volume I).

Administrative controls
A category of laboratory safety practices that are not physically built into a facility but are based on the policies and procedures enforced within a particular facility (e.g., escort and/or background check requirements for visitors).

Adsorption
The binding of molecules or particles to a surface. Selective adsorption of one substance in a mixture to a substrate can be used as a means of separation (i.e., in chromatographic methods).

Aerobiology
A branch of biology that studies organic particles that are passively transported by the air, such as bacteria, fungal spores, very small insects, pollen grains, and viruses.

Aerosol
A gaseous suspension of fine solid particles or liquid droplets.

Aerosolised
Existing as a gaseous suspension of fine solid particles or liquid droplets.

Affinity
An attraction or force between particles that draws them together and/or causes them to combine.

Affinity-based methods
A variety of separation processes that are based on differences in the affinity (or binding preferences) of chemicals in a mixture for different media. Also referred to as chromatographic methods.

Agent
In the context of biological weapons, an agent is a living microorganism that is pathogenic to humans, animals, or plants. Some biological agents cause harm to animals or humans by producing chemical toxins, which are poisonous in very small quantities. For more information, see the Introduction to Biological Weapons and Dual-Use Biotechnology and the Introduction to Pathogens and Toxins in Volume II of the Handbook.

In the context of chemical weapons, an agent is a toxic chemical that *could* be used as a chemical weapon. Precursors to CW agents are not considered to be CW in the context of this Handbook; instead, they are considered to be chemicals that can be used to produce CW agents. The Introduction to Chemical Weapons and Dual-Use Chemical Technology in Volume I provides a discussion of CW agent terminology and a brief overview of agent classes.

Aggregate order
An order placed with a manufacturer/supplier that is composed of a collection of individual items. In some cases, a combination of many small items may be functionally equivalent to a single larger item. For example, 10 fermenters with individual capacities of 5 litres each combine to give a total fermentation capacity of 50 litres. See the Small Fermenters secton in Volume II.

Alkaline
Related to the ability of an aqueous solution to neutralise an acid. Alkaline solutions have a pH greater than 7.

Alkyl alkanolamine
Chemical compounds that have a hydrocarbon backbone bearing both hydroxyl (-OH) and amine (-NH_2, -NHR, and –NR_2, where R is a carbon group) functional groups.

Alkylation
The transfer of an alkyl (i.e., hydrocarbon) group from one molecule to another.

Amoeba
A unicellular microorganism that does not have a definite shape.

Ampoule
A small sealed vial used to hold a sample and protect it from environmental exposure.

Anhydrous
A substance that contains no water.

Annular
Ring-shaped. In a multi-walled piping system (Volume I), this describes the space between the inner pipe carrying the fluid being transported and the outer containment pipe.

Anteroom
An outer chamber or waiting room situated before the main work room. In Biosafety Level 3 and Biosafety Level 4 facilities, the anteroom is located between the containment work area and the regular laboratory. The anteroom typically contains facilities for changing into protective suits prior to entry into the containment work area and facilities for removing protective suits and showering after exiting the containment work area.

Antibody
Protein complex found in the blood or other bodily fluids of humans and animals. Antibodies are used by the immune system to identify and neutralise foreign objects, such as bacteria and viruses.

API
See active pharmaceutical ingredient.

Aqueous
A solution in which the solvent is water.

Arthralgia
Non-inflammatory joint pain that is a symptom of infection, disease, injury, or illness.

Atomisation
The process of converting a stream of liquid into a fine spray or aerosol.

Atomiser
A device that converts a stream of liquid into a fine spray or aerosol.

Autoclavable
Manufactured of materials designed to withstand sterilisation by an autoclave (i.e., using high-pressure and high-temperature steam).

Axial
In a direction parallel to an axis. In the context of agitators (Volume I), axial mixing occurs along the same direction as the agitator shaft's orientation.

Bacteria
A unicellular microorganism. With few exceptions, bacteria are independent living microorganisms that are not dependent on another organism for replication.

Baffle
A structure inside a chemical reaction vessel used to disrupt the flow of its contents to promote mixing.

Base metal
The primary metal in an alloy.

Basic scientific research

The AG defines basic scientific research as "experimental or theoretical work undertaken to acquire new knowledge of fundamental principles of phenomena or observable facts, not primarily directed towards a specific practical aim or objective."

Batch operation

A method of operation that requires distinct start and end points to the process. Data or products are collected at the end of the process as part of individual batches. Following collection, the process may be restarted.

Binary fission

Reproduction of a bacterium where the microorganism divides itself into two independent cells.

Biodegradation

The chemical dissolution of materials by microorganisms or other biological means, returning the material to the form of components found in nature.

Biological weapon

A weapon that delivers toxins or microorganisms, such as viruses and bacteria, with the intent of deliberately causing disease and inflicting destruction among people, animals, or agriculture.

Biopesticide

A form of pesticide based on microorganisms or natural products.

Bioreactor

An apparatus used to carry out any kind of bioprocess. See fermenter an chemostat. See also the section on Fermenters in Volume II.

Bioremediation

Any process using microorganisms, fungi, green plants, or their enzymes to return a natural environment altered by contaminants to its original condition.

Biovar

A group of strains distinguishable from other strains of the same species on the basis of their physiological characteristics.

Biphasic disease

A disease that has two distinct phases. For example, patients who are infected with *Omsk hemorrhagic fever virus* can experience biphasic expression of the disease. Initially, patients experience symptoms typically associated with mild viral hemorrhagic fever. After symptoms subside and the patient seems to have recovered from the virus, a second set of symptoms including fever and encephalitis can develop.

Blister agent

See vesicant.

Blood agent
A type of chemical weapons agent that acts by interfering with oxygen transport from blood to body tissues (e.g., hydrogen cyanide and cyanogen chloride). See the Volume I Introduction to Chemical Weapons and Dual-Use Chemical Technology.

Blood fraction
An end product of separating blood (by centrifugation) into its component parts. These blood fractions include blood plasma, white blood cells, and red blood cells.

Blood plasma factor
Blood plasma factors are proteins that regulate the ability of blood to clot and are very important in the process of minimising blood loss after a wound.

Brackish water
Water that is higher in salt content than freshwater but lower in salt content than ocean water. This occurs naturally in tidal estuaries where fresh and salt water mix.

Bung hole
A hole bored in a liquid-tight barrel to remove contents.

Carbide
A compound of carbon with another element, namely an element that attracts electrons more strongly than carbon does. Silicon carbide and titanium carbide are two examples and are considered ceramics.

Carboy
A rigid container with a typical capacity of 20–60 litres (5–15 gallons). Carboys are primarily used for transporting fluids.

CAS#
A unique registry number assigned to each chemical by the Chemical Abstract Service (CAS). See Appendix C in Volume I for more details.

Catalyst
A substance that causes a chemical reaction to happen more quickly.

Caustic
Able to burn or corrode organic tissue by chemical action.

CDA
See controlled droplet application.

Centrifugal force
Force generated by rotation and experienced as outward force away from the centre of rotation.

Centrifugal separator
Also called a centrifuge. A machine used to separate components with varying density using the centrifugal force generated by high-speed rotation. See the Volume II section on Centrifugal Separators.

Ceramic
An inorganic, nonmetallic solid. Ceramics are generally known for their corrosion resistance, strength, hardness, and high thermal conductivity.

Chemical neutralisation
A chemical weapons destruction method that involves the mixing of chemical weapon agents with hot water or hot water and sodium hydroxide to convert the agents into less-harmful chemicals.

Chemical reaction
A process that transforms one set of chemical molecule(s) to another with distinctly different chemical identities.

Chemical synthesis
A sequence of chemical reactions conducted to obtain a product, or several products. Often this involves the construction of complex chemical compounds from simpler ones.

Chemical weapon
In the context of this Handbook, a toxic chemical loaded into a delivery system such as a munition (i.e., a complete device for exposing a population to a substance that can cause death or other injuries through its chemical action).

Chemical weapon (CW) agent
A toxic chemical that could be used as a chemical weapon. See the Introduction to Chemical Weapons and Dual-Use Chemical Technology in Volume I for an extensive discussion of CW agent-related terminology.

Chemostat
A bioreactor in which constant growth conditions for microorganisms are maintained over prolonged periods of time by supplying the reactor with a continuous input of nutrients and continuous removal of growth medium and waste products. See the section on Fermenters in Volume II.

Chlor-alkali
An industrial process involving the electrolysis of brine (salt water) to generate other chemicals; products can include hydrogen gas, chlorine, sodium hydroxide (caustic soda), sodium chlorate, and/or sodium hypochlorite (bleach), depending on the specific methods used.

Chloroplast
Specialised sub-cellular compartment within plant or algae cells where photosynthesis takes place.

Choking agent
A type of chemical weapons agent that acts by damaging lung tissue, leading to pulmonary edema. See the Volume I section Introduction to Chemical Weapons and Dual-Use Chemical Technology.

Cholinesterase inhibition
The inhibition of the breakdown of acetylcholine. See acetylcholinesterase.

Chromatographic methods
Laboratory techniques used to separate mixtures. See affinity-based methods.

Chromosome
A mixture of nucleic acid (DNA or RNA) and protein located in the nuclei of cells.

Clarify
To make a liquid clear or pure, usually by freeing it from suspended matter.

Clean room
A room with a controlled environment and constant, highly filtered airflow. It has a very low level of pollutants, dust, airborne microbes, aerosol particles, or chemical vapours. Biosafety Level 3 and Biosafety Level 4 facilities (see Volume II) are examples of clean rooms, but clean rooms are also widely used in the electronics industry or in any application where dust elimination is required.

Colourimetric
A technique in which the concentration of a chemical element or compound in a mixture is determined by measuring a colour change or the absorption of light in a particular colour range.

Commensalism
An association between two organisms in which one benefits and the other derives neither benefit nor harm.

Condensation
The change of a physical state of matter from a gas into a liquid.

Condenser
A device used to remove heat from a liquid or vapour, causing it to cool and transform to a solid or liquid, respectively.

Conjunctivitis
Inflammation and/or infection of the eye and inner surface of the eyelids.

Controlled droplet application
A spraying technology that produces an aerosol of uniform droplet size. This technology allows droplet size to be altered to known droplet diameters so one can achieve the “optimum” size for an intended application.

Copolymer
A polymer derived from more than one type of monomer.

Corrosive
A characteristic of a chemical that will destroy or damage other substances with which it comes into contact.

CRISPR-Cas
A system of molecular tools and a laboratory technique that facilitates cutting of an organism’s DNA or RNA in a robust and sequence specific manner. Subsequent cellular repair of this break in the nucleic acids can result in the incorporation of a change or an “edit” to the nucleic acid sequence.

Cross-flow filtration

A filtration technique where the material to be filtered passes tangentially across (not perpendicular to) the filter surface, minimising fouling and clogging of the filter. Also called tangential flow filtration. See the Volume II section on Cross (Tangential) Flow Filtration.

Crystallisation

The process of forming solid crystals from a gaseous or liquid solution.

Culling

The process of removing animals from a group based on specific criteria. For the purposes of the AG Handbook, culling is a containment strategy that refers to the slaughtering of animals affected with or potentially exposed to controlled pathogens to prevent further spread of the disease.

Cultivar

A race or variety of plant that has been created or intentionally chosen and maintained in a population through cultivation. For example, farmers may preferentially grow a particular cultivar of rice that produces a higher crop yield or is more resistant to environmental stressors (e.g., temperature).

Cyanobacteria

Bacteria that obtain nutrients through photosynthesis. These bacteria are also known as blue-green algae.

Dead-end host

Any host from which a pathogen cannot escape to continue its life cycle. Once in a dead-end host, the pathogen is not transmissible from that host to another organism.

Decanter centrifuge

A type of centrifuge that features a horizontal spinning metal bowl encased in another metal housing. A scroll or screw conveyor within the bowl rotates at a different speed than the bowl and removes separated solids for discharge. See the Volume II section on Centrifugal Separators.

Dehydration

In the context of freeze- or spray-drying, dehydration refers to the removal of water or other fluids from a solid by evaporation. See the Volume II sections on Freeze-Drying Equipment and Spray-Drying Equipment.

Demilitarisation

The reduction of a nation's armed forces, weapons, and/or military vehicles to an agreed maximum. In the context of this Handbook, demilitarisation is used to refer to the destruction of CW agents, precursors, and/or munitions.

Density

Mass per unit volume. Density is a measure of the "heaviness" of an object when comparing it to another object of a similar volume.

Development

In reference to development technology, the AG defines development as "related to all stages before 'production' such as: design, design research, design analysis, design concepts, assembly of prototypes, pilot production schemes, design data, process or transforming design data into a product, configuration design, integration design, and layouts."

Dewatering
The process of removing water from a solid by centrifugation or filtration.

Diaphragm
A flexible membrane. In the context of the AG, this refers to a type of seal-less pump (Volume 1) that uses the reciprocating action of a diaphragm to cause pumping action.

Disinfection
Destruction of pathogenic and other types of microorganisms. Disinfection is less lethal than sterilisation because it destroys most recognised pathogenic microorganisms but not necessarily all microbial forms (e.g., bacterial spores).

Disk stack centrifuge
This centrifuge design features a prominent conical metal bowl with at least three connections – one feed inlet and two outlets. The inside of the metal bowl contains not only the spinning part of the centrifuge, but also a stack of disks to assist the separation. See the Volume II section on Centrifugal Separators.

Dissolution
The process of a solute forming a solution with a solvent.

Distillation
A separation technique based on differences in boiling points between different components of a chemical mixture. See the Introduction to Chemical Weapons and Dual-Use Chemical Technology in Volume I for more details.

DNA
An acronym for deoxyribonucleic acid. DNA is a self-replicating material present in nearly all living organisms that carries a species' genetic information.

Dopant
A trace impurity element that is inserted into a material in order to alter the electrical or optical properties of that material. Also known as a doping agent.

Downcomer
In the context of distillation columns, a pipe used to facilitate the movement of liquid to lower sections of the column. See the Volume I section on Distillation or Absorption Columns.

Drift spraying
A spraying application where the particles generated are intended to "drift" for an extended period of time, covering a wide area. Drift spraying typically uses smaller particles.

Dual-use
The potential of products and technologies with peaceful civilian purposes to be used in applications related to weapons of mass destruction.

Dystonia
A neurological movement disorder characterised by sustained muscle contractions, which result in repetitive movements and uncontrollable twisting.

EC#
The European Commission (EC) number is a reference number for chemicals listed in the EC Inventory. See Appendix C in Volume I for more details.

Eccentrically
Describes the motion of a disk or wheel having its axis of revolution displaced from its centre so that it is capable of imparting reciprocating motion. In the context of this Handbook, this refers to the orientation of liquid ring pump impellers that are mounted offset from the casing axis.

Effluent
Liquid or gas that flows out from a larger body of liquid or gas.

Elastomer
A polymer with the elastic properties of natural rubber.

Electrochemical detection
A sensitive and selective detection technique that is based on oxidising or reducing parts of a chemical's structure.

Electrolysis
A method of using a direct electric current to drive a chemical reaction.

Electronegativity
A property describing the tendency for an atom or group of atoms to draw electrons toward itself. An atom that is more electronegative than its neighboring atoms in a molecule will attract more electrons toward it.

Elution
The process of removing an adsorbed component from a substrate by washing with a solvent to which the component has more affinity than the adsorbent.

Emulsion
A mixture of two or more immiscible liquids, which cannot form a homogeneous solution.

Encephalitis
Inflammation and swelling of the brain.

Encephalomyelitis
Inflammation and swelling of the brain and spinal cord.

Endemic
Commonly found within a particular population or in a certain geographic area.

Engineering thermoplastics
A group of plastic materials that have better mechanical and/or thermal properties than other commonly used plastics. Engineering thermoplastics are generally used in applications that better heat resistance, chemical resistance, impact, fire retardancy, or mechanical strength than common plastics.

Entrainment pump
A type of pump that functions by moving the process fluid via the movement of another fluid.

Enzyme
Biological molecules, usually proteins, that can cause specific chemical changes to a separate molecule.

Excipient
An inactive substance mixed with the "active" material (e.g., an active pharmaceutical ingredient or a pathogen) to be dried and preserved. Excipients typically improve the preservation of biological material without disrupting its activity.

Exotoxin
A toxin naturally secreted by certain bacteria. By contrast, an endotoxin is a toxin produced by bacteria that is only released when the bacteria breaks apart and dies.

Extraction
The process of removing something from a mixture or compound. In the context of purification, this term often refers to extraction of a desired compound from a mixture through the use of immiscible solvents. See the discussion of purification in the Volume I section, Introduction to Chemical Weapons and Dual-Use Chemical Technology.

Extrusion
In the context of this Handbook, a method of encapsulation whereby the material to be coated is drawn through a nozzle to form microcapsules. Several types of extrusion methods are practiced, differing by nozzle configuration and coating method. See the Volume II section on Encapsulation Equipment and Technology.

Family
The next taxonomic category above genus, usually ending in -idae (animals) or -aceae (plants).

Feedstock
A raw material or solution from which a product is made. In spray-drying, the liquid to be atomised and dried into powder. See the Volume II section on Spray-Drying Equipment.

Fermenter
A bioreactor that enables optimal fermentation conditions to be maintained, allowing addition of nutrients, removal of products and insertion of measuring and/or control probes as well as other necessary equipment (for heating, cooling, aeration, agitation, sterilisation, etc.) under sterile conditions. See the Volume II section on Fermenters.

Filtrate
Following a filtration process, the part of a solution that is left after unwanted material is removed.

Flame photometric detector

A detector used to detect compounds containing sulphur or phosphorus utilising chemiluminescent reactions. It can also be used to detect certain metals.

Flocculant

A substance added to a suspension to clarify it by enhancing the aggregation of the suspended particles, causing them to drop out of the solution.

Fomite

A living or inanimate object that may be contaminated with infectious organisms and facilitate their transmission to a susceptible host.

Fouling

The accumulation of unwanted solid material on a filter, which decreases performance of the filter.

Fungi

A group of unicellular and multicellular organisms (e.g., molds, yeast, and mushrooms) that feed on organic matter as their source of nutrients.

Fungicide

A chemical substance that kills or inhibits the growth of fungi.

G-series nerve agent

A group of nerve agents so named because German scientists were the first to synthesize them. See the Volume I Introduction to Chemical Weapons and Dual-Use Chemical Technology.

Galvanised

The process by which a zinc coating is added to iron or steel to prevent rusting.

Gas chromatography

A chromatographic method used to separate and analyse mixture components by vapourising the mixture and passing it through a column with coated walls or packing. Different mixture components have different affinities for the wall or packing material, which affects the speed at which they travel through the column.

Gas tight

A measure of airtightness defined as preventing the passage of gas or aerosols, up to a particular pressure rating and over a particular length of time.

Gastroenteritis

Inflammation of the lining of the intestines that can be caused by a pathogen. Symptoms can include abdominal pain, diarrhea, vomiting, headache, fever, and chills.

Genetically modified

An organism that has had intentional changes introduced into its genetic material (DNA or RNA).

Genome
The entirety of an organism's hereditary information found in a cell and encoded by DNA or RNA.

Genus
A taxonomic category that ranks above species and below family.

Germicidal
The capability to kill or reduce germs, especially pathogenic microorganisms.

Germination
The process by which plants, fungi, and bacteria emerge from seeds and spores and begin to grow.

Graphite
A form of carbon that can exhibits high corrosion resistance and excellent thermal conductivity.

Halogen specific detector
A selective detector for halogenated compounds (i.e., compounds containing fluorine, chlorine, and/or bromine).

Hazard Class
A designation assigned to each entry in the UN Dangerous Goods List of the United Nations Recommendations on the Transport of Dangerous Goods. The Hazard Class assigns material to a general category of chemical or physical hazards (e.g., Hazard Class 3 indicates flammable liquids). See the Volume I section on Chemical Packaging and Transportation.

Head
An end cap on a chemical reaction vessel or heat exchanger that provides ports for connection of piping or instruments. See the Volume I sections on Chemical Reaction Vessels or Reactors and Heat Exchangers or Condensers.

Heat transfer area
The total area in a heat exchanger or condenser over which thermal transfer occurs (e.g., the surface area of the tube bundle in a shell and tube heat exchanger design). See the Volume I section on Heat Exchangers and Condensers.

HEPA
See high efficiency particulate air.

High efficiency particulate air
A type of air filtration system or filter rated to remove at least 99.7% of airborne particles 0.3 μm in diameter.

High vacuum
Describes a pressure range lower than medium or low vacuum systems; high vacuum pumps are able to pump more molecules out of a chamber than medium or low vacuum pumps, giving a "high" degree of vacuum. Definitions for the pressure range can vary, but are often in the 1×10^{-1} to 1×10^{-7} Pascal range.

Host
An organism that is susceptible to or harbours a pathogen under natural conditions.

Host cell
Viruses lack the ability to reproduce or replicate on their own. Therefore, viral replication depends on using the replication machinery of another cell. The cells that viruses use to reproduce are called host cells.

Host range
The geographical and/or species distribution that is susceptible to an infectious agent under natural conditions.

Hygroscopic
The ability of a substance to draw and retain water molecules from the surrounding environment.

IBC
See intermediate bulk container.

Immiscible
Unable to form a uniform solution or mixture when combined.

Impervious
Describes a characteristic of a substance that does not allow liquids to pass through it.

Impregnated
Describes a material in which another substance is embedded throughout to reduce porosity (i.e., block pores so that fluids do not penetrate the material).

In situ
Latin phrase meaning "in the place." In biology, this term refers to examining an event exactly in the place it occurs. Thus, "*in situ* steam sterilisation" of a fermenter refers to steam sterilisation that takes place inside the fermenter.

In the public domain
The AG defines this as "technology or software that has been made available without restrictions upon its further dissemination. (Copyright restrictions do not remove technology or software from being in the public domain)."

Incapacitant
A chemical (e.g., tear gas) used to temporarily incapacitate individuals. See the Volume I Introduction to Chemical Weapons and Dual-Use Chemical Technology.

Incineration
The destruction of chemicals or other materials by burning at very high temperatures.

Industrial scale
Refers to production or manufacturing on a large (often commercial) scale or equipment that is capable of enabling large-scale production (e.g., a 1000-litre fermenter would be considered a piece of industrial-scale

equipment, while a 5-litre fermenter would be considered laboratoryscale). This is on the opposite end of the production spectrum from laboratory scale.

Infection control zone

An area of infection control, usually a room in a hospital, most frequently used to isolate a patient with an illness easily spread by physical contact or through the air. This is accomplished by HEPA filtering the air and making air flow into the room (negative pressure). An infection control zone can also protect a patient from infection by setting filtered air to flow out of a room (positive pressure).

Infectivity

The ability of a pathogen or a biological agent to establish an infection.

Inhibition

The process of stopping or retarding a chemical reaction (e.g., inhibition of acetylcholinesterase by a nerve agent).

Inoculation

The process of introducing a pathogen into a living organism. When referring to production of large quantities of a pathogen (e.g., growing bacteria in a fermenter), it can also refer to the process of introducing a pathogen to suitable media to facilitate growth.

Inoculum

The biological sample used as starting material for growth of microorganisms or viruses. Inocula are used for legitimate production of pharmaceutical or bacterial products (such as vaccines, insulin, or ethanol), but also can be used for illegitimate production of a biological weapon agent or toxin.

Intangible technology transfers

Transfers of technologies that are not physically tangible or tactile (e.g., software, program, and code transmission).

Interfacial polycondensation

A method used to produce microcapsules, in which a chemical reaction occurs at the interface between a droplet and the liquid in which it is suspended, resulting in the formation of a capsule surrounding the remaining compound. See the Volume II section on Encapsulation Equipment and Technology.

Interferon

A protein made and released by cells in response to the presence of a pathogen, that can include viruses, bacteria, other parasites, or even cancerous cells. Interferons are communication signals between cells that trigger protective actions of the immune system to destroy pathogens or cancerous cells.

Intermediate bulk container

A reusable industrial container designed for the storage and transport of bulk substances (e.g., food, pharmaceuticals, and chemicals).

Inter-modal container

See ISO container

Ion mobility spectroscopy

An analytical method used to separate and identify ionised molecules in the gas phase based on differences in their mobility in a carrier gas.

ISO container

International Organization for Standardization (ISO) containers are designed for transport by more than one mode (e.g., truck and rail); hence they are also known as inter-modal containers. There are several standard types of ISO containers. Tank-style ISO containers are used to transport chemicals and are composed of a tank mounted inside a rectangular metal rack. For example, see Figure 45.C in the Volume I Chemical Weapons Precursors entry on sodium cyanide.

ITT

See intangible technology transfers.

Jacketed

Describes a vessel design in which there are separated inner and outer walls; fluid can be circulated between the walls for temperature control. See the Volume I section on Chemical Reaction Vessels or Reactors.

Laboratory scale

Refers to experiments conducted on a small scale or items of a size appropriate for such experiments (e.g., a 5-litre fermenter would be considered laboratory scale, while a 1000-litre fermenter would be considered industrial scale). This is on the opposite end of the production spectrum from industrial scale.

Laryngitis

Swelling, irritation, and/or inflammation of the larynx (voice box). This is usually associated with hoarseness and/or loss of voice.

LC_{50}

Lethal concentration, 50%. The concentration of a chemical, pathogen, or toxin in air needed to kill 50% of exposed and unprotected animals via inhalation.

LD_{50}

Lethal dose, 50%. The amount of liquid or solid needed to kill 50% of exposed and unprotected animals. Typically expressed as milligrams (mg) of chemical, pathogen, or toxin per kilogram (kg) of animal body weight. LD_{50} values can be reported for any route of exposure such as dermal, oral, inhalation, or injection.

Lentogenic

Describes the virulence of a virus that causes a mild or minor infection in its host.

Lighter than air vehicle

An aerospace vehicle that stays aloft primarily through use of an envelope or balloon filled with a gas lighter than air (e.g., helium).

Low vacuum

Describes a pressure range higher than medium or high vacuum systems; low vacuum pumps pump fewer molecules out of a chamber than high or medium vacuum pumps, giving a “low” degree of vacuum. Definitions for the pressure range can vary, but are usually just below atmospheric pressure in the 1×10^5 to 3×10^3 Pascal range.

Lyophilisation

A dehydration process used to stabilise nearly any perishable material in order to increase its shelf life and reduce its sensitivity to environmental stresses. Also known as freeze drying. See the Volume II section on Freeze-Drying Equipment.

Lyophiliser

Another name for a freeze dryer. See the Volume II section on Freeze-Drying Equipment.

Manifold

A chamber having several outlets through which liquid or gas is distributed or gathered.

Manway

A port or opening through which a human can pass. See the Volume I section on Chemical Reaction Vessels or Reactors.

Material Safety Data Sheet

See Safety Data Sheet.

Media

Liquid or solid material containing nutrients needed to grow microorganisms.

Medium vacuum

Describes a pressure range lower than low vacuum systems, but not as high as high vacuum systems; medium vacuum pumps are able to pump more molecules out of a chamber than low vacuum pumps but not as many as high vacuum pumps, giving a "medium" degree of vacuum. Definitions for the pressure range can vary, but are often in the 3×10^{3} to 1×10^{-1} Pascal range.

Meningitis

An infection and inflammation of the protective tissues surrounding the brain and spinal cord.

Meningoencephalitis

A medical condition that simultaneously resembles both meningitis (inflammation of the protective tissues surrounding the brain) and encephalitis (inflammation of the brain).

Mesogenic

Describes the virulence of a virus that causes moderate to severe infection in its host.

Microorganism

Also known as a "microbe." An organism that is too small to be seen with the human eye. Microorganisms are very diverse and include bacteria, fungi, protists, microscopic plants (green algae), and microscopic animals (e.g., plankton). Most microorganisms are single-cell organisms. Viruses meet the size definitions of microorganisms, but they are considered nonliving when separated from the host they require for replication. Although most microorganisms in the environment are not harmful, some are especially dangerous, causing lethal or severely debilitating diseases in humans, animals, or plants. Many disease-causing microorganisms can pose a biological weapons threat. See the Volume II Introduction to Pathogens and Toxins.

Microprogram
The AG defines this as "A sequence of elementary instructions maintained in a special storage, the execution of which is initiated by the introduction of its reference instruction into an instruction register."

Midge
A small flying insect that closely resembles a mosquito.

Miscible
Capable of being mixed to form a uniform solution or mixture.

Mist eliminator
A device designed to separate liquid droplets from a gas phase.

Mole
A unit of measurement in chemistry defined as 6.022×10^{23} electrons, ions, atoms, or molecules.

Momentum-transfer pump
A pump that moves gas molecules from the inlet to the discharge side by imparting momentum to the molecules to "push" them toward the exhaust.

Monoclonal antibody
Globular proteins found in blood or other bodily fluids of humans and animals. They are used by the immune system to identify and neutralise foreign objects, such as bacteria and viruses.

Monomer
A term applied to a molecule or that can react with itself or other monomers to form a polymer.

Morbidity rate
A measure of the frequency of occurrence of disease in a defined population during a specific period of time. For a specific disease, the morbidity rate describes the average percentage of diseased individuals given the total number of individuals exposed to a pathogen.

Mortality rate
A measure of the frequency of occurrence of death in a defined population during a specific period of time. For a specific disease, the mortality rate describes the average percentage of deaths given the total number of individuals infected.

MSDS
See Safety Data Sheet.

Multi-fluid nozzle
A device used, primarily in pharmaceutical spray dryers, to atomise a liquid feedstock by contacting the liquid feed with pressurised gas. The interaction of high-velocity gas and low-velocity liquid leads to the atomisation of the liquid. See the Volume II section on Spray-Drying Equipment.

Mutation rate
A measure of the rate at which changes occur in DNA or RNA over a specific period of time.

Nameplate
A label or engraving affixed to the outside of industrial equipment. Typically provides important information such as the manufacturer name and model number.

Necrotic
Describes death of cells or tissues that generally occurs through injury or disease.

Negative pressure
Pressure within a system that is less than that of the environment surrounding it. Consequently, a leak in a negatively pressurised system will not allow air to escape into the surrounding environment. Biological Safety Cabinets designed to protect workers from exposure to biological agents operate under negative pressure relative to their larger environment. See the Volume II section on Protective and Containment Equipment.

Nerve agent
A group of chemical weapon agents that inhibit the action of the enzyme acetylcholinesterase. Inhibition of acetylcholinesterase causes continuous stimulation of target organs, which primarily include muscles. Physical symptoms of nerve agent exposure include pupil constriction, muscle paralysis, and death due to respiratory failure – all due to the muscles' inability to relax or stop constricting. See the Volume I Introduction to Chemical Weapons and Dual-Use Chemical Technology.

Neurotoxin
Toxins that target the nervous system and disrupt signaling that allows neurons to communicate effectively with other neurons and their target organs, such as muscle.

Neurotransmitter
A chemical produced in nerve cells that transmits signals between nerve cells.

New World
The geographic part of the world referring to North and South America.

Nucleic acid
A large macromolecule that encodes genetic information in the form of DNA or RNA. See also oligonucleotide.

Old World
The geographic part of the world referring to Europe, Asia, Africa, and Australia.

Oleochemistry
The study of vegetable oils, animal oils, and fats.

Oligonucleotide
A short polymer of nucleotides (also called DNA bases), typically from 20 to 200 nucleotides. Oligonucleotides are short pieces of DNA.

Ore floatation
The process by which valuable minerals are separated from other valuable or less valuable materials by grinding the ore into small particles and submerging them in water. Materials are separated based on how they float or are suspended in the solution.

Organophosphorus
Describing organic compounds containing carbon-phosphorus bonds.

Overwintering
To last through or pass the winter. For example, although many pathogens are susceptible to temperature extremes, *Synchytrium endobioticum* that causes potato wart will stay viable in the soil for up to 30 years.

Oxidant
Also known as an oxidising agent, an oxidant is the compound in an oxidation-reduction reaction that accepts an electron from another compound.

Oxide
A compound that contains oxygen and one other element.

Packing Group
A designation assigned to entries in the UN Dangerous Goods List of the United Nations Recommendations on the Transport of Dangerous Goods. The Packing Group designates the risk level of an item intended for shipment. Specific shipping requirements for an item may vary based on Packing Group assignment (e.g., certain items may have an increased risk level and Packing Group assigned for shipments with larger quantities). See the Volume I section on Chemical Packaging and Transportation.

Particulate
A general term for tiny pieces of solid or liquid matter associated with the atmosphere. Often the tiny pieces are suspended as an aerosol.

Passive controls
A category of laboratory safety practices that are built into a facility and do not require active participation from employees to work (e.g., air monitoring devices).

Pathogen
An infectious agent or microorganism that causes disease in its host. The Australia Group Common Control Lists list pathogens that cause disease in humans, animals, and plants. See the Volume II sections on Human and Animal Pathogens and Toxins and Plant Pathogens.

Pathogenic
Disease causing.

Pathogenicity
The potential of a particular microorganism to cause disease. Often, pathogenicity is characterised by the mechanism of infection, whether the microorganism produces a toxin, and the ability of medical treatment to reverse the disease.

Peptide
A short polymer of amino acids. Thus, a "polypeptide" is a small protein.

Periodic table
A table that organises elements based on their atomic number, electron configuration, and similar chemical properties.

Phase
The physical state of a substance (e.g., liquid, solid, or gas). Transitions between physical phases do not involve a change in the chemical composition of the material.

Phase separation
A process used to form microcapsules. Occurs when the compound used to form the coat of the microcapsule is induced to change phases from liquid to solid and coat the core material as a result. See the Volume II section on Encapsulation Equipment and Technology.

Phosphorylating
Phosphorylation is the chemical addition of a phosphate group (PO_4) to a molecule.

Photoionisation detection
A type of gas detector that measures volatile compounds in very small concentrations by ionising them and detecting the resulting electric current.

Photosynthesis
A process used by plants and other organisms to convert light energy into chemical energy.

Pickling
The process of removing impurities (e.g., rust) from the surface of metals using a solution containing strong acids.

Pilot scale
A scale that facilitates the transition from laboratory scale to industrial scale production. Pilot scale equipment is intermediate in size between laboratory- and industrial-scale equipment.

Plasmid
A small circular DNA molecule.

Plasticiser
Additives that increase the fluidity and plasticity of a material.

Polymer
A large molecule that contains multiple repeating subunits or monomers. Large polymers are also known as macromolecules.

Polymerase chain reaction or PCR
A laboratory technique used to make multiple copies of a segment of DNA. PCR is very precise and can be used to amplify, or copy, a specific DNA target from a mixture of DNA molecules.

Polysaccharide
A polymer of carbohydrates used to store energy or provide structure. Examples include starch or cellulose.

Pore
A hole in a filter membrane that allows passage of items smaller than the pore size through the filter. See the Volume II section on Cross (Tangential) Flow Filtration Equipment. May also refer to a hole found in the surface of a plant (see stomata) or holes in a bulk material's structure (see impregnated).

Positive displacement pump
A class of pumps that rely on internal moving parts to create an expanding cavity on the inlet side, trap incoming gases, compress them by shrinking the cavity, and release them out the discharge side.

Positive pressure
Pressure within a system that is greater than that of the environment surrounding the system. Consequently, a leak in a positively pressurised system will allow air into the surrounding environment. Suits designed to protect workers from exposure to biological agents have a tethered air supply operating under positive pressure. See the Volume II section on Protective and Containment Equipment.

Potentiometric
Describing a type of chemical analysis used to determine the concentration of a particular component of a solution by measuring the voltage of the solution.

Precursor
A chemical that can be used to produce another chemical via chemical reaction. In the context of the Handbook, this term refers to a chemical that can be used to make a chemical weapon agent. Also generally known as a reactant.

Pressure nozzle
A device used to atomise a liquid feedstock by forcing the liquid to exit a small-diameter opening under high pressure. See the Volume II section on Spray-Drying Equipment and Spraying and Fogging Equipment.

Probiotic
A microorganism that is believed to provide health benefits when consumed.

Product lot
A specific batch of material from a single manufacturer, typically identified by a unique identification number.

Production
The AG defines this as "all production phases such as: construction, production engineering, manufacture, integration, assembly (mounting), inspection, testing, and quality assurance."

Program
The AG defines this as "A sequence of instructions to carry out a process in, or convertible into, a form executable by an electronic computer."

Proper Shipping Name
A name assigned to each entry in the UN Dangerous Goods List of the United Nations Recommendations on the Transport of Dangerous Goods. See the Volume I section on Chemical Packaging and Transportation.

Protist
A catchall taxonomic kingdom for unicellular living organisms. Protists are grouped in their own kingdom because member species are too genetically different to be considered plants, animals, fungi, or bacteria.

Proton scavenger
A compound that reacts with free protons in a solution to form a compound that will not undergo further reaction.

Pulmonary edema
An accumulation of fluid in the lungs that leads to shortness of breath and can lead to respiratory failure.

Purification
The process of isolating a desired chemical product from a mixture of substances.

Race
In the context of plant biology, a group of plants having similar characteristics that distinguish them from other plants within the same species. For example, the plant pathogen Ralstonia solanacearum, race 3, biovar 2 is controlled by the AG, but other races and biovars are not. The species is divided into race based on the host range and further subdivided into biovar to distinguish between subtle differences in metabolic pathways that contribute to the pathogenicity of the agent.

Radial
Radiating from a central point. In the context of agitators (Volume I), radial mixing occurs perpendicular to the agitator shaft's orientation (i.e., outward from the shaft).

Reactant
Also known as a precursor, reactants are combined and undergo a chemical reaction to generate a desired chemical known as the product.

Reboiler
A heat exchanger used to provide heat to an industrial-scale distillation column.

Recombination
The process by which pieces of an organism's genome (DNA or RNA) are broken and rejoined.

Reflux
The portion of condensed vapour returned to the distillation column during distillation.

Reservoir
The habitat in which a pathogen normally lives (e,g., animals, humans, or the environment).

Retentate
In a filtration process, the part of a solution that does not cross the membrane.

Reverse osmosis

A filtration method that removes many types of large molecules and ions from solutions by applying pressure to the solution when it is on one side of a selective membrane. As a result, the solute is retained on the pressurised side of the membrane and the pure solvent is allowed to pass to the other side. To be selective,this membrane should not allow large molecules or ions through the pores (holes), but should allow smaller components of the solution (such as the solvent) to pass freely. Reverse osmosis is most commonly known for its use in purifying drinking water from seawater, removing the salt and other substances.

RNA

An acronym for ribonucleic acid. RNA is a genetic material present in all living cells. RNA acts as an intermediary carrying instructions from DNA to synthesize proteins in the cell. Some viruses have RNA as the primary carrier of genetic information in place of DNA.

Rotary atomiser

A device used to atomise a liquid feedstock by contacting the liquid with a spinning wheel containing tiny holes for atomised particles to exit. The design of the wheel and its rotational speed dictate the final properties of the resulting aerosol. See the Volume II sections on Spray-Drying Equipment and Spraying and Fogging Systems.

Rough vacuum

See low vacuum.

Safety Data Sheet

A document identifying hazards posed by a chemical and measures to mitigate them.

Sanitary connection

A type of fitting that is durable and easily cleaned to promote sanitary conditions in biological processing.

Scrubbing

The process of chemically removing impurities from a gas.

Sedge

A plant that resembles grass and grows in moist environments.

SDS

See Safety Data Sheet

Shaft seal

A seal located where a rotating or reciprocating drive shaft passes through a pump body.

Skimming

The process of separating a liquid or solid from the top of a liquid, e.g. in the removal of cream from milk.

Software

AG defines software as “a collection of one or more ‘programs’ or ‘microprograms’ fixed in any tangible medium of expression.”

Solubility
The ability of a substance to dissolve in a given solvent (usually a liquid) and form a homogeneous solution.

Solvent
The liquid or other substance in which a solute is able to be dissolved to form a solution.

Solvent purification/reclamation
The process of purifying and isolating a previously used solvent in order to recycle it for reuse.

Souring
In the context of laundry, an acidic solution used to neutralise alkalinity in textiles.

Spastic paralysis
A condition in which muscles undergo persistent spasms and exaggerated reflexes because nervous system control of the muscles has been disrupted or altered.

Species
A group of living organisms with similar characteristics that is capable of exchanging genetic material and interbreeding. It is a taxonomic unit that ranks below a genus.

Spore
An inactive form of a microorganism, particularly a bacterium or a fungus, that can survive for a long time in harsh environmental conditions. Spores can reactivate upon exposure to an environment that supports growth (e.g., an environment containing water and nutrients).

Sporulation
The process by which bacteria or fungi form spores.

Spray chilling
Also known as spray congealing, a method of producing microcapsules by atomising a solution of core and matrix materials into a stream of cold gas, solidifying liquid droplets into particles.

Steam distillation
A type of distillation used for temperature-sensitive materials. Steam distillation introduces water or steam into the system to lower the boiling points of compounds, allowing them to evaporate and separate at lower temperatures.

Sterilisable
Manufactured of materials capable of withstanding processes used to kill all microorganisms. Typically, this means construction of materials that withstand high-pressure and high-temperature steam.

Sterilisation
A validated process used to render a product free of all forms of viable microorganisms. Sterilisation is more powerful than disinfection because it destroys all microbial forms of microorganisms (e.g., bacterial spores and bacteria).

Stomata
A pore found on the surface of a plant that is used to control gas exchange.

Strain
A highly specific taxonomic rank used to describe a group of organisms of the same species with similar characteristics that are distinct from other members of the same species.

Sublimate
To transition a substance from the solid phase to the gas phase without passing through an intermediate liquid phase.

Surface acoustic wave spectroscopy
In the context of chemical detection, the detection of gases through selective absorption by measuring acoustic vibrations that change based on the chemical absorbed.

Surfactant
A compound that decreases the surface tension between a liquid and a solid or between two liquids. Surfactants can be used, for example, as emulsifiers, detergents, wetting agents, or dispersants.

Synthetic biology
A field of study that applies engineering principles to the fundamental components of biology. Goals include the design and construction of new biological parts, devices and systems and the re-design of existing natural biological systems for useful purposes.

Taxonomy
The branch of science concerned with classification, especially of organisms. Biological classification is a method used to group organisms with other similar organisms. The groups most typically used to classify organisms are (from largest to smallest): domain, kingdom, phylum, class, order, family, genus, and species.

Technical assistance
According to the AG, this "may take forms such as: instruction, skills, training, working knowledge, consulting services. Technical assistance may involve transfer of 'technical data'."

Technical data
According to the AG, this "may take forms such as blueprints, plans, diagrams, models, formulae, tables, engineering designs and specifications, manuals and instructions written or recorded on other media or devices such as disk, tape, read-only memories."

Technology
The AG defines this as "specific information necessary for the 'development', 'production' or 'use' of a product. The information takes the form of 'technical data' or 'technical assistance'."

Terminal diffuser
A type of HEPA filter system that does not integrate the fan and the HEPA filter in the same unit. In a terminal diffuser setup, the fan and HEPA filter are connected by tubing or ducting.

TIC
See toxic industrial chemical

Tissue culture
The growth of cells or tissues outside of an organism, often in a petri dish, flask, or bioreactor. Cultured cells may be used to grow viruses.

Tote bin
Containers used for shipping bulk quantities of chemicals and other materials.

Toxic
Containing poison or being poisonous in a way that is capable of causing serious harm or death.

Toxic chemical
The CWC defines this as "any chemical which through its chemical action on life processes can cause death, temporary incapacitation or permanent harm to humans or animals. This includes all such chemicals, regardless of their origin or their method of production, and regardless of whether they are produced in facilities, in munitions or elsewhere."

Toxic industrial chemical
Industrial chemicals that are manufactured and used in large quantities but that pose dangerous chemical or physical hazards.

Toxicity
The potency or degree to which a toxic substance or compound can damage an organism.

Toxicology
A branch of biology and medicine concerned with the study of the adverse effects of chemicals on living organisms.

Toxin
A poisonous substance produced by living cells or organisms. Toxins can be small molecules, peptides, or proteins that are capable of causing disease on contact with or absorption by body tissues. Toxins vary greatly in the severity of their effects, ranging from minor and short-acting to almost immediately deadly.

Transcribe
To convert information encoded in DNA into RNA. Transcription is the process of converting the genetic information contained in DNA into RNA. This is a necessary intermediate step required for protein production.

Translate
To convert information encoded in RNA into protein. Translation is the process by which a cell uses RNA as the blueprint for protein synthesis.

Transposon
A DNA sequence that has the ability to change position within a genome. Transposons are also known as jumping genes and are common in plants.

UAV

See unmanned aerial vehicle.

UN number

Four-digit codes used to identify hazardous substances and articles in transport. The master list of UN Numbers is the Dangerous Goods List of the United Nations Recommendations on the Transport of Dangerous Goods. See the Volume I section on Chemical Packaging and Transportation.

Unmanned aerial vehicle

An aircraft that flies without a human pilot on board the vehicle.

Ultrahigh vacuum

Describes a pressure range lower than high vacuum systems; ultrahigh vacuum pumps are able to pump more molecules out of a chamber than high vacuum pumps, giving an "ultrahigh" degree of vacuum. Definitions for the pressure range can vary, but are often in the 1×10^{-7} to 1×10^{-10} Pascal range.

Ultrasonic nozzle

A device used, primarily in pharmaceutical spray dryers, to atomise a liquid feedstock by subjecting the liquid feed to high-frequency vibrations. See the Volume II section on Spray-Drying Equipment.

Use

The AG defines this as the "operation, installation, (including on-site installation), maintenance (checking), repair, overhaul or refurbishing."

V-series nerve agent

A type of nerve agent first discovered in the 1950s. See the Volume I Introduction to Chemical Weapons and Dual-Use Chemical Technology.

Vaccine

A biological preparation that enhances the vaccinated subject's immunity to a particular disease. A vaccine stimulates the subject's immune system with a weakened pathogen so the immune system becomes prepared to recognise and destroy the virulent disease-causing pathogen.

Vacuum

A vacuum technically is a space devoid of matter. Vacuum pumps reduce pressure in a chamber by removing air from it (i.e., reducing the amount of matter it contains). There are different levels of vacuum that are associated with different pressure ranges (and, by extension, amounts of matter); see Glossary entries on rough, low, medium, high, and ultrahigh vacuum.

Vacuum distillation

A method of distillation where the pressure above a liquid mixture intended for distillation is reduced to less than its vapour pressure. This allows separation of compounds at temperatures below their usual boiling points and/or improved separation of compounds that normally have very similar boiling points.

Vector

A living intermediary (e.g., mosquitos, ticks, and fleas) that carries a pathogen from a reservoir to a susceptible host. In the context of genetic elements, the term vector refers to plasmids used in molecular biology to carry a desired DNA sequence into a target cell.

Velogenic
Describes the virulence of a virus that generally causes lethal infection in its host.

Venom
A toxin – or more typically a mixture of toxins – produced by certain types of animals that inject it into their victims by means of a bite, sting, or other puncture caused by a sharp body structure.

Venomous
Capable of producing toxin/venom and capable of inflicting a poisoned wound.

Venturi
A type of jet ejector pump that produces a vacuum using the Venturi effect; fluid pressure is reduced by forcing the fluid through a constricted section of a pipe.

Vesicant
Also known as blister agents, vesicants cause large and often life-threatening blisters on moist tissues. See the Volume I Introduction to Chemical Weapons and Dual-Use Chemical Technology.

Viability
The ability of a microorganism to survive, grow, and reproduce.

Virulent
Describes a disease or toxin that creates extremely severe or harmful symptoms in its host.

Virus
An infectious agent generally composed of genetic material packaged within a protein coat. Viruses must infect host cells in order to replicate, burst out of the host cell, and spread the infection.

Viscosity
The property of a liquid that describes its resistance to flow. Liquids with high viscosity tend to be thick and sticky, and they do not flow easily.

Viscous
High-viscosity liquids often are referred to as being viscous.

Volatility
A measure of the tendency of a substance to vapourise or turn from a liquid phase to a gas phase.

Vulcanisation
The process of converting rubber and related compounds into more durable materials by adding materials that cross-link (connect) polymer chains together.

Weir
An internal structure within a distillation column tray that keeps an appropriate level of liquid in the tray for effective separations.

Wetted surfaces

Surfaces coming into direct contact with processed or contained chemicals. For the purposes of AG control specifications on dual-use chemical equipment, these are the surfaces of chemical processing equipment that must be made of corrosion-resistant materials.

Xylem

A vascular tissue plants use to transport water and minerals.

Zoonotic

Describes a pathogen that is capable of being transmitted from animals to humans or from humans to animals. The latter is sometimes referred to as reverse zoonosis.

Appendix G: Unit Conversions

Many Australia Group (AG) control specifications for dual-use biological and chemical equipment include units of measurement. Equipment manufacturers use a variety of units that may not be the same as those specified in the control lists. The tables below provide control specifications that appear in the AG chemical equipment control list and the biological equipment control list in a variety of different units. The applicable controlled commodity is noted in each table. All units stated in the AG control language are shown in ***bold and italics***. Non-exact conversion factors are provided above the tables to four decimal places; calculations in the tables that use these non-exact conversion factors are rounded to the nearest 0.1. Numbers are shown in scientific notation ($a \times 10^b$) when the value is <0.01.

Note that any conversions of a control specification into units other than those in the AG control language are not official AG control specifications and in many cases are simply approximations. Conversions are provided here informally for reference purposes only and not for use in official control determinations.

Length/Diameter

1 metre (m) = 100 centimetres (cm) = 39.3701 inches (in) = 1×10^6 micrometres[138] (µm)

Metres (m)	Centimetres (cm)	Inches (in)	Micrometres (µm)	Applicable AG Commodity	Handbook Volume
1×10^{-5}	1×10^{-3}	3.9×10^{-4}	***10***	Spray-Drying Equipment and Awareness Raising Guidelines: Encapsulation	II
5×10^{-5}	5×10^{-3}	2.0×10^{-3}	***50***	Spraying or Fogging Systems	II
0.01	***1***	***⅜***	10,000	Valves	I
0.0254	***2.54***	***1***	25,400	Valves	I
0.1	10	3.9	100,000	Distillation or Absorption Columns	I
0.1016	***10.16***	***4***	101,600	Valves	I

[138]The term micrometre is used synonymously with the term micron in AG control language.

Surface Area

1 square metre (m^2) = 10.7639 square feet (ft^2)

Square Metres (m^2)	Square Feet (ft^2)	Applicable AG Commodity	Handbook Volume
0.15	1.6	Heat Exchangers or Condensers	I
0.2	2.2	Cross Flow Filtration Equipment	II
1	10.8	Cross Flow Filtration Equipment	II
20	215.3	Heat Exchangers or Condensers	I

In addition:
1 m^2 = 10,000 cm^2
1 ft^2 = 144 in^2

Volume

1 cubic metre (m^3) = 1000 litres (litre) = 35.3147 cubic feet (ft^3) = 264.1721 U.S. gallons (US gal)

Cubic Metres (m^3)	Litres (l)	Cubic Feet (ft^3)	U.S. Gallons (US gal)	Applicable AG Commodity	Handbook Volume
0.02	***20***	0.7	5.3	Fermenters and Awareness Raising Guidelines: Fermenters	II
0.1	***100***	3.5	26.4	Reaction Vessels and Storage Tanks, Containers, or Receivers	I
1	1000	35.3	264.2	Aerosol Inhalation Equipment	II
20	***20,000***	706.3	5283.1	Reaction Vessels	I

In addition:
1 m^3 = 1,000,000 cm^3
1 ft^3 = 1728 in^3

Flow Rate[139]

1 cubic metre per hour (m^3/h) = 1,000 litres per hour (l/h) = 16.6667 litres per minute (l/min) = 0.5886 cubic feet per minute (CFM) = 4.4029 U.S. gallons per minute (GPM)

Cubic Metres per Hour (m^3/h)	Litres per Hour (l/h)	Litres per Minute (l/min)	Cubic Feet per Minute (CFM)	U.S. Gallons per Minute (GPM)	Applicable AG Commodity	Handbook Volume
0.1	***100***	1.7	0.1	0.4	Centrifugal Separators	II
0.12	120	***2***	0.1	0.5	Spraying or Fogging Systems	II
0.6	600	10	0.4	2.6	Pumps	I
5	5000	83.3	2.9	22.0	Pumps	I

Temperature

273 Kelvin (K) = 0 degrees Celsius (°C) = 32 degrees Fahrenheit (°F)[140]

Kelvin (K)	Degrees Celsius (°C)	Degrees Fahrenheit (°F)	Applicable AG Commodity	Handbook Volume
273	***0***	32	Pumps	I
1273	***1000***	1832	Incinerators	I

Mass

1 kilogram (kg) = 2.2046 pounds (lb)

Kilograms (kg)	Pounds (lb)	Applicable AG Commodity	Handbook Volume
10	22.0	Freeze-Drying Equipment	II
1000	2204.6	Freeze-Drying Equipment	II

[139]For pumps, these flow rates reflect measurements taken under standard temperature (273 K [0° C]) and pressure (101.3kPa) conditions.

[140]Conversion between degrees Celsius and degrees Fahrenheit uses the following formula: °F = (9/5)°C + 32.

Evaporation and Condensation Capacity

1 kilogram per hour (kg/h) = 24 kilograms per 24 hours (kg/24h) = 2.2046 pounds per hour (lb/h)

Kilograms per Hour (kg/h)	Kilograms per 24 Hours (kg/24h)	Pounds per Hour (lb/h)	Applicable AG Commodity	AG Volume
0.4	9.6	0.9	Spray-Drying Equipment	II
0.4	***10***	0.9	Freeze-Drying Equipment	II
41.7	***1000***	91.9	Freeze-Drying Equipment	II
400	9600	881.8	Spray-Drying Equipment	II

Pressure

1 kilopascal (kPa) = 0.0099 atmospheres (atm) = 7.5001 mm Hg = 7.5001 torr (Torr) = 0.1450 pounds per square inch (psi) = 4.0146 inches of water gauge (in w.g.)

Kilopascals (kPa)	Atmospheres (atm)	Millimetres of Mercury (mm Hg)/ torr (Torr)	Pounds per Square Inch (psi)	Inches of Water Gauge (in w.g.)	Applicable AG Commodity	AG Volume
101.3	1.0	759.8	14.7	406.7	Pumps	I

Detection Level

Conversion between mg/m^3 and ppm (parts per million) requires knowledge of the molecular weight of the chemical in question. See the Volume I section on Toxic Gas Monitoring Systems and their Dedicated Detection Components for a table of detection levels by chemical and further details on this calculation.

Appendix H: Bibliography

The following represents an edited compilation of key references and websites from government agencies, non-governmental organisations, scientific societies, and scientific publications. Further information on specific Australia Group (AG)-listed commodities may be found in the text and footnotes of individual commodity entries.

Chemical Weapons Precursors

- Abstract for "Sodium Cyanide," IHS (September 2016). https://www.ihs.com/products/sodium-cyanide-chemical-economics-handbook.html
- American Chemical Society. Chemical Abstract Service. "CAS Registry-The gold standard for chemical substance information." http://www.cas.org/content/chemical-substances
- Australian Government, Australian Safeguards and Non-Proliferation Office. "The Chemical Weapons Convention: A Guide for Australian Industry Producing, Using or Trading Chemicals" (2014). https://www.dfat.gov.au/about-us/publications/Pages/a-guide-for-industry-producing-using-or-trading-chemicals-2014
- Chemical and Biological Defense Information Analysis Center. "State-of-the-Art Report on the Australia Group and related Chemicals." SOAR-98-04 (June 1998).
- Comité Technique Europeen du Fluor. "Eurofluor HF: A snapshot of the Fluorine Industry" (May 2013). http://www.eurofluor.org
- *CRC Handbook of Chemistry and Physics*, 73rd Edition. (Boca Raton, FL: CRC Press) 1992-93.
- Ellison, D.H. *Handbook of Chemical and Biological Warfare Agents* (Boca Raton, FL: CRC Press), 1999.
- European Chemicals Agency (ECHA), "Guidance for identification and naming of substances under REACH and CLP." V.2.1. (May 2017)). https://echa.europa.eu/documents/10162/23036412/substance_id_en.pdf/ee696bad-49f6-4fec-b8b7-2c3706113c7d
- European Chemicals Agency (ECHA), EC Inventory; http://echa.europa.eu/information-on-chemicals/ec-inventory
- International Program on Chemical Safety. "Poisons Information Monographs Archive." http://www.inchem.org/pages/pims.html
- *Kirk-Othmer Encyclopedia of Chemical Technology*. Wiley Interscience. http://onlinelibrary.wiley.com/book/10.1002/0471238961
- MatWeb. Metal Alloy UNS Number search engine. http://www.matweb.com/search/SearchUNS.aspx
- *The Merck Index: an Encyclopedia of Chemicals, Drugs, and Biologicals*, 13th Edition. (Whitehouse Station, NJ: Merck), 2001.
- Organisation for the Prohibition of Chemical Weapons. "Most Traded Scheduled Chemicals 2017" (November 2017). https://www.opcw.org/our-work/non-proliferation/declarations-adviser/most-traded-scheduled-chemicals/
- Organisation for the Prohibition of Chemical Weapons. "Which chemicals are controlled?" https://www.opcw.org/resources/declarations/handbook-chemicals
- Organisation for the Prohibition of Chemical Weapons. "Convention on the Prohibition of the Development, Production, Stockpiling and Use of Chemical Weapons and on their Destruction (Chemical Weapons Convention)." http://www.opcw.org/chemical-weapons-convention/
- Safety Emporium. "MSDS Hyper Glossary." http://www.ilpi.com/msds/ref/index.html

- Sax's Dangerous Properties of Industrial Materials, 10th Edition (New York: John Wiley), 2000.
- Sweet, D.V., ed. 1997. *Registry of Toxic Effects of Chemical Substances (RTECS): A Comprehensive Guide to the RTECS.* U.S. Dept. of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health. Cincinnati, Ohio.
- Transport Canada. "TDG Bulletin: Dangerous Goods Safety Marks" (January 2015). https://www.tc.gc.ca/media/documents/tdg-eng/Bulletin_-_Safety_Marks.pdf
- United Nations Economic Commission for Europe. "About the GHS." http://www.unece.org/trans/danger/publi/ghs/ghs_welcome_e.html
- United Nations Economic Commission for Europe. United Nations (UN) Model Regulations. "UN Recommendations on the Transport of Dangerous Goods – Model Regulations" 21th revised edition. https://www.unece.org/trans/danger/publi/unrec/rev21/21files_e.html
- United States Army. Field Manual FM 3-11.9, "Potential Military Chemical/Biological Agents and Compounds" (January 2005). http://www.dtic.mil/dtic/tr/fulltext/u2/a457455.pdf
- United States Centers for Disease Control and Prevention. "Chemical Agents." https://emergency.cdc.gov/agent/agentlistchem.asp
- United States Centers for Disease Control and Prevention. "Air Monitoring for Chemical Warfare Agents." http://www.cdc.gov/nceh/demil/amcwafs.htm
- United States Defense Threat Reduction Agency. Featured Articles Archive, "CW Issues in Depth – Toxic Industrial Chemicals and the CWC."
- United States Defense Threat Reduction Agency. *Guide to Scheduled Chemicals* (June 2004).
- United States Department of State. "Australia Group Export Controls on Materials Used in the Manufacture of Chemical and Biological Weapons, Control List of Dual-Use Chemicals: Commercial and Military Application (January 20, 2001)." http://2001-2009.state.gov/t/isn/rls/fs/2001/3525.htm
- United States National Institute of Standards and Technology. "NIST Chemistry WebBook." http://webbook.nist.gov/chemistry/
- United States National Library of Medicine. "Toxicology Data Network." https://chem.nlm.nih.gov/chemidplus/chemidlite.jsp
- World Customs Organization. "Recommendation of the Customs Co-Operation Council on the Insertion in National Statistical Nomenclatures of Subheadings for Substances Controlled under the Convention on the Prohibition of the Development, Production, Stockpiling and Use of Chemical Weapons and on their Destruction." http://www.wcoomd.org/en/topics/nomenclature/instrument-and-tools/~/media/WCO/Public/Global/PDF/About%20us/Legal%20Instruments/Recommendations/HS/Recommendation%20CWC%202009_HS2012.ashx

Dual-Use Chemical Manufacturing Facilities and Equipment and Related Technology and Software

- Aliasso, J. "Choose the Right Vacuum Pump," *Chemical Engineering.* 106(3), 96-100 (1999). http://www.graham-mfg.com/usr/pdf/TechLibVacuum/222.PDF
- Collins, D. "Vacuum systems for chemical and pharmaceutical processes." *Chemical Industry Digest* (June 2011).
- Fair, J.R. "Distillation" in *Kirk-Othmer Encyclopedia of Chemical Technology*, Volume 8 (John Wiley & Sons, Inc., 1993).
- Flowserve Corporation. "Duriron and Durichlor 51M." http://www.crp.co.uk/UserFiles/Documents/Corrosion%20Resistance/Duriron%20and%20Durichlor%2051M.pdf

- Grandview Materials. “Niobium Industry: Chemical, Pharmaceutical and Medical.” http://www.grandviewmaterials.com/product/niobium-industry
- Haynes International. “Corrosion Resistant Alloys.” http://www.haynesintl.com/alloys/technical-literature-list#librarycorrosion
- *Kirk-Othmer Encyclopedia of Chemical Technology*. Wiley Interscience. http://onlinelibrary.wiley.com/book/10.1002/0471238961
- Laso, M. and von Stockar, U. “Absorption” in *Kirk-Othmer Encyclopedia of Chemical Technology*, Volume 1 (John Wiley & Sons, Inc., 2003).
- *Metals & Alloys in the Unified Numbering System*, 10th Edition, Society of Automotive Engineers and American Society for Testing and Materials (Warrendale, PA: 2004).
- Newcastle University. “Distillation: An Introduction.” No longer available online.
- Pearson, G.S. and Magee, R.S. “Critical Evaluation of Proven Chemical Weapon Destruction Technologies (IUPAC Technical Report).” *Pure and Applied Chemistry*. 74(2), 187-316 (2002). http://www.iupac.org/publications/pac/2002/7402/7402x0187.html
- Rochester Institute of Technology. “Vacuum Pumps.” http://people.rit.edu/vwlsps/LabTech/Pumps.pdf
- Ryans, J.L. and Croll, S. “Selecting vacuum systems,” *Chemical Engineering* p. 72 (December 14, 1981).
- Special Metals. “Chemical Processing.” http://www.specialmetals.com/chemical-processing
- Sutherlin, R. “Zirconium, Anyone.” http://www.chemicalprocessing.com/articles/2003/261.html
- United States Army Chemical Materials Activity. https://www.cma.army.mil/

Human and Animal Pathogens and Toxins

- American Biological Safety Association. “Risk Group Classification for Infectious Agents.” https://my.absa.org/Riskgroups
- American Chemical Society. Chemical Abstract Service. “CAS Registry-The gold standard for chemical substance information.” http://www.cas.org/content/chemical-substances
- ConusServer. A database of conotoxins. http://www.conoserver.org/
- Ellison, D.H. *Handbook of Chemical and Biological Warfare Agents* (Boca Raton, FL: CRC Press), 1999.
- European Centre for Disease Prevention and Control. “Health topics A-Z.” http://www.ecdc.europa.eu/en/healthtopics/Pages/AZIndex.aspx
- European Commission Health and Consumer Protection Directorate. “The Definition of Avian Influenza: The use of Vaccination against Avian Influenza.” Scientific Committee on Animal Health and Animal Welfare. (June 2000). Please see https://ec.europa.eu/food/sites/food/files/safety/docs/sci-com_scah_out45-final_en.pdf
- Gill, D.M. 1982. “Bacterial Toxins: A Table of Lethal Amounts.” *Microbiological Reviews*; 46: 86-94.
- Government of Australia, New South Wales Ministry of Health. “Factsheets.” http://www.health.nsw.gov.au/Infectious/factsheets/Pages/default.aspx
- Government of Canada, Canadian Centre for Occupational Health and Safety. “What is LD_{50} and LC_{50}?” http://www.ccohs.ca/oshanswers/chemicals/ld50.html
- Heymann, D.L. *Control of Communicable Diseases Manual*. American Public Health Association. 19th Edition. 2008.
- International Air Transport Association. “About us.” http://www.iata.org/about/Pages/index.aspx
- International Committee on Taxonomy of Viruses. https://talk.ictvonline.org/

- Iowa State University of Science and Technology. “Animal Disease Information.” The Center for Food Security and Public Health. http://www.cfsph.iastate.edu/DiseaseInfo/index.php
- *The Merck Index: an Encyclopedia of Chemicals, Drugs, and Biologicals*. 13th Edition (Whitehouse Station, NJ: Merck), 2001.
- Nature Education. “Transposons. The Jumping Genes.” http://www.nature.com/scitable/topicpage/transposons-the-jumping-genes-518
- Paddle, B.M. 2003. “Therapy and Prophylaxis of Inhaled Biological Toxins.” *Journal of Applied Toxicology*. 23: 139-170.
- International Program on Chemical Safety. “Poisons Information Monographs Archive.” http://www.inchem.org/pages/pims.html
- Safety Emporium. “MSDS Hyper Glossary.” http://www.ilpi.com/msds/ref/index.html
- Stirpe, F., et al. 1992. “Ribosome-Inactivating Proteins from Plants: Present Status and Future Prospects.” *Biotechnology*. 10: 405-412.
- Sweet, D.V., ed. 1997. *Registry of Toxic Effects of Chemical Substances (RTECS): A Comprehensive Guide to the RTECS.* U.S. Dept. of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health. Cincinnati, Ohio.
- United Nations Economic Commission for Europe. United Nations (UN) Model Regulations. “UN Recommendations on the Transport of Dangerous Goods – Model Regulations” 21th revised edition. https://www.unece.org/trans/danger/publi/unrec/rev21/21files_e.html
- United States Army. Field Manual FM 3-11.9, “Potential Military Chemical/Biological Agents and Compounds” (January 2005). http://www.dtic.mil/dtic/tr/fulltext/u2/a457455.pdf
- United States Centers for Disease Control and Prevention. *Biosafety in Microbiological and Biomedical Laboratories* (BMBL), 5th Edition. http://www.cdc.gov/biosafety/publications/bmbl5/index.htm
- United States Centers for Disease Control and Prevention. “Bioterrorism Agents/Diseases.” https://emergency.cdc.gov/agent/agentlist.asp
- United States Centers for Disease Control and Prevention. “Chemical Agents.” https://emergency.cdc.gov/agent/agentlistchem.asp
- United States National Human Genome Research Institute. “Talking Glossary of Generic Terms.” https://www.genome.gov/genetics-glossary
- United States National Institutes of Health. “Health Topics: MedlinePlus.” U.S National Library of Medicine. http://www.nlm.nih.gov/medlineplus/healthtopics.html
- United States National Library of Medicine. “Toxicology Data Network.” http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB
- World Health Organization. “Fact Sheets.” http://www.who.int/mediacentre/factsheets/en/
- World Health Organization. *Laboratory Biosafety Manual*, 3rd Edition. http://www.who.int/csr/resources/publications/biosafety/WHO_CDS_CSR_LYO_2004_11/en/
- World Organisation for Animal Health. “Animal Disease Information Summaries.” http://www.oie.int/for-the-media/animal-diseases/animal-disease-information-summaries/

Plant Pathogens

- American Biological Safety Association. “Risk Group Classification for Infectious Agents.” https://my.absa.org/Riskgroups
- National Human Genome Research Institute. “Talking Glossary of Generic Terms.” https://www.genome.gov/genetics-glossary

- Nature Education. “Transposons. The Jumping Genes.” http://www.nature.com/scitable/topicpage/transposons-the-jumping-genes-518
- Safety Emporium. “MSDS Hyper Glossary.” http://www.ilpi.com/msds/ref/index.html

Dual-Use Biological Equipment and Related Technology and Software

- American Society for Microbiology. “Threading the NEIDL – Inside a BSL-4.” https://vimeo.com/59246199
- Chui, P., et al. “Mobile Biosafety Level-4 Autopsy Facility – An Innovative Solution.” no longer available online
- Clayton, J.S. and Sander, T.P.Y. “Aerial application for control of public health pests.” *Aspects of Applied Biology* 66 (2002). http://www.micron.co.uk/files/aerialcontrol_2002.pdf
- Compendium of Chemical Technology. IUPAC. http://goldbook.iupac.org
- Franjione, J., and Vasishtha, N. “The Art and Science of Microencapsulation.” no longer available online
- “Freeze Drying / Lyophilisation Info Online.” http://freezedryinginfo.com/
- Greb, E. (2009) “Is Spray Drying a Viable Alternative to Lyophilisation?” http://www.pharmtech.com/spray-drying-viable-alternative-lyophilization
- Hewett, A.J. “The Importance of Nozzle Selection and Droplet Size Control in Spray Applications. *Proceedings of the North American Conference on Pesticide Spray Drift Management* (1998).
- Menyhart, L. “Lyophilisation: Freeze-Drying, A Downstream Process.” No longer available online.
- Millrock Technology. “What is freeze drying?” http://www.millrocktech.com/what-is-freeze-drying/
- United States Centers for Disease Control and Prevention. *Biosafety in Microbiological and Biomedical Laboratories* (BMBL), 5th Edition. http://www.cdc.gov/biosafety/publications/bmbl5/index.htm
- United States Department of Energy. *Nuclear Air Cleaning Handbook*. https://www.standards.doe.gov/standards-documents/1100/1169-bhdbk-2003-pt1/@@images/file
- World Health Organization. *Laboratory Biosafety Manual*, 3rd Edition. http://www.who.int/csr/resources/publications/biosafety/WHO_CDS_CSR_LYO_2004_11/en/

General References

- The Australia Group. https://www.dfat.gov.au/publications/minisite/theaustraliagroupnet/site/en/index.html
- Commission Delegated Regulation (EU) No 2019/2199, amending Council Regulation No 428/2009. https://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX:32019R2199
- Missile Technology Control Regime. http://www.mtcr.info/
- Nuclear Suppliers Group. http://www.nuclearsuppliersgroup.org
- United States International Trade Commission. “By Chapter, Harmonised Tariff Schedule of the United States.” http://www.usitc.gov/tata/hts/bychapter/
- Wassenaar Arrangement. http://www.wassenaar.org
- WCO Strategic Trade Control Enforcement Implementation Guide. http://www.wcoomd.org/en/topics/enforcement-and-compliance/instruments-and-tools/guidelines/wco-strategic-trade-control-enforcement-implementation-guide.aspx

This page intentionally left blank.

Appendix I: Figure Attributions

Introduction to Biological Weapons and Dual-Use Biotechnology

Figure	Credit
1	Argonne National Laboratory

Introduction to Pathogens and Toxins

Figure	Credit
1	U.S. Centers for Disease Control and Prevention
2	U.S. Centers for Disease Control and Prevention

Table	Credit
2	United Nations Economic Commission for Europe http://www.unece.org/fileadmin/DAM/trans/danger/publi/unrec/rev18/English/Rev18_Volume2_Part5.pdf

Human and Animal Pathogens and Toxins

Figure	Credit
T1.A (top)	© Parithimathi / Wikipedia Commons http://commons.wikimedia.org/wiki/File:Abrus_precatorius.JPG License CC BY-SA 3.0 http://creativecommons.org/licenses/by-sa/3.0/deed.en
T1.A (bottom)	© Eyeweed / Flickr https://www.flickr.com/photos/eyeweed/4334523672/in/photostream License CC BY-NC-ND 2.0 https://creativecommons.org/licenses/by-nc-nd/2.0/
T6.A	© Richard Ling / Wikimedia Commons http://en.wikipedia.org/wiki/File:Textile_cone.JPG License CC BY-SA 3.0 http://creativecommons.org/licenses/by-sa/3.0/deed.en
T11.A (left)	© Alvesgaspar / Wikimedia Commons http://en.wikipedia.org/wiki/File:Ricinus_March_2010-1.jpg License CC BY-SA 3.0 http://creativecommons.org/licenses/by-sa/3.0/deed.en
T11.A (right)	© Schnobby / Wikimedia Commons http://en.wikipedia.org/wiki/File:Seeds_of_Ricinus_communis.jpg License CC BY-SA 3.0 http://creativecommons.org/licenses/by-sa/3.0/deed.en
T16.A	© Amanda / Wikimedia Commons http://en.wikipedia.org/wiki/File:Puffer_fish.jpg License CC BY 2.0 http://creativecommons.org/licenses/by/2.0/deed.en

Plant Pathogens

Figure	Credit
PB1.A	© Donald Groth, Louisiana State University / Forestry Images http://www.forestryimages.org/browse/detail.cfm?imgnum=5390511 License CC BY 3.0 US http://creativecommons.org/licenses/by/3.0/us/
PB2.A	U.S Animal and Plant Health Inspection Service
PB3.A	© Donald Groth, Louisiana State University / Forestry Images http://www.forestryimages.org/browse/detail.cfm?imgnum=5390468 License CC BY 3.0 US http://creativecommons.org/licenses/by/3.0/us/
PB4.A	U.S. Agricultural Research Service
PB5.A	© Clemson University / Forestry Images http://www.forestryimages.org/browse/detail.cfm?imgnum=1234078 License CC BY 3.0 US http://creativecommons.org/licenses/by/3.0/us/
PF1.A	© counterculturecoffee / Flickr https://www.flickr.com/photos/counterculturecoffee/8264691834/ License CC BY-NC-ND 2.0 https://creativecommons.org/licenses/by-nc-nd/2.0/
PF2.A	© Donald Groth, Louisiana State University / Forestry Images http://www.forestryimages.org/browse/detail.cfm?imgnum=5410673 License CC BY 3.0 US http://creativecommons.org/licenses/by/3.0/us/
PF3.A	Food and Agriculture Organization of the United Nations http://www.fao.org/docrep/010/ai003e/AI003E25.htm
PF4.A	U.S. Agricultural Research Service
PF5.A	U.S. Agricultural Research Service
PF6.A	U.S. Agricultural Research Service
PF6.B	© Donald Groth, Louisiana State University / Forestry Images http://www.forestryimages.org/browse/detail.cfm?imgnum=5390481 License CC BY 3.0 US http://creativecommons.org/licenses/by/3.0/us/
PF8.A	Courtesy C. De Leon; Reproduced, by permission, from White, D.G. 1999. Compendium of Corn Diseases, Third Edition. The American Pytopathological Society, St. Paul, MN.
PF9.A	U.S Animal and Plant Health Inspection Service
PF10.A	U.S. Agricultural Research Service
PF11.A	© William M. Brown Jr. / Forestry Images http://www.forestryimages.org/browse/detail.cfm?imgnum=5356848 License CC BY 3.0 US http://creativecommons.org/licenses/by/3.0/us/
PF11.B	© William M. Brown Jr. / Forestry Images http://www.forestryimages.org/browse/detail.cfm?imgnum=5356849 License CC BY 3.0 US http://creativecommons.org/licenses/by/3.0/us/

Figure	Credit
PV2.A	United Nations Economic Commission for Europe http://www.unece.org/fileadmin/DAM/trade/agr/standard/potatoes/ListOfDiseasesAndPests.htm
PWF2.A	Plant Health Progress, doi:10.1094/PHP-2001-0709-01-RV

Dual-Use Biological Equipment and Related Technology and Software

Figure	Credit
1.A (left)	University of Chicago
1.A (right)	Lawrence Livermore National Laboratory
1.A (inset)	Source: Solid State Technology
1.B (left)	Photo courtesy of HDR Architecture, Inc.; © 2005 Balthazar Korab
1.B (centre)	Courtesy of Smith Carter Architects and Engineers Incorporated
1.B (right)	U.S. National Institutes of Health
1.C (all)	Images courtesy of GERMFREE®
1.D (top)	Image courtesy of Consolidated Sterilizer Systems (https://consteril.com/)
1.D (bottom left)	Image courtesy of Consolidated Sterilizer Systems (https://consteril.com/)
1.D (bottom centre)	Image courtesy of Consolidated Sterilizer Systems (https://consteril.com/)
1.D (bottom right)	Tuttnauer USA Co., Ltd., Hauppauge, NY
1.E (left)	U.S. Centers for Disease Control and Prevention
1.E (right)	U.S. Centers for Disease Control and Prevention
1.F (top)	U.S. National Institutes of Health
1.F (bottom left)	Photo courtesy of Germfree Laboratories, Inc.
1.F. (bottom centre)	Permission granted/No attribution requested
1.F. (bottom centre)	Permission granted/No attribution requested
1.F. (bottom right)	Permission granted/No attribution requested
2.A (left)	© KVDP / Wikimedia Commons http://commons.wikimedia.org/wiki/File:Real_life_bioreactor.png License CC-BY-SA-3.0 http://creativecommons.org/licenses/by-sa/3.0/deed.en
2.A (right)	Argonne National Laboratory
2.B (left)	Courtesy of Sartorius North America
2.B (centre)	Pacific Northwest National Laboratory
2.B (right)	Argonne National Laboratory
2.C	Argonne National Laboratory
2.D (left)	Courtesy of Sartorius North America

Figure	Credit
2.D (centre)	Argonne National Laboratory
2.D (right)	Argonne National Laboratory
2.E	Photo courtesy of Aaron Equipment Company
3.A	Photo courtesy of GEA Mechanical Equipment U.S., Inc.
3.B (top left)	Image courtesy of Flottweg Separation Technology, Inc. Image of centrifugal separator not capable of *in situ* steam sterilisation.
3.B (bottom left)	Image courtesy of Flottweg Separation Technology, Inc. Image of centrifugal separator not capable of *in situ* steam sterilisation.
3.B. (right)	Argonne National Laboratory
3.C	Reprinted with permission of TEMA/Siebtechnik
3.D (left)	Image courtesy of Flottweg Separation Technology, Inc. Image of decanter not capable of *in situ* steam sterilisation.
3.D (centre)	Image courtesy of Flottweg Separation Technology, Inc. Image of decanter not capable of *in situ* steam sterilisation.
3.D (right)	Photo courtesy of GEA Mechanical Equipment U.S., Inc.
3.E (left)	Photo courtesy of Aaron Equipment Company
3.E (centre)	Photo courtesy of Aaron Equipment Company
3.E (right)	Photo courtesy of Aaron Equipment Company
4.A	Image courtesy of SpectrumLabs.com
4.B	Image courtesy of Pall Corporation
4.C (top left)	Image courtesy of SpectrumLabs.com
4.C (top centre)	Office of Science and Technical Information, U.S. Department of Energy
4.C (top right)	Argonne National Laboratory
4.C (bottom left)	Image courtesy of Pall Corporation
4.C (bottom right)	© wikiwayman / Wikimedia Commons http://commons.wikimedia.org/wiki/File:Filtration_unit_(crossflow_filtration).jpg License CC-BY-SA-3.0 http://creativecommons.org/licenses/by-sa/3.0/deed.en
4.D (top left)	Courtesy of Novasep
4.D (top right)	Image supplied courtesy of Mantec Technical Ceramics Ltd.
4.D (middle)	Image courtesy of SpectrumLabs.com
4.D (bottom left)	Courtesy of Novasep
4.D (bottom centre)	Image supplied courtesy of Mantec Technical Ceramics Ltd.
4.D (bottom right)	Image courtesy of Pall Corporation
4.E	Courtesy of EMD Millipore Corporation
4.F (left)	Courtesy of EMD Millipore Corporation
4.F (centre)	Courtesy of EMD Millipore Corporation
4.F (right)	Argonne National Laboratory

Figure	Credit
4.G	Image courtesy of SpectrumLabs.com
5.A (all)	Images courtesy of labequip.com
5.B (all)	Photos courtesy of Aaron Equipment Company
5.C (left)	This work has been released into the public domain by its author, Millrock at the English Wikipedia project. This applies worldwide. http://en.wikipedia.org/wiki/File:Production_freeze_dryer.JPG
5.C (inset)	Agriculture Research Service, U.S. Department of Agriculture
5.C (right)	Photo courtesy of Aaron Equipment Company
6.A	Argonne National Laboratory
6.B (all)	Permission granted/No attribution requested
6.C	Argonne National Laboratory
6.D (all)	Argonne National Laboratory
7.A (left)	U.S. Centers for Disease Control and Prevention
7.A (right)	U.S. National Institutes of Health
7.B (all)	Photographs used with permission of Bioquell UK LTD.
7.C (top left)	Image courtesy of GERMFREE®
7.C (top right)	Esco Technologies Ltd.
7.C (bottom left)	Permission granted/No attribution requested
7.C (bottom right)	University of Chicago
8.A (left)	Permission granted/No attribution requested
8.A (centre)	TSE Systems Whole Body Exposure Unit (0.95 m3) for rodents and uniform aerosol distribution
8.A (right)	Glas-Col LLC, Terre Haute, Indiana (USA)
8.B	Individually dosage adjustable inhalation cage system. (Multipurpose Inhalation Cage (MIC) Unit, Shibata Biotechnology Inc.)
8.C	University of Chicago
8.D (all)	University of Chicago
10.A	Argonne National Laboratory
10.B	Argonne National Laboratory
10.C (top left)	Courtesy of SGI-DNA, Inc., A Synthetic Genomics Inc. Company
10.C (top right)	Courtesy of SGI-DNA, Inc., A Synthetic Genomics Inc. Company
10.C (bottom)	Courtesy of SGI-DNA, Inc., A Synthetic Genomics Inc. Company
10.D	ALT/American Laboratory Trading
ARG 1.A	Southwest Research Institute
ARG 1.B	Argonne National Laboratory
ARG 2.A (top left)	© El Carlos / Wikimedia Commons http://commons.wikimedia.org/wiki/File:Labfors_4_with_touchscreen.jpg License CC-BY-SA-3.0 http://creativecommons.org/licenses/by-sa/3.0/deed.en

Figure	Credit
ARG 2.A (top right)	Courtesy of Sartorius North America
ARG 2.A (bottom)	Courtesy of Sartorius North America
ARG 3.A (top left)	Courtesy of AAF International
ARG 3.A (top right)	Courtesy of AAF International
ARG 3.A (bottom left)	U.S. Centers for Disease Control and Prevention
ARG 3.A (bottom right)	Argonne National Laboratory
ARG 3.B	Courtesy of AAF International