Food and Agriculture Organization of the United Nations

Guidelines for African swine fever (ASF) prevention and control in smallholder pig farming in Asia

CULLING AND DISPOSAL OF PIGS IN AN AFRICAN SWINE FEVER OUTBREAK

USAID
FROM THE AMERICAN PEOPLE

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Contents

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The definition of a smallholder pig farm is not applied consistently across all countries in the Asia-Pacific region. While these guidelines present materials targeted to smallholders, all measures described in these guidelines are applicable for reducing the risk of African swine fever (ASF) in all pig farming enterprises.

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Abbreviations and acronyms

ASF	African swine fever
ASFV	African swine fever virus
AVMA	American Veterinary Medical Association
CFSPH	Center for Food Security and Public Health, Iowa State University of Science and Technology
DEFRA	Department for Environment Food and Rural Affairs, United Kingdom
FAO	Food and Agriculture Organization of the United Nations
ICA	Infection control area
IP	Infected premises
OIE	World Organisation for Animal Health
Terrestrial Code	OIE Terrestrial Animal Health Code
USDA	United States Department of Agriculture

Summary of key points

1. Introduction

This document aims to provide guidance for government officials and small pig holders in:

- Planning and conducting pig culling and disposal operations;
- Other relevant actions, such as cleansing and disinfection, in the context of ASF for preparedness and contingency planning in the event of an ASF outbreak.

2. Culling

2.1. Planning of culling operation

- Develop an action plan for culling (culling plan) before carrying out relevant activities in consultation with appropriate officials and relevant stakeholders.
- Operational activities of culling should be led by an official veterinarian assigned by the veterinary authority, or an appropriately trained person. This leader should provide overall guidance to personnel and logistic support for culling operations in adherence to the World Organisation for Animal Health (OIE) animal welfare and animal health recommendations.

2.1.1. Selection of culling site

- Wherever possible, culling is preferably conducted on-site to minimize handling and movement of animals.
- If on-site culling not applicable, animals have to be moved to another location for culling, and appropriate transportation arrangements should be made with appropriate biosecurity measures.
- Practical methods of carcass removal from the farm facilities should be planned in prior.
- The factors that need to be considered in selecting such a culling site depend on the culling method to be used as well as other factors such as facilities, animal security, disposal site, safety of personnel, acceptability for stakeholders, carcass transportation, likelihood of damage to property and services, and protection of public view.

2.1.2. Order of culling

- Normally, the order of culling shall be:
  - Affected animals;
  - Direct contacts of affected animals; and
  - Other susceptible animals in order of epidemiological importance based on ASFV-infection risk in response to the outbreak.

2.2. Culling methods

- The culling method chosen should address animal welfare as far as possible and be consistently reliable to ensure that all designated animals are humanely, quickly and safely killed.
- In applying any culling method, confirm death of the animals before disposal of the animal carcasses.
- A combination of criteria is most reliable for confirming death, including:
  - Lack of pulse, breathing, corneal reflex and response to a firm toe pinch;
  - Fixed glazed expression in eyes;
  - Inability to hear respiratory sounds and heartbeat by use of a stethoscope (the stethoscope must be properly disinfected afterwards);
  - Greying of the mucous membranes; and
  - Unable to support own weight.

2.2.1. Firearms

- Firearm operators should be properly trained and experienced in shooting pigs, and can be contacted at short notice to cope with emergency outbreak situations.
- Firearm licensing requirements and relevant legislation or regulations should be consulted and followed.
- Persons other than the firearm operators and assistants should be cleared from the area or be appropriately positioned.
- To ensure effective killing, the pigs should be shot at the appropriate position. The shooting range should be as short as practical, but the barrel should not be in contact with the head of the animals.
- Do not fire free bullets in a building with solid walls, as ricocheting bullets can cause injury or death.

2.2.2. Penetrating captive-bolt and pithing

- The pig should be restrained such that the head of the animal is accessible.
- The operator should fire the captive-bolt at a right angle to the skull in the optimal position.
- The bolt length and cartridge combinations should be appropriate to the size and age of the pig being culled.
- To ensure the effectiveness of using penetrating captive-bolt in culling, pithing should follow as soon as possible after the blow to ensure death of the animal.
  - Pithing is the process of destroying nervous tissue in the region of the brain stem to ensure the death of the animal, which is done by inserting a rod through the hole made by the captive-bolt in the head.

2.2.3. Lethal injection

- Anaesthetic overdose can be used for culling but may not be practical for the culling of large numbers of pigs.
- Ideally, lethal injection should be done by the intravenous or intracardiac route.
- Animals culled by this method should not be supplied for human or animal consumption.
- Personnel performing this method should be trained and knowledgeable in anaesthetic techniques.
- The use of the anaesthetic agents and the disposal of culled carcasses by this method should comply with relevant legislation and regulations.
- The pigs should be appropriately restrained to facilitate effective administration. If necessary, sedation should be done prior to injection.

2.2.4. Electrocution

- Electrocution kills animals by passing an appropriate electric current through the heart to induce ventricular fibrillation and stop it from pumping blood.
- For effective culling, it is essential to ensure that the electrodes are in full contact with the pig prior to applying electricity and stay in contact with the pig for the full time of electricity application.
- The pigs to be culled should be located in a pen that has a reliable supply of electricity and the pigs should be appropriately restrained.
- The culling team should wear appropriate protective clothing for electricity insulation (e.g. rubber gloves and boots).
- A stunning current should be applied using scissor-type stunning tongs in a position that spans the brain for a minimum of three (3) seconds; followed immediately by transferring the electrodes to a position that spans the heart to apply the current for another minimum of three (3) seconds.

2.2.5. Gaseous methods

2.2.5.1. Carbon dioxide (CO_2)

- Inhalation of CO_2 induces respiratory and metabolic acidosis and hence reduces the pH of cerebrospinal fluid and neurones thereby causing unconsciousness and eventually death after prolonged exposure.
- Chambers (i.e. gas-filled containers or apparatus) are mandatory to accomplish culling by CO_2 inhalation for a large number of pigs.
- For CO_2 to be an effective culling method, the animals must be exposed to an atmosphere of at least 30 percent CO_2 to ensure loss of consciousness, and then an atmosphere of at least 70 percent CO_2 to ensure death.
- The CO_2 concentrations required could be achieved by using cylinders of CO_2 or dry ice and monitored by CO_2 detectors.
- To ensure death of the animals, maintaining exposure of the animals to CO_2 up to at least 20 minutes is preferable, or even longer for neonatal or juvenile animals.

2.2.6. Slaughtering

- Slaughtering may be considered if on-site culling is not a viable option for the pigs and the animals to be culled are located close to an existing slaughtering facility.
- Specific conditions need to be met, including the following:
  - Permission is granted to transport the pigs to the slaughtering facility.
  - Owner of the slaughtering facility is willing to conduct the slaughter.
  - The pigs being culled do not pose a public safety risk.
  - The pigs are mobile with no outward signs of diseases.
  - During animal transit/movement, appropriate biosecurity measures need to be in place to minimize risk to other susceptible animals.
  - The pigs must pass pre- and post-mortem inspections at the slaughtering facility.
  - Members of the slaughterhouse staff have had proper biosecurity training to avoid spreading ASFV.

3. Disposal

3.1. Environmental and biosecurity considerations

3.1.1. Environmental considerations

- Environmental aspects of proposed disposal activities should be properly considered, taking into consideration the current legislation with advice from relevant environmental agencies where possible.
- Consultations with relevant authorities, e.g. environmental protection agencies, are necessary.
- Disposal planning should include measures to prevent or mitigate negative environmental effects that may also ultimately impact human or animal health.
- Locations of disposal sites must be comprehensively documented.

3.1.2. Biosecurity considerations

- In the event of an ASF outbreak, the veterinary authority along with the local authorities shall identify various zones and areas in respect to the infected premises for implementation of suitable biosecurity and disease control measures.
- Biosecurity measures (e.g. movement control) for personnel, animals and resources may vary between zones and are subject to the decision of the veterinary authority.
- Careful contingency planning and implementation of a biosecurity plan to prevent the spread of ASFV from trucks and other equipment involved in transportation is critical to limiting the effect of the disease on wild boars and domestic pigs.
- Observance of strict biosecurity, cleansing and disinfection measures by the disposal personnel is essential to prevent the spread of ASFV between premises.

3.2. Disposal site

- The primary objective of disposal of animal carcasses and other relevant materials is to prevent the spread of ASFV and contamination of the environment.
- Disposal should be completed as soon as possible after culling and should require the least possible use of transportation.
- From a biosecurity perspective, depending on the local circumstances, on-site disposal methods are preferable to transporting carcasses off-site.
- When off-site disposal is considered, particular attention should be taken to maintain strict biosecurity measures for transportation of animal carcasses and relevant materials.

3.3. Disposal methods

3.3.1. Thermal disposal

- The thermal disposal method uses high-temperature combustion to destroy animal carcasses and associated materials.
- As pigs typically have a high fat content, thermal disposal is considered an efficient disposal method for pigs.

3.3.1.1. Open-air burning

- Open-air burning refers to burning carcasses in open fields, on combustible heaps or with other burning techniques that are unassisted by incineration equipment.
- Open-air burning should be conducted as far away as possible from the public and from local communities.
- Fire-beds should be constructed prior to the scheduled burning with ignition points at 10 metres intervals along the length of the fire-bed. In general, a fire-bed length of 1 metre allows 4 to 5 pig carcasses depending on the size of the pigs.
- General guide of fuel requirement per 4 to 5 adult pig carcasses:
  - Heavy timber: 3 pieces, 2.5 m × 100 mm × 75 mm;
  - Straw: 220 kg;
  - Small timber: 35 kg;
  - Coal: 200 kg;
  - Liquid fuel: 5 litres.

3.3.1.2. Pit burning

- Pit burning can be conducted in a trench, or alternatively, in a refractory box.
- Pit burning is a technique for burning materials using fan-forced air. The equipment consists of a large capacity-fan and ducts to deliver the air into the long side of a trench or box.
- Solid fuels such as straw, hay, coal, kindling wood and untreated lumber should be used. For proper combustion, an appropriate solid fuel-to-carcass weight ratio ranging from 1:1 to 2:1 shall be used.

3.3.1.3. Fixed-facility incineration

- Fixed-facility incineration usually takes place in a highly controlled and completely contained environment.
- A fixed-facility incinerator is equipped with an afterburner that burns the remaining volatile materials exiting the combustion chamber.
- Transportation of carcasses and relevant materials for fixed-facility incineration should be carefully considered, and appropriate biosecurity procedures must be established and strictly followed.
- Some larger animal production facilities, veterinary schools and diagnostic laboratories may have on-site incinerators that may be considered for use for emergency purposes.

3.3.2. Burial

- Carcasses of all ages and contaminated materials (such as litter and manure) can be disposed of by burial if suitable burial sites are available.
- There are different categories of burial methods, such as trench burial, commercial landfill, mass burial and above ground burial.
- The burial site should be of a width such that the equipment can fill it evenly with the materials to be buried.
- In general, there must be at least 0.6 metre of impermeable soil between the bottom of the burial site and the watertable, and at least 0.6 metre depth of soil is required to cover the carcasses.
- Regular inspection of the burial site after closure is recommended so that appropriate actions can be taken in the event of seepage or other problems.

3.3.3. Rendering

- Rendering is the process of heating raw materials to liberate fat from tissues and to separate fat from other solid tissues.
- The objective of rendering is to convert animal carcasses into pathogen-free feed protein and other valuable end products while reducing the negative effects of the carcasses on public health and the environment. The end product of rendering must pass relevant microbiological tests before release.
- The primary resource required for rendering is the rendering facility itself. Rendering may be considered for the disposal of carcasses provided that a suitable rendering facility is available.
- Rendering processes should be performed within 24 to 48 hours of death of the animals unless the carcasses are stored at a proper temperature (below 4 °C).

3.3.4. Composting

- Composting is a carcass disposal method that may take place indoors or outdoors, and promotes decomposition through placement of carcasses between layers of carbon-rich organic materials.
- To conduct composting, a compost windrow should be constructed. A composting process with a temperature of 60 °C maintained for two days could effectively inactivate ASFV in pig carcasses, even in the bone marrow.
- During the composting process, the addition of adequate carbon (i.e. carbon-rich organic materials such as sawdust, wood chips, ground cornstalks and ground straw) is necessary to absorb excess moisture and retain heat/sustain high internal temperatures for rapid decomposition and pathogen suppression.
- Carcasses can be composted whole or be ground and mixed with co-compost (i.e. carbon-rich organic materials). For every 500 kg of carcasses, it is anticipated that 2.5 m^3 to 5 m^3 of carbon materials will be needed.

4. Cleansing and disinfection

- After culling and disposal operations, thorough cleansing and disinfection of the affected premises and the environs should be conducted.
- Any remaining potentially contaminated materials such as manure, bedding, straw and feedstuff should be removed and disposed of appropriately.
- Preliminary cleansing is necessary before the use of any disinfectant. After preliminary cleansing, disinfection shall be followed by application (e.g. spraying) of appropriate disinfectants to any potentially contaminated surfaces.

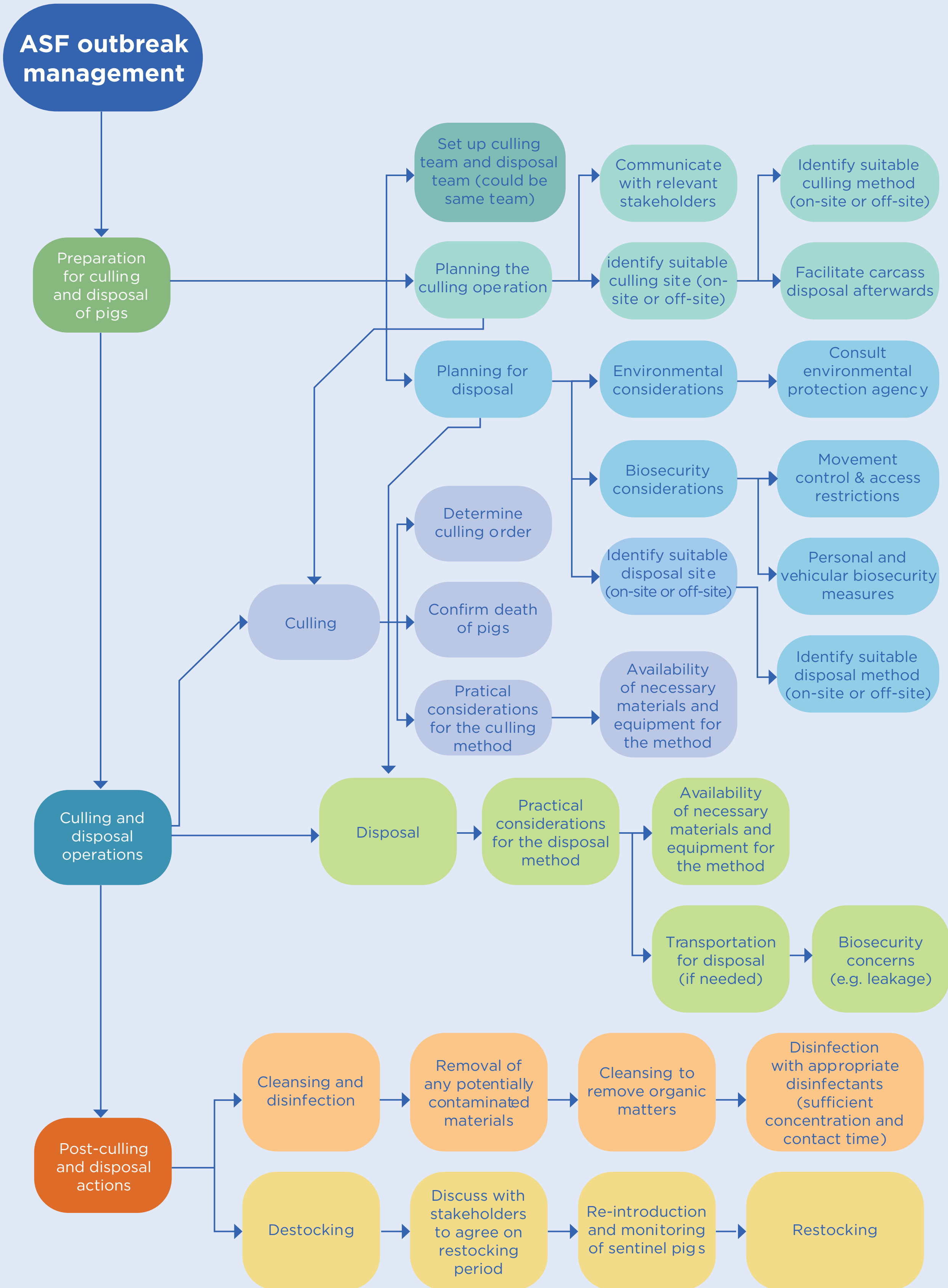
5. Destocking period

- The destocking period shall be discussed and agreed among the veterinary authority, farm owner and other relevant stakeholders.
- As a general rule, the destocking period would be shorter in hot climates than in cold or temperate climates, with the recommended minimum as 40 days.
- At the end of the agreed destocking period, new pigs may be restocked to the previously affected premises starting with the introduction of sentinel pigs.
- In occurrences of ASF that are linked to soft tick vectors, a longer destocking period is generally recommended.

6. Future considerations and directions

- Further exploration is needed to evaluate the effectiveness of tooth extraction partial culling approach in ASF outbreak management.
- The most practical and appropriate culling and disposal methods should be selected for use adapting to the local context and specific field conditions.
- To maintain preparedness for ASF outbreak management, training and refreshment for relevant personnel are recommended on a regular basis.
- Feasible and appropriate methods for culling and disposal of wild boars should be considered and explored taking into account local wild boar ecology.
- Veterinary authorities are encouraged to engage the private sector, livestock associations and other relevant stakeholders to explore the possibility of implementation of an affordable compensation scheme.

Mindmap



ASF outbreak management
Preparation for culling and disposal of pigs
Set up culling team and disposal team (could be same team)
Planning the culling operation
Planning for disposal
Communicate with relevant stakeholders
identify suitable culling site (on-site or off-site)
Identify suitable culling method (on-site or off-site)
Facilitate carcass disposal afterwards
Environmental considerations
Consult environmental protection agency
Biosecurity considerations
Movement control & access restrictions
Identify suitable disposal site (on-site or off-site)
Personal and vehicular biosecurity measures
Identify suitable disposal method (on-site or off-site)
Culling
Determine culling order
Confirm death of pigs
Pratical considerations for the culling method
Availability of necessary materials and equipment for the method
Culling and disposal operations
Disposal
Practical considerations for the disposal method
Availability of necessary materials and equipment for the method
Transportation for disposal (if needed)
Biosecurity concerns (e.g. leakage)
Post-culling and disposal actions
Cleansing and disinfection
Removal of any potentially contaminated materials
Cleansing to remove organic matters
Disinfection with appropriate disinfectants (sufficient concentration and contact time)
Destocking
Discuss with stakeholders to agree on restocking period
Re-introduction and monitoring of sentinel pigs
Restocking

1 Introduction

In the absence of treatment and vaccination available for African swine fever (ASF), the main control measure of ASF is the culling of animals to prevent and control further spreading of the disease. It is essential that the animals are rapidly and humanely culled and are confirmed dead before disposal of carcasses commences (FAO, 2001). As any live animals will continue to produce and possibly disseminate ASF virus (AFSV), speed and location are critical once the disease has been confirmed. However, in the planning of culling, public interest should be considered (FAO, 2001). Following culling, disposal of the carcasses and relevant materials are of vital importance to prevent the spread of ASFV. Disposal should be completed as soon as possible after culling in order to minimize opportunities for any infectious materials to disperse (FAO, 2001). Other follow-up actions, including cleansing and disinfection of affected premises and implementation of destocking period, should be adopted to enhance ASF control.

These guidelines provide guidance for government officials and small pig holders in planning and conducting pig culling and disposal operations, as well as other relevant actions such as cleansing and disinfection, in the context of ASF for preparedness and contingency planning in the event of an ASF outbreak. The Annex provides a template checklist on personal protective equipment (PPE) on relevant procedures for personnel involved in culling and disposal procedures.

2 Culling

2.1. Planning a culling operation

Developing an action plan for culling (culling plan) is important. The culling plan should be developed taking into account the country/territory-specific situation (AVMA, 2018). Factors need to be considered in a culling plan generally include time constraints, worker safety, ownership of animals, indemnity, public perception, number and size of pigs, animal environment (e.g. indoor or outdoor), availability of personnel and equipment for culling, staging of human resources and equipment, animal handling, culling method, carcass removal and disposal methods (AVMA, 2018). In addition to these, the availability of compensation would be an important concern for the animal owner and may affect the efficiency and effectiveness of culling operations, which should also be taken into careful consideration, preferably to be discussed with relevant stakeholders in prior during contingency planning.

The culling plan should be developed in consultation with appropriate officials and relevant stakeholders. The operational activities of culling should be led by an official veterinarian assigned by the veterinary authority, or, in the absence of an official veterinarian, an appropriately-trained person (e.g. farmer in the neighbourhood/village who has undergone proper training recognized by the veterinary authority). This leader should provide overall guidance and has the authority to appoint personnel with required competencies in the operation teams (e.g. culling team and disposal team) and ensure adherence to the required OIE animal welfare, biosecurity standards and animal health recommendations (FAO, 2001).

The official veterinarian, or the appropriately trained person, should undertake these tasks (FAO, 2001):

- Discuss the situation with affected pig holders, village leaders and other relevant stakeholders, and brief them on what is going to happen, including the method of compensation if any.

  Consult the pig holders, farm owners/manager and/or village leaders to establish:
  - farm layout, facilities and equipment;
  - the number and location of the designated pigs to be culled;
  - the culling method to be used; and
  - the time-frame for commencement and completion of culling.
- Decide on the methods and facilities needed for safe, humane and efficient culling of the pigs.
- Provide advice to the culling team(s) on the anticipated resources needed in preparation for the culling operation.
- Consult the disposal team, if different from the culling team, to determine the appropriate disposal method and site.
- Draw up a culling plan (which could also be a contingency plan in prior):
  - culling site(s)
  - culling method(s)
  - order of culling
  - personnel required
  - facilities and equipment needed
- Depict the infected premises (IP) and the infection control area (ICA) on a map including details of the culling site(s).
- In case there is compensation for the culled pigs, value all the designated pigs before culling and ensure the complete inventory of pigs to be destroyed is available; where there is no prior agreement on valuation, closely supervise the culling operation to ensure that all the designated pigs are available for culling. Seek legal authority whenever necessary to ascertain timely culling to avoid compromising the effectiveness of the culling operation for ASF control.
- Request pig owners to properly assemble, confine and restrain their pigs prior to the culling team starts the operations.
- Ensure that animals not to be culled, if any, including domestic pets, are confined well away from the culling site.
- Inspect the surrounding countryside to assess the presence of free-roaming or unrestrained susceptible animals (e.g. wild boars). If present, arrange culling teams to round up and cull such animals appropriately (e.g. shooting by trained personnel) with proper disposal.
- Ensure necessary support services, such as police and army personnel, are available.

Before commencing and during the culling operation, the culling team should carry out the tasks below, preferably under the supervision of the veterinary authority (FAO, 2001):

Move the designated animals to be culled to the designated location of the IP or to areas most remote from other susceptible animals, including wild boars, as appropriate.

Ensure that culling facilities, methods and working conditions are in compliance with personnel safety and animal welfare.

Avoid damage to property as far as possible; any damage must be recorded and reported appropriately and promptly.

Countercheck the culled pigs against the authorized inventory to ensure that all animals scheduled for culling are destroyed at the end of each day.

Provide a situation report of the culling operation at the end of each day.

Provide estimation on resource requirements for the next 48 hours on a daily basis and arrange for replenishment of resources as and when necessary.

Report to the veterinary authority regularly on the culling progress and immediately once culling operation has been completed to ensure other tasks such as disposal and disinfection can be followed without delay.

The following sub-sections provide guidance on the selection of appropriate culling site(s) and deciding the order of animal destruction.

2.1.1. Selection of culling site

Wherever possible, it is preferable that culling be conducted on-site to minimize handling and movement of animals (OIE, 2019). However, there may be circumstances that require the animals be moved to other locations, such as a slaughterhouse, for culling. Appropriate transportation arrangements should be made (e.g. leak-proof conveying vehicles that transport pigs via the shortest route with minimal domestic/wild boars nearby). Pig carcasses may not be easily removed from farm facilities after culling, particularly for smallholder pig farms of which physical constraints of the farm settings may limit the tools (e.g. clamp truck and crane lorry) that could access for carcass removal. In view of this, it is particularly important to plan practical methods of carcass removal from the farm facilities before applying any of the culling methods. Ideally, the pigs should be moved to a designated location which could better facilitate the removal of carcasses prior to commencing culling operation. In general, the factors that need to be considered in selecting such a culling site depends on the culling method to be used as well as other factors including but not limited to the following (FAO, 2001):

- facilities available on site (e.g. firearms, proper gas chamber, captive-bolts, electrocution facilities, etc.);
- additional facilities and equipment required for the preferred culling method;
- animal security (e.g. whether the pigs could be confined in a secured area or are free-roaming in the culling site);
- proximity of the disposal site and ease of access. In general, it is preferable to have close and easy access to the disposal site from the culling site;
- safety of personnel (e.g. whether the preferred method allows personnel in the culling site to be safe from occupational risks, such as safe use and storage of firearms);
- acceptability to the owner/manager (e.g. does the owner/manager of the premise object to have the culling operation conducted there?);
- safe and secure means of transporting carcasses from the culling site;
- likelihood of damage to property and services; and
- protection from public view.

It is also possible to conduct culling at a slaughterhouse/abattoir, where the recommendations in Chapter 7.5. of the OIE Terrestrial Code should be followed (OIE, 2019).

2.1.2. Order of culling

The veterinary authority shall determine the order of culling based on the specific situation. Normally, the culling is in this order (FAO, 2001):

Affected animals

↓

Direct contacts of affected animals

↓

Other susceptible animals in order of epidemiological importance based on ASFV-infection risk in response to the outbreak

Irascible and potentially dangerous animals, such as sows with litters, and boars, should be culled first to facilitate smooth culling operation (FAO, 2001).

2.2. Culling methods

In designing a culling plan, it is essential that the culling method chosen be consistently reliable to ensure that all designated animals are humanely, quickly and safely killed (OIE, 2019). Animal welfare should be addressed as far as possible in a culling operation. In general, methods used should result in immediate death or immediate loss of consciousness lasting until death. When loss of consciousness is not immediate, induction of unconsciousness should be non-aversive or the least aversive possible, and should not cause avoidable anxiety, pain, distress or suffering in animals (OIE, 2019). This section presents a number of culling methods as examples.

Table 1 summarizes the characteristics of these culling methods as reference for selecting an appropriate method that takes into consideration the case-specific situation. The following culling methods are not presented in the order of preference but from the simplest to the most sophisticated one. As guidance for selecting an appropriate culling method, **Figure 1** presents a decision tree for selecting a culling method. In applying any of these culling methods, there must be a confirmation of the animal's death before disposal of the animal carcasses. A combination of criteria is most reliable for confirming death, including (AVMA, 2018; Humane Slaughter Association, 2017):

- Lack of pulse, breathing, corneal reflex, and response to a firm toe pinch;
- Fixed glazed expression in eyes;
- Inability to hear respiratory sounds and heartbeat by use of a stethoscope (the stethoscope must be properly disinfected afterwards);
- Greying of the mucous membranes; and
- Unable to support own weight.

Table 1. Characteristics of different culling methods

Culling method	Duration*	Technical requirement	Cost#	Applicability	Advantages	Disadvantages
Firearms	+	✓✓	$$	Suitable for animals that cannot be confined in an enclosed area	• Quick and effective • Requires minimal or no restraint of animals • Applicable for killing from a distance • Suitable for killing agitated animals in open spaces	• Potentially dangerous to humans and other animals in the area • Potential for non-lethal wounding • Legal restriction may hinder the usage • Limited availability of competent personnel • Leakage of body fluid may pose biosecurity risk
Penetrating captive-bolt and pithing	++	✓✓✓	$$	Suitable for small number of large pigs that are not easily moveable (e.g. sick or disabled pigs)	• Minimal animal movement is required • Induces immediate unconsciousness of the animal	• Improper application and usage may result in poor animal welfare • Post-stunning convulsions may make pithing difficult and hazardous • Difficult to use on agitated animals • Repeated use may result in over-heating of the gun • Leakage of body fluid may pose biosecurity risk
Lethal injection	++	✓✓	$$$	Suitable for culling small to moderate number of pigs if sufficient drugs are available, or as a backup euthanasia method to other culling methods	• Death can be induced smoothly	• May require restraint or sedation • May cause suffering if administered inappropriately • May have legal restriction that injection only to be used by veterinarians

Source: AVMA, 2018; OIE, 2019

Table 1. Characteristics of different culling methods *(continued)*

Culling method	Duration*	Technical requirement	Cost#	Applicability	Advantages	Disadvantages
Electrocution	++	✓✓✓	$$$	Suitable for culling small to moderate number of pigs if reliable electricity supply is available	• Minimal post-stunning convulsions • Non-invasive method that poses minimal biosecurity risk	• Reliable supply of electricity is required • Correct positioning is vital for effective application • Contact impedance may affect the effectiveness of application • Physically demanding procedure that may result in operator fatigue and affect the culling effectiveness
Gaseous method	+++	✓	$$	Suitable for culling a moderate to large number of pigs	• Simple application • Volume of gas can be readily calculated • Outdoor operations improve personnel health and safety • Chambers can be readily cleansed and disinfected • Required animal catching skills and relevant equipment are readily available in the industry • Non-invasive method that poses minimal biosecurity risk	• Proper chamber required • Aversive nature of the gaseous agents used • Animals do not immediately lose consciousness • Risk of suffocation due to overcrowding • Difficult to verify death of animals inside the chamber

Source: AVMA, 2018; OIE, 2019

Table 1. Characteristics of different culling methods *(continued)*

Culling method	Duration*	Technical requirement	Cost#	Applicability	Advantages	Disadvantages
Slaughtering	+	✓	$^	Suitable for culling large number of pigs if the site is near an existing slaughtering facility	• Utilizes existing slaughtering facility purpose-built for large-scale humane killing of animals • Applicable for culling of large numbers of animals • Meat product may be saleable (subject to acceptance)	• Requires transportation of animals, which may pose considerable biosecurity risks • Owner of slaughtering facility may not be willing to conduct such slaughtering operation • Potential cross-contamination of ASF-free meat product • Trade restrictions may subsequently be imposed on the meat product from the slaughtering facility • Thorough cleansing and disinfection of the slaughtering facility after operation is required

Remarks:

+	Short	++	Fair	+++	Long
✓	Low	✓✓	Fair	✓✓✓	High
$	Inexpensive	$$	Fair	$$$	Expensive

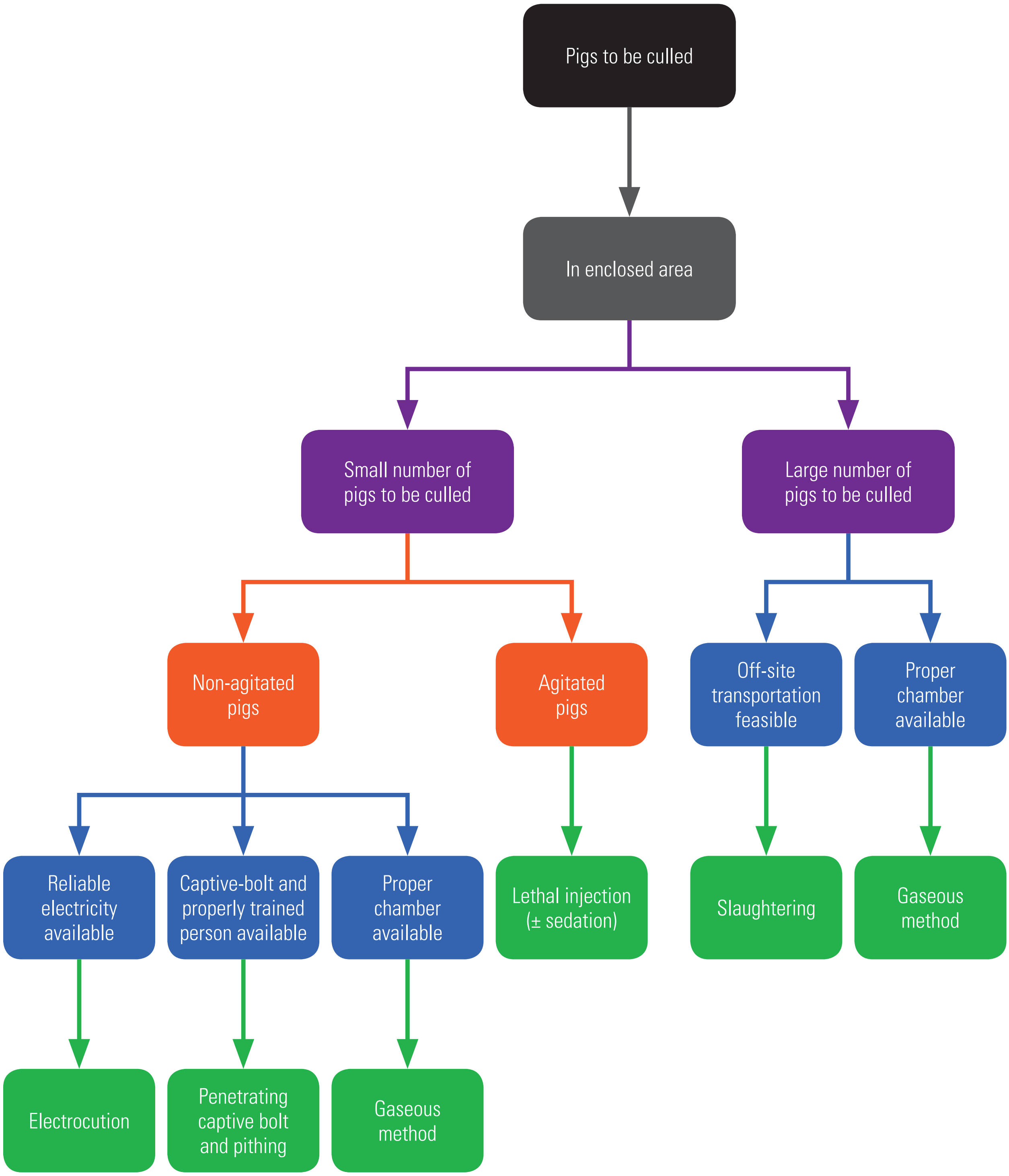
* Qualitative estimation on the time spent for preparation and implementation of the culling operation using the specified method till death of animals could be achieved

Including the cost of the equipment for implementation of the culling methods and other relevant expenses

^ Assuming existing slaughtering facility is available

Source: AVMA, 2018; OIE, 2019

Figure 1. Decision tree for culling methods



Note: Firearms may be considered as appropriate in open area

2.2.1. Firearms

Introduction

Firearms refers to the use of free projectile fired by handgun (close range: less than 10 cm), shotgun (medium range: 5–25 cm), rifle (long range: up to few metres), or other tailored firearms for humane killing of animals (EFSA, 2004). To ensure effective killing, the pigs should be shot at the appropriate position **(Figure 2a)**. The firearm operators should be properly trained and experienced in shooting pigs, and can be available if contacted at short notice to cope with emergency outbreak situations (OIE, 2019). It is important to ensure compliance with any firearm licensing requirements and relevant legislations or regulations, including the use of trained and approved operators for firearms (OIE, 2019). Wherever possible, notify the police before using firearms for culling, especially near populated areas (FAO, 2001).

Practical considerations for culling

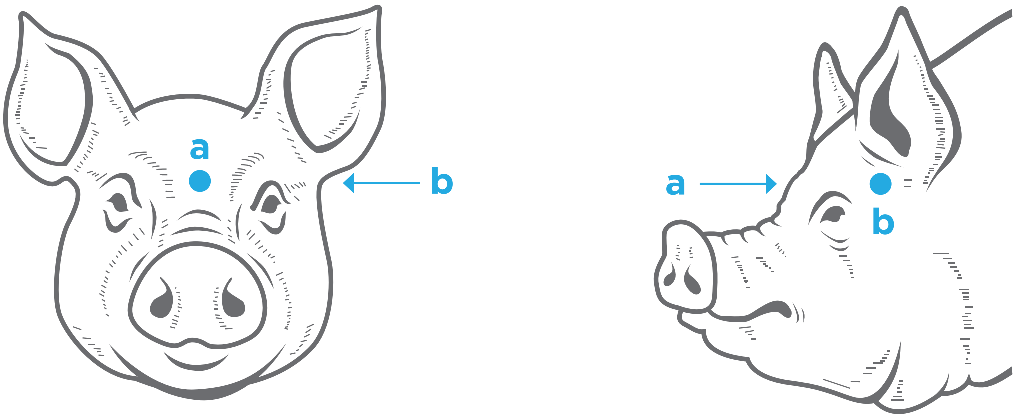
- Persons other than the firearm operators and assistants should be cleared from the area or be appropriately positioned (e.g. behind the shooters). The line of fire must be chosen to prevent accidents or injury from stray bullets or ricochets (FAO, 2001).
- To provide maximum impact and the least possibility of misdirection, the shooting range should be as short as practical, but the barrel should not be in contact with the animals (FAO, 2001; OIE, 2019).
- When shooting at short range, relatively low-velocity hollow/soft-point ammunition should be used. Solid-point ammunition should be avoided, because the projectiles can leave the target at high velocity, which is dangerous to personnel in the area (FAO, 2001).
- When shooting at long range, high velocity hollow/soft-point ammunition should be used and be aimed to penetrate the skull or soft tissue at the top of the neck of the animals (high neck shot) to cause irreversible concussion and death (FAO, 2001; OIE, 2019).
- Do not fire free bullets in a building with solid walls as ricocheting bullets can cause injury or death.
- Shot animals should be checked to confirm death (OIE, 2019).

2.2.2. Penetrating captive-bolt and pithing

Introduction

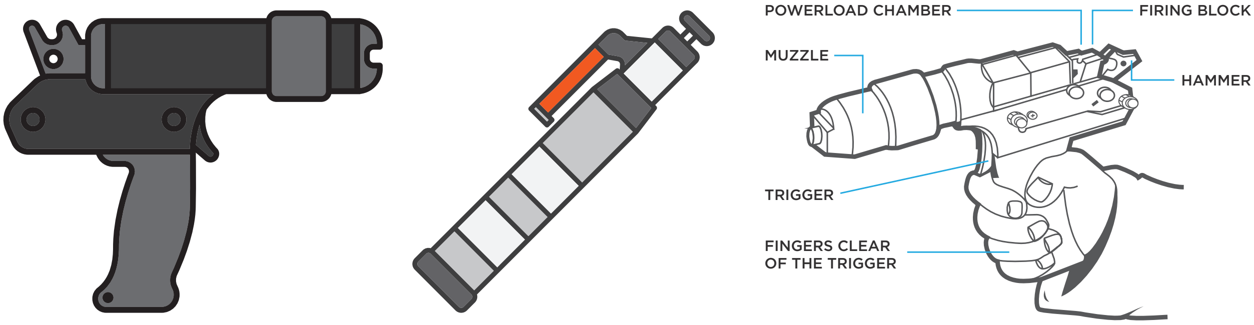
Captive-bolt is an alternative to firearms where animals are sufficiently restrained and is preferably to be done by appropriately trained person. One should be aware that the animals may be stunned instead of killed (FAO, 2001) as adult pigs have a wide frontal sinus and strong-boned skull. A captive-bolt is fired from a gun powered by either compressed air or a blank cartridge, without a free projectile **(Figure 2b)**. The gun should be placed on the front of the skull of the pig to deliver the impact blow at the appropriate position **(Figure 2a)** (OIE, 2019). To ensure the effectiveness of using penetrating captive-bolt in culling, pithing should follow as soon as possible after the blow to ensure death of the animals (OIE, 2019). Pithing is the process of destroying nervous tissue in the region of the brain stem to ensure the death of the animal. This is done by inserting a rod through the hole made by the captive-bolt in the head (FAO, 2001). Pithing is preferable to exsanguination, or bleeding, which may also serve the same purpose but could release much larger amount of infectious materials contaminating the environment and make the culling site slippery and dangerous (FAO, 2001).

Figure 2a. Recommended positions and direction of fire for humane destruction of pigs (a) frontal position in the mid line of the forehead 1–2 cm above the eye level (suitable for captive-bolt or firearms); or (b) temporal position at midway point between the eye and the base of the ear on the same side of the head (suitable for firearms only)



Source: EFSA, 2004; FAO, 2001

Figure 2b. Two examples of captive bolts



Source: Humane Slaughter Association

Practical considerations

- To ensure effective and efficient stunning, regular maintenance of the captive-bolt is essential (FAO, 2001).
- The bolt length and cartridge combinations should be appropriate to the size and age of the pig being culled (AVMA, 2018).
- The pig should be restrained that the head of the animal is accessible (OIE, 2019).
- The operator should fire the captive-bolt at a right angle to the skull in the optimal position (OIE, 2019). **(Figure 2a)**
- Spare captive-bolt guns should be on hand to avoid overheating and in case of ineffective shot (FAO, 2001; OIE, 2019).
- To ensure death of the animals, pithing should be performed as soon as possible after the impact blow (OIE, 2019). It should be noted that the animal should be sufficiently stunned (e.g. checking for the absence of corneal reflex) before pithing as it is inhumane to pith unstunned animals (FAO, 2001).
- Animals should be monitored continuously until death is confirmed (OIE, 2019).

2.2.3. Lethal injection

Introduction

Anaesthetic overdose can be used for culling but may not be practical for the culling of large numbers of pigs (AVMA, 2018). In practice, an overdose of any of the barbiturates, or in combination with other drugs, can be used for euthanasia by causing CNS depression, unconsciousness and death (OIE, 2019). Ideally, in pigs, it should be done by an intravenous route, or intracardiac route, if achievable. The pigs should be confined and handled with extreme care. Specific euthanasia solutions are available (e.g. sodium pentobarbitone 325 mg/kg) (FAO, 2001). Injection of barbiturates should not be administrated by the intrathoracic, subcutaneous or intramuscular route, as the drugs are extremely irritating to tissues (AVMA, 2018). Note that animals culled by this method should not be supplied for human or animal consumption due to risk of potential poison exposure and should be appropriately disposed of to avoid accidental consumption by other animals.

Practical considerations

- Personnel performing lethal injection should be trained and knowledgeable in anaesthetic techniques (OIE, 2019).
- The use of anaesthetic agents (e.g. used by veterinarians or under veterinary supervision) and the disposal of culled carcasses by this method should comply with relevant legislation and regulations (FAO, 2001).
- The pigs should be appropriately restrained to facilitate effective administration (OIE, 2019).
- If the animals are excitable or vicious, prior sedation may be required for these animals. Drugs for sedation, such as tranquillizers, analgesics or depressants (e.g. ketamine, opioids or xylazine) can be given by the subcutaneous or intramuscular route. An overdose of barbiturate can then be given intravenously to kill the animal (FAO, 2001; OIE, 2019).
- The pigs should be monitored closely after administration of the drug until death is confirmed (OIE, 2019).

2.2.4. Electrocution

Introduction

Electrocution kills animals by passing an appropriate electric current through the heart to induce ventricular fibrillation and stop it from pumping blood around the body. When ventricular fibrillation occurs, the heart muscles fibres will contract in a rapid and uncoordinated manner, stopping blood circulation and causing rapid death due to cerebral anorexia (Humane Slaughter Association, 2017).

A two-stage application of electric current is effective for killing pigs with appropriate current and voltage subject to age. The first stage comprises the application of current to the head by scissor type tongs that spans the brain and stuns the animal **(Figure 3)**, while the second stage should follow immediately with the application of the tongs across the chest in a position that spans the heart to cause death by cardiac arrest (Humane Slaughter Association, 2017). The application of sufficient electric current to the head in the first stage will induce 'tonic/clonic' epilepsy and unconsciousness. Once the animal is unconscious, the second stage will induce ventricular fibrillation resulting in cardiac arrest and death. The second stage should only be applied to unconscious animals to prevent unacceptable levels of pain (OIE, 2019).

Figure 3. Electrocution: scissor-type tongs and application of current to the head of the pig spanning the brain

For effective culling, it is essential to ensure that the electrodes are in full contact with the pig prior to applying electricity and stay in contact with the pig for the full time of the application of electricity (Humane Slaughter Association, 2017). The minimum voltage and current required for pigs of different ages are summarized in **Table 2**.

Table 2. Minimum electrical parameters for stunning and killing pigs

Age of pigs	Minimum current (A)*^	Minimum voltage (V)
> 6 weeks	1.3	220
< 6 weeks	0.5	125

* The frequency of the current applied should be no greater than 80Hz because, as frequency increases, ventricular fibrillation is less likely to result.

^ The contact resistance should be as low as possible to maximize the flow of current. The conductivity of the exterior of the animal may be improved by wetting the skin or fleece, and applying electrodes in the correct position and with constant pressure for the duration of the electricity application.

Source: Humane Slaughter Association, 2017; OIE, 2019

Practical considerations

- The culling team should wear appropriate protective clothing for electricity insulation (e.g. rubber gloves and boots) (Humane Slaughter Association, 2017).
- The pigs should be located in a pen which has a reliable supply of electricity and be appropriately restrained (Humane Slaughter Association, 2017).
- A minimum of a two-person unit of the culling team is required: one person to restrain and position the animal, and one person to apply the electrodes (OIE, 2019). Additional labour may be required for moving animals from the barn to the location where electrocution will be performed (AASV, 2020).
- A stunning current should be applied via scissor-type stunning tongs in a position that spans the brain for a minimum of three seconds; followed immediately by transferring the electrodes to a position that spans the heart to apply the current for another minimum of three seconds (OIE, 2019).
- Regular cleaning of the electrodes is necessary to ensure optimal electrical contact (OIE, 2019).
- The pigs should be monitored closely after applying the current until death is confirmed (OIE, 2019).

2.2.5. Gaseous methods

2.2.5.1. Carbon dioxide

Introduction

Carbon dioxide (CO_2) is a practical means for culling by a controlled atmosphere, provided that certain criteria are met to address the numbers and sizes of pigs and the overall throughput, which means the overall productivity of the culling method (i.e. number of pigs culled) based on turnover rate (AVMA, 2018). Inhalation of CO_2 induces respiratory and metabolic acidosis, which reduces the pH of cerebrospinal fluid and neurones, thereby causing unconsciousness and eventually death after prolonged exposure (OIE, 2019). Chambers (i.e. gas-filled container or apparatus) are mandatory to accomplish culling by CO_2 inhalation for large numbers of pigs, which can be tailor-made or achieved by modifying a waste dumpster enclosed by covering it with clear polyethylene sheeting **(Figure 4)** (Meyer *et al.*, 2014). The limitations of utilizing CO_2 in culling operations include available gas volume, chamber volume and size of pigs. For effective culling, the animals must be exposed to an atmosphere of at least 30 percent CO_2 to ensure loss of consciousness and then at least 70 percent CO_2 to ensure death. To ensure death of the animals, maintaining exposure of the animals to CO_2 up to 20 minutes is recommended, an even longer time (e.g. 30 minutes) may be necessary in neonatal or juvenile animals, which are more tolerant of CO_2 (FAO, 2001). The CO_2 concentration required could be achieved by using cylinders of CO_2 or dry ice and monitored by CO_2 detectors (FAO, 2001). For personnel safety, oxygen detectors can be equipped to alert relevant staff of potential risk during the operation.

Practical considerations

- The chamber used should allow maintenance and accurate measurement of the required CO_2 concentration, and observation of the animals inside the chamber (OIE, 2019).
- The animals should be appropriately loaded into the chamber (e.g. with the use of loading ramp) (Meyer *et al.*, 2014).

- When using cylinders of CO_2 in a proper chamber, a CO_2 displacement rate of 20 percent of the chamber volume/minute for five minutes is an effective method to achieve required CO_2 concentration for on-site culling (Meyer *et al.*, 2014). Alternatively, the chamber may be filled with CO_2 before animals are placed in it depending on the actual practicability (FAO, 2001).
- When using dry ice for culling, the dry ice should be placed in the bottom of the chamber under a gauze floor such that there is no direct contact between animals and the dry ice. Animals should then be placed in the container and left there until unconsciousness and/or death ensues (FAO, 2001).
- The culling team should ensure that there is sufficient time allowed to ensure death of each batch of animals before subsequent batches are introduced into the chamber (OIE, 2019).
- Death must be confirmed before disposal of animal carcasses. If necessary, unconscious animals may be removed and killed by other methods (e.g. by lethal injection of overdose of barbituates) (FAO, 2001).

Figure 4 Carbon dioxide culling chamber: chamber for CO_2 culling using a waste dumpster enclosed by a covering of clear polyethylene sheeting

2.2.6. Slaughtering

Slaughtering facilities (e.g. slaughterhouses and abattoirs) are purposely built to handle humane killing of large numbers of animals on a daily basis. If on-site culling is not a viable option for the pigs and the animals to be culling are located close to an existing slaughtering facility, the animals may be transported to the slaughtering facility with the use of routine stunning and killing methods in the established slaughtering facility. This method is recommended provided that certain circumstances are met, including the following (Securing Indiana Pork's Supply, 2019):

- A competent authority grants permission to transport the pigs from the IP and/or the ICA to the slaughtering facility.
- The owner of the slaughtering facility is willing to conduct emergency slaughter.
- The pigs being killed do not pose a public safety or health risk.
- The pigs are mobile with no outward signs of diseases, not limited to ASF.
- Animal movement during transit implements appropriate biosecurity measures (such as leak-proof pig-conveying vehicle with appropriate cover via the shortest route with minimal domestic/wild pigs nearby) and poses minimal risk to other susceptible animals.
- The pigs pass pre- and post-mortem inspections at the slaughtering facility.
- Slaughterhouse staff is properly trained in biosecurity, which includes changing their clothes and shoes/personal protective equipment, and showering as appropriate when they finish work before leaving the slaughterhouse to avoid spreading ASFV.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3 Disposal

After culling in response to an ASF outbreak, proper disposal prevents or mitigates the spread of ASFV as well as environmental contamination. The goal is to conduct operations in a timely, safe, biosecure, aesthetically acceptable and environmentally responsible manner. Waste that requires disposal includes carcasses, animal products, contaminated manure, litter, bedding, contaminated feed, contaminated personal protective equipment, and contaminated materials and equipment that cannot be cleansed and disinfected (USDA & CFSPH, 2012).

3.1. Environmental and biosecurity considerations

Consideration of potential negative environmental impacts and biosecurity factors must figure into effective disposal planning and response. All disposal options present some potential negative environmental effects that must be accounted for in planning. Biosecurity risks are also present to varying degrees in all disposal methods (USDA & CFSPH, 2012).

3.1.1. Environmental considerations

Disposal of animal carcasses and other infectious materials may involve some adverse environmental consequences. These consequences need to be properly considered and take into account the current legislation, along with advice from relevant environmental agencies where possible, to ensure that the impacts are minimized. Consultation with relevant authorities, e.g. environmental protection agencies, is necessary to obtain specific information on these factors (Australian Veterinary Emergency Plan, 2015; FAO, 2001). Appropriate environmental regulatory agencies and stakeholders should be included in planning for the disposal site selection. Potential negative environmental effects of the selected disposal method on the air quality, water quality, soil integrity and other environmental factors should be considered. It is also crucial that disposal planning include measures to prevent or mitigate negative environmental effects that may also impact human or animal health (USDA & CFSPH, 2012).

In addition, post-disposal monitoring and remediation should be discussed with environment protection agencies to determine appropriate roles and responsibilities. Long-term risk management and monitoring costs are likely to be future considerations. Locations of disposal sites must be comprehensively documented, which may include the use of a geographic information system to map for potential carcass disposal sites (Australian Veterinary Emergency Plan, 2015).

3.1.2. Biosecurity considerations

In the event of an ASF outbreak, the veterinary authority along with the local authorities should identify various zones and areas as appropriate for the implementation of suitable biosecurity and disease control measures in accordance with the national contingency plan (e.g. movement control and access restriction). Section 4.1 of the Guidelines on Farm Biosecurity, Slaughtering and Restocking for ASF Prevention and Control provides further guidance for identification of various zones and areas.

Effective biosecurity and surveillance play key roles in the detection and prevention of further ASF spreading. Biosecurity measures (e.g. movement control) for personnel, animals and resources may vary between zones and areas subject to the decision of the veterinary authority (USDA & CFSPH, 2012). Personnel biosecurity measures as well as vehicular and equipment biosecurity are critical to helping contain the disease and prevent further spread. Potential human and vehicular traffic must be considered, and measures should be taken to maintain biosecurity in the corresponding zones and areas. In planning for disposal, the initial stages will require access to roads and open areas that can provide a way for large trucks and other vehicles to access the disposal site. Careful contingency planning and implementation of a biosecurity plan to prevent spread of ASFV from trucks and other equipment involved in such transportation is also critical to limiting the effect of the disease on wild boars and domestic pigs (Natural Resources Conservation Service, 2016; USDA & CFSPH, 2012). Section 4.2 of the *Guidelines on Farm Biosecurity, Slaughtering and Restocking* provides further guidance on movement control during an ASF outbreak.

In addition, observance of strict biosecurity, and cleansing and disinfection measures by the disposal personnel is also essential to prevent the possible spread of ASFV between premises. Disposal personnel must be aware of what zone they are in and what biosecurity protocols and restrictions are in place. In general, disposal teams are expected to clean and disinfect their clothing, including boots and hats, according to an established protocol as appropriate. For example, upon arrival at the entrance to the premises, the disposal team may need to change to protective clothing (e.g. coveralls, rubber boots, and hat) and follow other relevant biosecurity procedures. Upon departure from the premises, strict adherence to biosecurity protocols should be maintained. Appropriate procedures should be in place for the removal and disposal of personal protective equipment (USDA & CFSPH, 2012).

3.2. Disposal sites

The primary objective of disposal after culling is to prevent the spread of ASFV and contamination of the environment. Therefore, disposal should be completed as soon as possible after culling with the least transportation possible in order to minimize opportunities for infectious materials to disperse (FAO, 2001). Measures to prevent scavengers should also be in place as far as possible.

3.2.1. On-site disposal

Depending on the local circumstances, on-site disposal methods are preferable to transporting carcasses off-site from a biosecurity perspective (FAO, 2001).

General factors to be considered for on-site disposal methods are:

- Nature and amount of carcasses and relevant material(s) for disposal for selection of disposal site and method
- Availability of sites suitable for the disposal method adjacent to the culling site
- Accessibility to disposal site by relevant transport vehicles to facilitate movement of necessary equipment and materials
- Nature of soil/rock formation and landscape in the available sites to determine suitability for burial
- Level of water table and proximity to water catchment areas, bores and wells to address the risk of potential pathogen entry into water sources
- Presence of services such as water, gas, electricity, telephone lines, drainage, sewerage and other improvements or structures, including aerial lines that should be avoided when selecting disposal site
- Proximity to built-up areas and dwellings, particularly in the case of thermal disposal
- Fire restrictions and hazards in the case of burning
- Weather conditions such as prevailing winds and humidity which may affect the effectiveness of burning
- Availability of necessary resources for the disposal method, such as plant for burial and supplies of suitable fuel for burning
- Presence of overhead structures such as power lines which must be avoided when selecting burial and burning sites
- Subsequent plans for the use of the land, e.g. the soil may be unstable for infrastructure building where burial is conducted

Source: FAO, 2021

3.2.2. Off-site disposal

Where on-site disposal is not considered practical or difficult to carry out due to reasons such as environmental non-compliance or refusal of the landowner, transferring carcasses and/or other relevant materials to another site for disposal by other appropriate disposal methods becomes necessary. This may also be necessary when considering the disposal of materials in situations where site limitations, such as space unavailability or high water table, significantly hinder on-site disposal (FAO, 2001). If the affected premises are in close proximity, a common disposal site may be used (FAO, 2001). When off-site disposal is being considered, particular attention should focus on the transportation of animal carcasses and contaminated materials. The beds, trailers, dumpsters, etc. that will be used to transport the mortality to another location for disposal should be leak-proof, tarped and covered as appropriate to avoid dispersion during transportation (Natural Resources Conservation Service, 2016).

3.3. Disposal methods

This section describes a number of disposal methods as examples for guidance. **Table 3** summarizes the general considerations, advantages and disadvantages, and **Table 4** provides qualitative cost involvement indicators of these disposal methods as reference for selecting a disposal method that is appropriate in different scenarios. As guidance for selecting an appropriate disposal method, **Figure 5** presents a decision tree for selecting a disposal method for practical use. Case-specific considerations should always be taken into account when selecting a disposal method in response to an ASF outbreak.

Table 3. General considerations, advantages and disadvantages of different disposal methods

Disposal method	General considerations	Advantages	Disadvantages
Thermal methods			
• **Open-air burning** • **Pit burning**	• Combustion completeness of carcasses • Capacity limitation • Air pollution • Relevant regulations and approvals • Trained personnel required • Transportation biosecurity issues (for off-site disposal) • Public opposition • Owner acceptance and terms of use (for fixed-facility incineration)	• Biosecure • Inexpensive • Can be used on-site when on-site burial is not feasible • Burn site can be easily and quickly rehabilitated with only short-term monitoring	• Fuel/labour intensive • Smoke/odour potential • Can be time-consuming for complete combustion • High fire risk at certain seasons • Poor public perception • Ash disposal to be considered • Combustion efficiency affected by weather conditions • Requires 24-hour operation to maintain and monitor burning • Difficult to conduct in wet season
• **Fixed-facility incineration**		• Biosecure • Concurrent ash disposal • Environmentally sound • Highly efficient and controlled • No requirement for site remediation or monitoring	• Fuel intensive • Volume constraint • Facility limitation • Biosecurity concerns in transport • Extra time may be needed for arrangements

Source: Miller *et al.*, 2018 & Miller *et al.*, 2020

Table 3. General considerations, advantages and disadvantages of different disposal methods *(continued)*

Disposal method	General considerations	Advantages	Disadvantages
Burial			
Burial	• Decomposition gases ∘ Bloating can displace burial mound ∘ Lance/vent carcasses prior to burial • Burial location ∘ Soil characteristics ∘ Area of land required and accessibility ∘ Intended future use of site ∘ Presence of scavengers • Environmental impacts ∘ Water sources ∘ Air quality (odour) ∘ Weather conditions • Biosecurity ∘ Movement control ∘ Cleansing and disinfection of vehicle/ equipment • Site security ∘ Limit unauthorized access • Relevant regulations and approvals • Public perception	• Biosecure • Inexpensive • Easy to operate • Allows any number of animals to be disposed of • Environmentally sound (except for ground water) • Minimizes odour risk	• Land availability and capacity constrains • Site selection is critical requiring suitable geology and land area • Leachate and gas may need to be treated • Not appropriate in area of shallow watertable and near local community • Large equipment may be needed for large operations • Aesthetics if improperly performed • May affect future use and rehabilitation of the land • Ongoing site monitoring required • Sourcing suitable land may delay disposal operations (for off-site disposal) • Biosecurity concerns in transport (for off-site disposal)
Rendering			
Rendering	• Facilities typically have established procedures for handling biosecurity, wastewater and by-products • Rendering facilities are closely regulated to maintain environmental safety • Transportation biosecurity issues • Require delivery coordination to avoid overwhelming the facility • Temporary storage may be needed if carcasses cannot be rendered right away	• Biosecure • Existing and purpose-built facilities are available that meet required technical standards • Useable and low-risk end-product (subject to acceptable use)	• Limited number of facilities available with capacity constraints • Biosecurity concerns in transport • Complexities associated with cleansing and disinfection of the facility • Overall cost would be higher if there is no available or accessible market for the end-product

Source: Miller *et al.*, 2018 & Miller *et al.*, 2020

Table 3. General considerations, advantages and disadvantages of different disposal methods *(continued)*

Disposal method	General considerations	Advantages	Disadvantages
Composting			
Composting	• High monitoring frequency to maintain optimal composting temperatures • On-site process reduces biosecurity risks associated with transport • Affected by weather and ambient temperature • Potential impacts from wind, rain, drying conditions and scavengers	• Inexpensive • Can be done on-site when other disposal methods are not applicable • Useable and low-risk end-product (subject to acceptable use) • Does not require long-term monitoring or remediation • Environmentally sound	• Volume constraint • Slow process • May require a large area and large supply of co-composting material • Possibility of localized odour and soil contamination if poorly managed • Requires daily control and monitoring during initial stages • Biosecurity risk if required temperatures are not achieved • Efficiency may be affected by adverse climatic conditions • Biosecurity concerns in transport (for off-site disposal) • May require final product testing to release compost

Source: Miller *et al.*, 2018 & Miller *et al.*, 2020

Table 4. Cost involvement indicators of different disposal methods

Disposal method	Direct cost indicators				Indirect cost indicators		Remark
	Initiation	Transport*	Labour	Input	Environmental/ public health	Public perception	
Thermal methods							
• **Open-air** • **Pit burning**	$	$	$$$	$$$$	$$$	$$$$	
• **Fixed-facility incineration**	$$^	$$$	$$$	$$	$$	$$$	
Burial	$	$	$$$	$	$$$	$$$$	
Rendering	$^	$$$	$$$	$$$	$	$$	Usable end-product that may be saleable to lower overall cost subject to acceptance
Composting	$$	$$$	$	$$	$	$$	Usable end-product that may be saleable to lower overall cost subject to acceptance

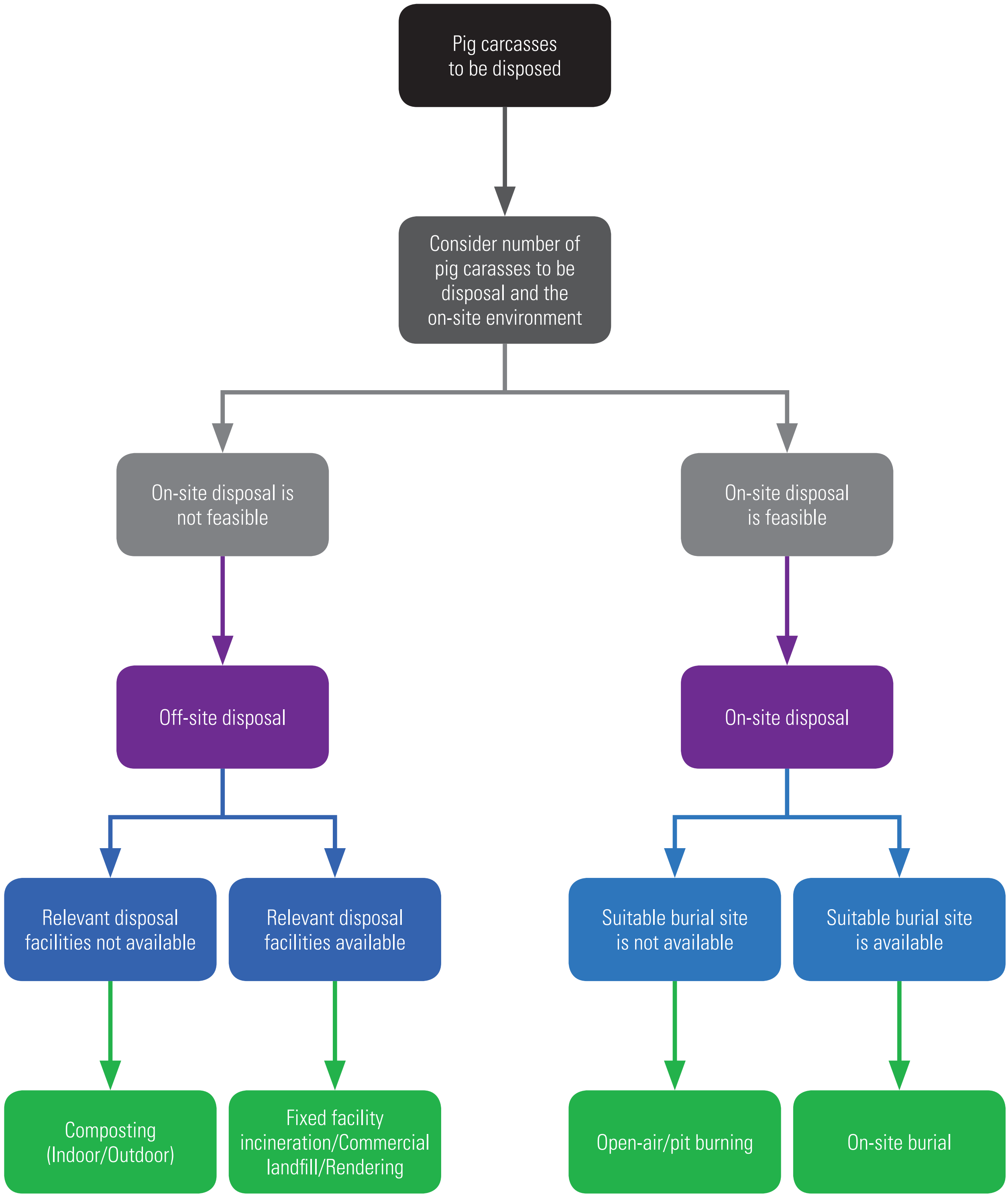
$ – low cost; $$ – medium cost; $$$ – high cost; $$$$ – very high cost

* Cost may vary with the actual transportation distances and the relevant materials and equipment that need to be transported

^ Assuming existing facilities are available.

Source: Australian Veterinary Emergency Plan, 2015; Baba *et al.*, 2017; USDA & CFSPH, 2012

Figure 5. Decision tree for disposal methods



3.3.1. Thermal disposal

Thermal disposal methods use high-temperature combustion to destroy animal carcasses and associated materials (USDA & CFSPH, 2012). The fat content of the animal carcasses influence the time required for burning, the greater the percentage of animal fat, the more efficiently a carcass will burn. As pigs typically have a high fat content, thermal disposal is considered an efficient disposal method for pigs (USDA & CFSPH, 2012). When thermal methods are considered for being applied outdoors, important considerations should be taken in account when selecting an appropriate site, including:

- **Location:** consider the possible effects of heat, smoke and odour on nearby structures, underground and aerial utilities, roads and residential areas (FAO, 2001).
- **Access:** consider the needed equipment to construct and maintain the fire and for delivery of fuel, carcasses or other materials to be burnt (FAO, 2001).
- **Environment:** consider the climate of the disposal site, if necessary consult local fire brigades or residents for advice, obtain permits for fire appliances to be on site during the burn (FAO, 2001).
- **Fuel:** the amount and type of available fuel may vary considerably depending on the method used and the carcasses to be burnt; and all required fuel should be on site before the burn is commenced (FAO, 2001) with refuelling performed as necessary (USDA & CFSPH, 2012).
- **Ash disposal:** ash should be buried on-site, or otherwise disposed of as appropriate, to restore the site to its original condition as fully as possible (Australian Veterinary Emergency Plan, 2015).

Common thermal disposal methods include open-air burning, pit burning and fixed-facility incineration (FAO, 2001). These methods are further described below.

3.3.1.1. Open-air burning

Open-air burning refers to burning carcasses in open fields, on combustible heaps called pyres, or with other burning techniques that are unassisted by incineration equipment. It is the lengthiest of all thermal disposal methods **(Figure 6)**. The principle is to place carcasses on top of sufficient combustible material, making sure that the arrangement of fuel and carcasses allows adequate air flow to enter the pyre from below, so as to achieve the hottest fire and the most complete combustion in the shortest time (FAO, 2001). Combustible materials may include hay, straw, dry timbers, or other kindling. In addition, diesel or other fuels are typically used in open-air burning. It should be noted that the potential for aerosol pathogen transmission from open-air burning must be addressed when considering this disposal method, e.g. restricting personnel and materials in the area near the burning site, followed by thorough cleansing and disinfection of the area before lifting the restriction (USDA & CFSPH, 2012).

Open-air burning is relatively uncontrollable and should be conducted as far away as possible from the public and outside the local communities. Only properly trained and credentialed personnel should conduct open-air burning, and local fire authorities should always be included in decision-making. Public perception of open-air burning is overwhelmingly negative, which must also be addressed during planning (FAO, 2001).

Prior to conducting open-air burning, the selected burning site should be staked out and fenced off for the fire-bed construction (Mukhtar *et al.*, 2008). Local availability will govern the type and amount of fuels to be used. The following can be used as a general guide of fuel requirement for four to five adult-pig carcasses (FAO, 2001):

- **Heavy timber: three pieces, 2.5 m × 100 mm × 75 mm**
- **Straw: 220 kg**
- **Small timber: 35 kg**
- **Coal: 200 kg**
- **Liquid fuel: 5 litres**

In general, a fire-bed length of 1 metre shall be allowed for every four to five pig carcasses, depending on the size of the pig (Mukhtar *et al.*, 2008). The carcasses should be positioned on the fire-bed on their backs with their feet in the air, with each laid alternately head to tail (Mukhtar *et al.*, 2008). Use a tractor with a front-mounted blade or a front-loader. When the carcasses have been loaded on the fire-bed, and the weather conditions suitable, saturate the fire-bed and carcasses with diesel or heating oil **(do NOT use petrol)** and prepare ignition points (e.g. rags soaked in kerosene) at 10-metre intervals along the length of the fire-bed. Move all vehicles, personnel and other equipment well away from the fire-bed. Start the fire from the direction against the wind and light the ignition points along the way. The fire must be attended at all times and be refuelled as necessary. Ensure that any carcasses or parts of carcasses that fall off the fire are put back on (FAO, 2001).

Figure 6. Open-air burning

3.3.1.2. Pit burning

Pit burning, also known as air-curtain incineration, is a technique for burning materials in a pit, using fan-forced air. Pit burning can be conducted in a trench, or alternatively, where trenches would be difficult or not practical to build, in a refractory box. A refractory box burns cleaner and produces less carbon monoxide and emissions than trenches. The equipment needed consists of a high-capacity fan, usually driven by a diesel engine, and ducts to deliver the air, which may be preheated, into the long side of a trench. The angle of the airflow creates a curtain of air that provides oxygen to the pit. Introduction of this high-volume of air greatly increases the temperature and accelerates the carcass combustion process compared to open-air burning (USDA & CFSPH, 2012). As a result, hot air recirculates in the pit, achieving more complete combustion (FAO, 2001), and can be up to six times faster than open-air burning. Pit burning has a higher throughput capacity than fixed-facility incineration, generating less ash at the same time because of its higher combustion temperatures. Thus, this option may be more suitable for disposing of a massive number of animal carcasses than fixed-facility incineration or open-air burning. Additional fuel is required to initiate combustion, however, once the fire is burning, the fuel requirement can be reduced (USDA & CFSPH, 2012). Before and during pit burning operations, the wind direction should be monitored and workers should be kept out of the path of the flame. Solid fuels such as straw, hay, coal, kindling wood, and untreated lumber should be used. For proper combustion, an appropriate solid fuel-to-carcass weight ratio ranging from 1:1 to 2:1 shall be used, determined by the moisture in the solid fuels, and the fat and moisture content of the carcasses (Mukhtar *et al.*, 2008).

3.3.1.3. Fixed-facility incineration

Fixed-facility incineration usually takes place in a highly controlled and completely contained environment (USDA & CFSPH, 2012). A fixed-facility incinerator is equipped with an afterburner that burns the remaining volatile materials exiting the combustion chamber and is typically fuelled by diesel, natural gas, or propane. A controlled fixed-facility incinerator has a more evenly distributed combustion temperature and burns carcasses more effectively and completely than open-air burning and pit burning (Mukhtar *et al.*, 2008). Transportation of carcasses and relevant materials for fixed-facility incineration must have appropriate procedures established and strictly followed, including the disinfection of containers and vehicles. Although fixed-facility incineration is an efficient carcass disposal method, achieving safe and complete disposal with minimal pollution can be difficult, and the cost of establishment and operation, and the lack of portability mean that incinerators may not be readily available (FAO, 2001). Some larger animal production facilities, veterinary schools and diagnostic laboratories may have on-site incinerators that may be considered for use in emergency situations, although they may not have sufficient continuous capacity to handle large quantities of carcasses or other contaminated materials (USDA & CFSPH, 2012).

Incinerators are usually only suited to disposal of small amounts of material (FAO, 2001). Because of the typical high fat content in pigs, personnel should avoid placing too much high fat material in the unit at one time because the liquid fat can accumulate and overflow the incinerator to surrounding areas (USDA & CFSPH, 2012).

3.3.2. Burial

Carcasses and other contaminated materials can be disposed of by burial if suitable burial site(s) are available **(Figure 7)**. Important considerations for selecting suitable burial sites include (FAO, 2001; USDA & CFSPH, 2012):

- Access for and availability of earthmoving equipment (e.g. excavator, loaders, bulldozers, road graders, backhoe, etc.) to dig the burial pit and for the delivery of carcasses or other materials to be buried.
- Environmental considerations:
  - Proximity to water bodies, wells, public areas, roadways, dwellings, residences, municipalities, or property lines; slope of the land; and drainage to and from the burial site.
  - Soil properties (texture, permeability, surface fragments, depth to water table, depth to bedrock), and space for temporary storage of overburden.
  - Direction of prevailing wind (odour).
  - Presence of scavengers that may dig the carcasses out.
- Construction considerations:
  - Avoid rocky areas, which slow digging and increase costs.
  - Select stable soils that can take the weight of equipment used to dig and fill the burial pits.
  - Construct diversion banks to prevent surface runoff from entering the pit.
  - Construct similar banks to prevent liquids escaping from the burial site.
  - Secure with fencing if necessary to exclude other susceptible animals until the site is safe for use.
  - Future intended use of the land.

Different categories of burial methods are available and their characteristics are described in **Table 5**.

The dimensions of the burial site depend on the equipment used, site considerations and the volume of carcasses and relevant materials to be buried. Reach of machinery, soil type and water-table level are the usual constraints. The burial site should be wide enough for the equipment to fill it evenly with the materials to be buried. In deciding the dimensions of the burial site, consideration needs to be given to the method of filling the site with carcasses and other relevant materials (USDA & CFSPH, 2012). In general, there must be at least 0.6 metre of impermeable soil between the bottom of the burial site and the water table and at least 0.6 metre depth of soil is required to cover the carcasses (Mukhtar *et al.*, 2008). When closing the burial site, surplus soil should be heaped over it as overfill. The weight of soil prevents carcasses from rising out of the pit because of gas entrapment, prevents scavengers digging up carcasses, helps filter out odours and assists in absorbing the fluids of decomposition. After subsidence of the burial site, it shall be necessary to replace any topsoil not utilized during closure (FAO, 2001).

Figure 7. Burial

(Top photo) Personal protective equipment is highly recommended for personnel when conducting burial.
(Center photo) The burial site should be of appropriate depth.

Table 5. Characteristics of different burial categories

Burial category	Characteristic
Trench burial	This burial method involves excavating a trench, placing the carcasses and other relevant materials in the unlined trench, and covering the trench with the excavated earth. Typically, this takes place on the site where animals originate.
Commercial landfill	This burial method involves using a highly regulated and approved pre-existing waste disposal facility, typically designed with a sophisticated by-product (e.g. methane and leachate) management systems to protect the environment.
Mass burial	Mass burial involves deposit of whole carcasses below ground level and to be covered by soil, which is appropriate if no approved landfill site nearby accepts animal carcasses. Such a burial site is normally not at a pre-existing waste facility; however, the burial site location may have been previously assessed for this purpose. This method could be used when large numbers of animal carcasses from multiple locations are disposed of. It is an engineered technology that requires a leadtime for proper design and construction that incorporate the use of sophisticated burial by-product management systems as well as prior regulatory approvals. Unlined burial is used when soil types or local geology can control the risk of leachate leakage, whereas lined burial is used when there are risks of leakage of leachate into subsoil or the water table.
Above-ground burial	Above-ground burial is undertaken by placing carcasses on a natural surface of earth and covering them with earth obtained from another source. Typically, this takes place on the site where animals originate.

Source: Australian Veterinary Emergency Plan, 2015

Regular inspection of the burial site after closure is recommended so that appropriate actions can be taken in the event of seepage or other problems. The objective is that the site should return to its original condition. For on-site burial, before restocking is permitted, the burial site should be inspected again to ensure that there is no possible biological or physical danger to the newly introduced stock (FAO, 2001). As the carcass mass decomposes over time, settlement of the site may occur. Hence, additional backfill may be required to prevent pooling of water at the site and to help restore the natural land surface. Depending on the volume of carcasses and relevant materials buried, some additional repair steps to contain gas or leachate may be needed (USDA & CFSPH, 2012).

3.3.3. Rendering

Rendering is the process of heating raw materials to liberate fat from tissues and to separate fat from other solid tissues (Australian Veterinary Emergency Plan, 2015). The primary resource required for rendering is the facility itself. Further resources might include extra personnel to monitor biosecurity, and additional equipment and facilities, including water and power supply (Australian Veterinary Emergency Plan, 2015).

Some examples of biosecurity protocols for rendering to be used for disposal of carcasses are listed below as reference:

- Keep unauthorized personnel and uninfected carcasses out of the rendering facility used for processing infected carcasses (Mukhtar *et al.*, 2008).
- Personnel involved in overseeing operations at a rendering facility should be aware of potential exposure to infectious material and be adequately trained in biosecurity procedures to prevent the spread of disease (Australian Veterinary Emergency Plan, 2015).
- Properly maintain the carcass-receiving section as the "dirty" area and the finished-product section as the "clean" area of the rendering facility, and keep them functionally separate from each other (Mukhtar *et al.*, 2008):
  - Prevent workers from moving from the clean area to the dirty area unless they have taken appropriate cleaning and disinfection measures.
  - Restrict equipment movement to keep contamination from the dirty area from moving to the clean area.
  - Prevent the drainage of liquids from the dirty area to the clean area to avoid contamination of finished products and their transportation system.
  - Direct the airflow within the rendering plant from the clean area to the dirty area.
- Monitor the cooking process periodically. A good indication of cooking is a slight grittiness in and fibrous nature of the cooked carcasses (cracklings). Slippery cracklings indicate under-cooking; a lack of fibre indicates overcooking (Mukhtar *et al.*, 2008).
- Routinely sanitize the equipment and maintain the tools used in the rendering facility with steam or appropriate disinfectant (Mukhtar *et al.*, 2008).
- Ensure that the end products are tested for disease agents (not limited to ASFV), and document that the rendering process has produced a safe product before release (Mukhtar *et al.*, 2008).

In a carcass rendering procedure, animal carcasses are broken down thermally and sterilized in a sealed and controllable container using pressurized steam; the process converts the carcasses into safe, nutritional and valuable products. The objective of rendering is to convert animal carcasses into pathogen-free feed protein and other valuable end products while reducing the negative effects of the carcasses on public health and the environment. Carcass rendering separates the fat, protein and water from a dead animals and sterilizes the final products and by-products, which include tallow, meat, bone meal and wastewater (Mukhtar *et al.*, 2008). The end product of rendering must pass relevant microbiological tests before release (FAO, 2001).

Rendering may be considered for the disposal of carcasses provided that a suitable rendering facility is available. Rendering processes should be performed within 24 to 48 hours after the death of the animals unless the carcasses are stored at a proper temperature (below 4°C). Although freezing or chilling of materials may allow temporary storage for subsequent disposal over a longer timeframe, it will increase costs and may increase the risk of dissemination of disease as a result of increased handling requirements (Australian Veterinary Emergency Plan, 2015).

If rendering is chosen as a carcass disposal option, selection of a facility with optimal biosecurity protocols is critical (USDA & CFSPH, 2012).

Two types of rendering methods are available, namely continuous rendering and batch rendering. From a biosecurity perspective, continuous rendering is often preferable when compared to batch-rendering because of the decreased risk of spreading infectious disease. During batch-rendering, each time a vessel is opened (e.g. for the discharge of rendered contents or for re-filling), airborne particles are released and biosecurity is threatened. The airborne particles released may compromise biosecurity (USDA & CFSPH, 2012). When considering rendering for carcass disposal, the proximity of the rendering facility to the affected premises must be evaluated. Where travel distances are long, or the only possible route is through intensive farming sectors or townships requiring biosecure transport, additional time and cost will be incurred, which should be taken into consideration (Australian Veterinary Emergency Plan, 2015). As an emergency disease outbreak response, the availability and capacity of rendering need to be carefully assessed to ensure disposal within a reasonable timeframe. The capacity of the facility (i.e. the number of carcasses able to be processed per day) will determine the time it takes to dispose of the carcasses.

3.3.4. Composting

Composting is a carcass disposal method that promotes decomposition through placement of carcasses between layers of carbon-rich organic materials (USDA & CFSPH, 2012). The end product of carcass composting is a homogenous, dark brown, soil-like material called 'humus'. This material contains mostly mesophilic bacteria and is suitable for use as a soil additive. ASFV is heat sensitive and can be deactivated at 50°C in 30 minutes, at 56°C within 90 seconds and at 60°C within a few seconds. A composting process with a temperature of 60°C maintained for two days could effectively inactivate ASFV in pig carcasses, even in the bone marrow. Hence, a correctly performed composting process is considered an appropriate carcass disposal method following an ASF outbreak (Franke-Whittle & Insam, 2013).

The major objectives of carcass composting are to (Mukhtar *et al.*, 2008):

- **Provide the proper conditions for carcass biodegradation**
- **Inactivate certain pathogens, including ASFV**
- **Prevent pig carcasses from generating environmental pollutants**
- **Convert the carcasses into useful end products for agricultural lands**

Carcasses can be composted whole or be ground and mixed with co-compost (i.e. carbon-rich organic material such as sawdust, wood chips, ground cornstalks and ground straw) to improve microbial activity and speed of decomposition (USDA & CFSPH, 2012). Grinding provides uniform porosity and suitable conditions for aeration, hence improving microbial activity and speed of decomposition considerably (Mukhtar *et al.*, 2008). Carcass composting consists of two principal phases: the active phase (Phase 1) and the curing phase (Phase 2) described as below (USDA & CFSPH, 2012):

- Active phase (Phase 1)
  - Characterized by aerobic reactions, high temperatures and large reductions in biodegradable solids. Adequate aeration is crucial to maintain a uniform temperature and moisture content throughout the pile.
  - Core temperature of the compost pile should be raised to 56 °C to 60 °C within 15 days, and be maintained at this temperature for several days if composting ground carcasses, or 3 to 12 weeks for composting intact carcasses depending on the size.
  - Bulk density may decrease up to 50 percent.
- Curing phase (Phase 2)
  - Aeration is not a critical factor, a series of slow-rate reactions (e.g. breakdown of lignin) occurs at temperatures below 40 °C.
  - Core temperature of the compost pile ranges from 25 °C to 30 °C, which shall be maintained for around 6 to 8 months for decomposition depending on the size of the carcasses.
  - Bulk density may decrease by 25 percent.

During the composting process, the addition of adequate carbon (i.e. carbon-rich organic materials) is necessary to absorb excess moisture and retain heat/sustain high internal temperatures for rapid decomposition and pathogen suppression (USDA & CFSPH, 2012). Therefore, when selecting composting as a disposal method, an important consideration is the availability of large quantities of carbon sources. For every 500 kg of carcasses, it is anticipated that 2.5 m^3 to 5 m^3 of carbon materials would be needed (USDA, 2017). If a very large number of carcasses is required to be disposed of, then locating, transporting and grinding sufficient quantities of carbon materials will be a significant task (USDA & CFSPH, 2012).

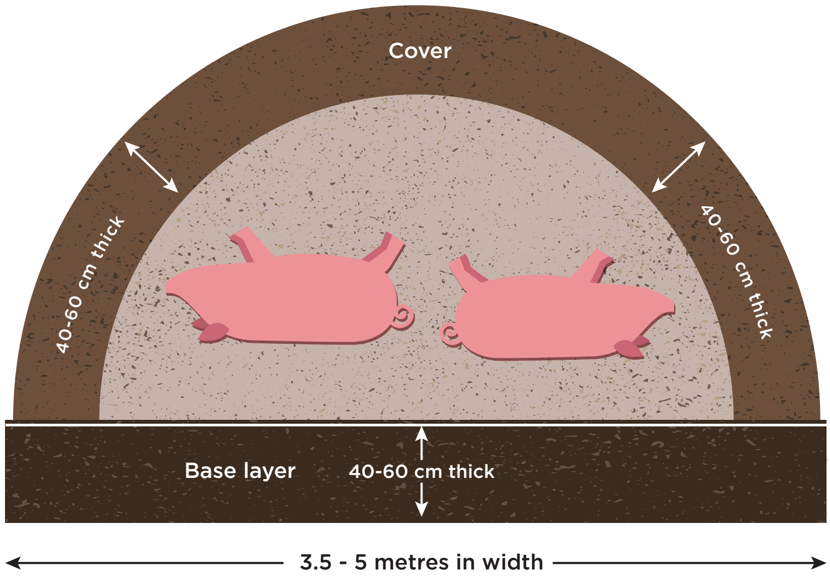
To conduct composting, a compost windrow **(Figure 8)** should be constructed, which should be composed of three critical elements (USDA, 2017):

1. A base layer that provides absorbency, structure and airflow (porous carbon material).
2. A windrow core containing a mixture of carcasses, manure and feed.
3. An adequate cap.

With the same principles, the windrow core can also be constructed by layering carcasses and carbon material alternately.

Depending on the actual situation, composting may take place indoors or outdoors, with similar underlying scientific principles (USDA & CFSPH, 2012). Indoor composting, could be applied for disposal of animals of small sizes and numbers. The processes are less affected by weather events, such as ambient temperatures and seasonality than outdoor composting. When compared to outdoor composting, indoor composting is more protected from various environmental factors such as wind, scavengers and drying conditions. However, indoor composting presents the challenges of space limitations and restricted space for access and use of heavy equipment. When outdoor composting is being considered, site selection is critical, and relevant experts should be consulted to identify and secure an optimal composting site. In general, potential sites for outdoor composting must be located at least 100 metres away from water bodies, and should be well drained and downwind of public areas or communities. Site accessibility should not be hindered by typical seasonal weather changes and a reasonable plan to control runoff must be in place. Since composting is very sensitive to environmental moisture levels, it is recommended that outdoor compost piles be covered with a tarp or roof in more humid environments to avoid excessive wetness prolonging the composting process (USDA & CFSPH, 2012).

Figure 8. Cross section of compost windrow



Base layer: absorbent, carbon-rich materials, such as ground hay/straw, compost, sawdust, etc.

Compost mix: carcasses, manure and carbon materials, such as sawdust or wood shavings.

Should be thick enough to deter predators while being made of the same material as the base layer.

Optional: In wet weather or rainy areas, take measures to keep the site dry.

4 Cleansing and disinfection

After culling and disposal operations, thorough cleansing and disinfection of the affected premises and the environs should be conducted, preferably under the supervision of the veterinary authority, with particular attention to places where animals have congregated (e.g. animal houses, sheds, pens, yards, water-troughs and culling sites) (FAO, 2001). Any remaining potentially contaminated materials such as manure, bedding, straw, sewage and feedstuff should be removed and disposed of appropriately, i.e. in the same way as the carcasses, or otherwise treated to inactivate any ASFV present. As the presence of organic matters would significantly affect the effectiveness of disinfectants, preliminary cleansing is necessary before the use of any disinfectants. Mechanical brushing with a detergent solution is highly effective in cleansing contaminated surfaces and objects, and is important to achieve an effective disinfection (Guberti *et al.*, 2019). After preliminary cleansing, disinfection shall be followed by application (e.g. spraying) of appropriate disinfectants to any potentially contaminated surfaces (e.g. to those areas of the premises in which infected animals have been and the areas used for culling). It may be simpler to burn poorly constructed animal housing where Ornithodoros soft ticks are present. If soft ticks are absent, application of a disinfectant effective to inactivate ASFV should be sufficient (FAO, 2001). **Section 3.9 of the *Guidelines on Farm Biosecurity, Slaughtering and Restocking*** provides further guidance on cleansing and disinfection, as well as appropriate disinfectants for inactivation of ASFV.

5 Destocking period

After completion of culling, disposal, cleansing and disinfection, the affected premises should be left destocked for an appropriate period determined by the estimated survival time of ASFV. The destocking period shall be discussed and agreed among the veterinary authority, farm owner and other relevant stakeholders. As a general rule, this would be shorter in hot climates than in cold or temperate climates, with the recommended minimum destocking period as 40 days. In practice it is unlikely that definitive eradication in an area would be completed in less than 40 days (FAO, 2001).

At the end of the agreed destocking period, new pigs may be restocked to the previously affected premises starting with the introduction of sentinel pigs (DEFRA, 2014; FAO, 2001). Dead or sick sentinel pigs should be tested for ASF as appropriate. **Section 6** of the *Guidelines on Farm Biosecurity, Slaughtering and Restocking* provides further guidance on restocking the affected premises.

In the case of the occurrence of ASF that is linked to soft tick vectors, a longer destocking period is generally recommended, subject to the veterinary authority's discretion. Additional vector surveillance may also be considered.

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6 Future considerations and directions

Total depopulation is a common practice for ASF outbreak management in many countries nowadays. Nevertheless, it is recently noted that the tooth extraction partial culling approach (i.e. spot elimination by culling only the designated pigs from affected pens, units or barns instead of the entire herd or barn) is also being considered as an ASF outbreak management option. To achieve successful outbreak management outcomes by this approach, the ASF outbreak should be detected sufficiently early and there should be effective isolation of the affected pigs from other herd or barn with corresponding biosecurity measures implemented, of which smallholder pig farms may be uneasy to achieve. Further exploration is still needed to evaluate the effectiveness of this approach in ASF outbreak management, in particular considering that the recent emergence of low virulence ASFV strains which could significantly hinder early detection of ASF. While there are various culling and disposal methods available, one should choose the most practical and appropriate methods for use adapting to the local context and specific field conditions. To maintain preparedness for ASF outbreak management, it is also recommended to offer training and refreshment programmes for relevant personnel on a regular basis. In view of the possible role of wild boars played in ASFV transmission in various Asian countries, feasible and appropriate methods for culling and disposal of wild boars should also be considered and explored taking into account of local wild boar ecology.

During the FAO Regional Workshop on ASF Preparedness and Response held on 9–10 March 2021, it was noted that the availability of compensation scheme for culling varies in different Asian countries. Considering that compensation would provide incentives for active disease reporting to allow timely actions to be taken (e.g. culling and disposal), which ultimately facilitate control and management of ASF outbreaks, veterinary authorities are encouraged to engage the private sectors, livestock associations, and other relevant stakeholders to explore the possibility for implementation of an affordable compensation scheme. Public-private partnership on this issue is highly recommended.

The FAO will continue to organize regular and ad hoc meetings and workshops in consultation with experts and relevant stakeholders to keep embrace of the latest ASF situation in the region and to provide timely updates and recommendations, as well as technical supports, as appropriate.

Annex:
Personal protective equipment (PPE) selection checklist template

Procedures	Risk of pathogen exposure/ contamination*^	PPE*
Moving animals to the culling site	**Aerosol** (High/Low/Negligible)	**Mask** (N95/Surgical/NA)
	Fluid spillage on face (High/Low/Negligible)	**Eye protection** (Goggles/Glasses/NA)
	Fluid spillage on hand (High/Low/Negligible)	**Gloves (Latex/Nitrile)** (Double/Single/NA)
	Fluid spillage on cloth (High/Low/Negligible)	**Body cover** (Coverall/Gown/NA)
	Contaminated environment (High/Low/Negligible)	**Footwear** (Boot cover/Boots/NA)
Culling operation (depends on culling method)	**Aerosol** (High/Low/Negligible)	**Mask** (N95/Surgical/NA)
	Fluid spillage on face (High/Low/Negligible)	**Eye protection** (Goggles/Glasses/NA)
	Fluid spillage on hand (High/Low/Negligible)	**Gloves (Latex/Nitrile)** (Double/Single/NA)
	Fluid spillage on cloth (High/Low/Negligible)	**Body cover** (Coverall/Gown/NA)
	Contaminated environment (High/Low/Negligible)	**Footwear** (Boot cover/Boots/NA)
Moving animal carcasses and other materials away from the culling site	**Aerosol** (High/Low/Negligible)	**Mask** (N95/Surgical/NA)
	Fluid spillage on face (High/Low/Negligible)	**Eye protection** (Goggles/Glasses/NA)
	Fluid spillage on hand (High/Low/Negligible)	**Gloves (Latex/Nitrile)** (Double/Single/NA)
	Fluid spillage on cloth (High/Low/Negligible)	**Body cover** (Coverall/Gown/NA)
	Contaminated environment (High/Low/Negligible)	**Footwear** (Boot cover/Boots/NA)

Procedures	Risk of pathogen exposure/ contamination*^	PPE*
Transporting animal carcasses and other materials to disposal site	**Aerosol** (High/Low/Negligible)	**Mask** (N95/Surgical/NA)
	Fluid spillage on face (High/Low/Negligible)	**Eye protection** (Goggles/Glasses/NA)
	Fluid spillage on hand (High/Low/Negligible)	**Gloves (Latex/Nitrile)** (Double/Single/NA)
	Fluid spillage on cloth (High/Low/Negligible)	**Body cover** (Coverall/Gown/NA)
	Contaminated environment (High/Low/Negligible)	**Footwear** (Boot cover/Boots/NA)
Disposal operation (depends on disposal method)	**Aerosol** (High/Low/Negligible)	**Mask** (N95/Surgical/NA)
	Fluid spillage on face (High/Low/Negligible)	**Eye protection** (Goggles/Glasses/NA)
	Fluid spillage on hand (High/Low/Negligible)	**Gloves (Latex/Nitrile)** (Double/Single/NA)
	Fluid spillage on cloth (High/Low/Negligible)	**Body cover** (Coverall/Gown/NA)
	Contaminated environment (High/Low/Negligible)	**Footwear** (Boot cover/Boots/NA)
Cleansing and disinfection of affected premises	**Aerosol** (High/Low/Negligible)	**Mask** (N95/Surgical/NA)
	Fluid spillage on face (High/Low/Negligible)	**Eye protection** (Goggles/Glasses/NA)
	Fluid spillage on hand (High/Low/Negligible)	**Gloves (Latex/Nitrile)** (Double/Single/NA)
	Fluid spillage on cloth (High/Low/Negligible)	**Body cover** (Coverall/Gown/NA)
	Contaminated environment (High/Low/Negligible)	**Footwear** (Boot cover/Boots/NA)

* Please circle your choice; NA – Not applicable

^ General guide for risk categories:

Risk category	Interpretation
Negligible	Event is so rare or the potential consequences of exposure/ contamination are negligible that it does not merit consideration
Low	Event sometimes occurs such that exposure/contamination may possibly lead to considerable consequences
High	Event occurs very often with considerable consequences of exposure/contamination.

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Glossary

Biosecurity
A set of management and physical measures designed to reduce the risk of introduction, establishment and spread of animal diseases, infections or infestations to, from and within an animal population.

Culling
The removal of an animal population from a particular area to control or prevent the spread of disease.

Disinfectant
A chemical used to destroy disease agents outside a living animal.

Disinfection
The application of procedures intended to destroy the infectious agents of animal diseases applies to premises, vehicles and different objects that may have been directly or indirectly contaminated.

Disposal
Sanitary removal of animal carcasses and other relevant materials by an appropriate process to prevent the spread of disease.

Groundwater
Any water contained in an aquifer.

Infected premises
A defined area which may be all or part of a property that animals meeting the ASF case definition are/were present; or ASFV is present; or there is a reasonable suspicion that ASFV is present subject to decision of the veterinary authority.

Leachate
Liquid impurities resulting from decomposition with the potential to percolate through soil.

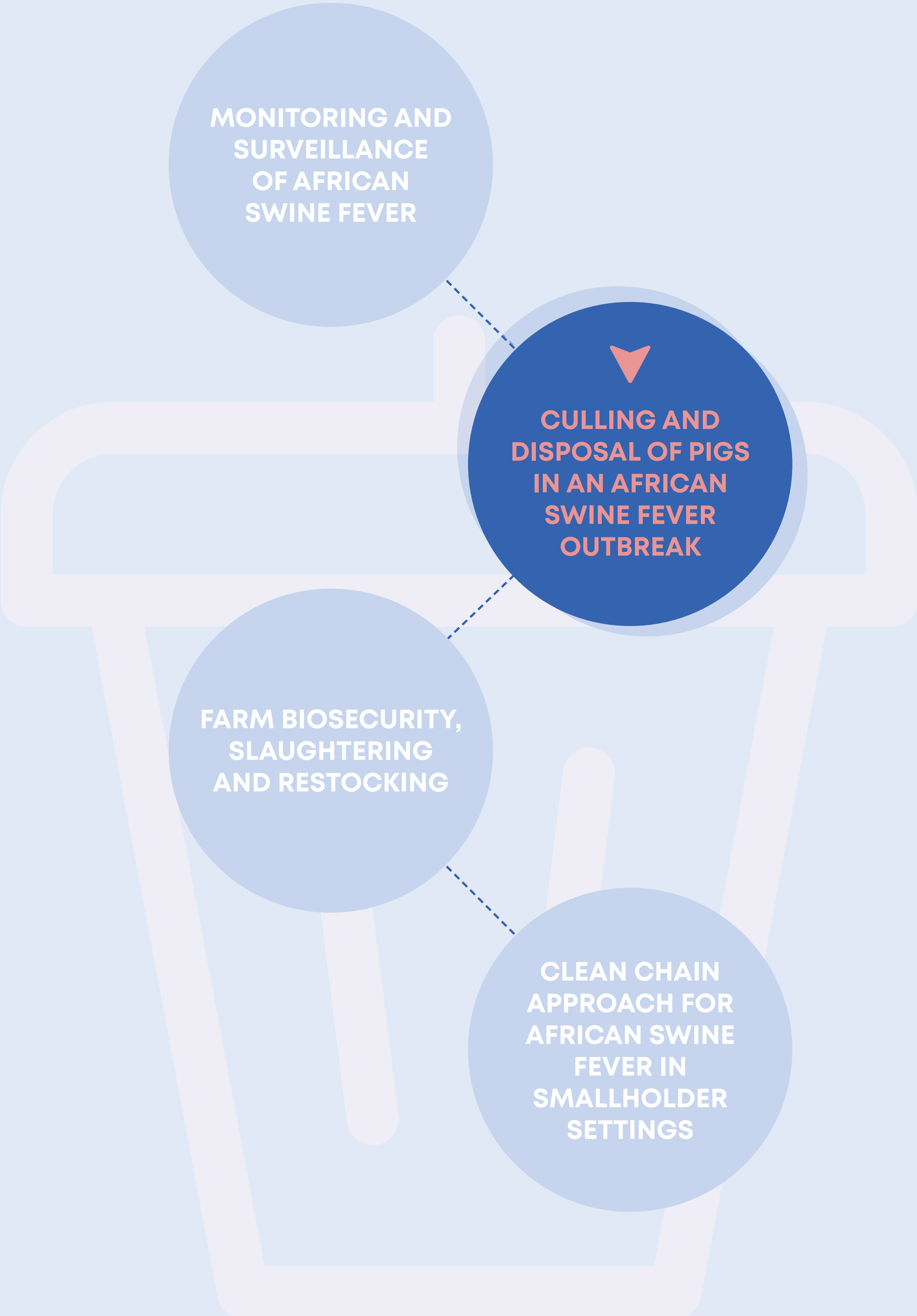
Premises
A tract of land including its buildings, or a separate farm or facility that is maintained by a single set of services and personnel.

Remediation
The remedying of a site to reverse or stop damage to the environment.

Sentinel pigs
Pigs of known health status that is monitored to detect the presence of a particular disease (i.e. ASFV)

Susceptible animals
Animals that can be infected with a particular disease (i.e. ASF).

Vector
A living organism (e.g. arthropod) that transmits an infectious agent (i.e. ASFV) from one host to another.



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