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Killing of animals for disease control purposes

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Summary
In emergency disease outbreaks, large numbers of animals may need to be killed for control, containment and/or eradication purposes. Strategies for disease control will usually involve complete depopulation of herds/flocks, and may extend to depopulation across designated areas. Live animals present the major risk of spreading infectious agents so their slaughter should be completed as quickly as possible, with minimal pain and distress to the animals. The method chosen for killing of animals must be humane, efficient and safe for people and the environment. The tasks should be conducted under the supervision of an official veterinarian, supported by a sufficient number of adequately trained and competent personnel. It is essential to ensure all animals are dead, as demonstrated by the cessation of cardiac and respiratory movements. This paper discusses methods by which animals may be killed for disease control purposes.

Keywords
Animal – Control – Disease – Humane – Killing – Slaughter.

Definitions

Animal handler

A person with knowledge of the behaviour and needs of animals. With appropriate experience and a professional and positive approach to an animal's welfare requirements, this knowledge results in effective management and good welfare. The competency of handlers should be demonstrated through independent assessment and certification.

Death

Irreversible termination of brain activity as demonstrated by the loss of brain stem reflexes.

Killing

Any procedure that causes the death of an animal.

Neonate

A young animal, from birth to four weeks.

Restraint

The application to an animal of any procedure designed to restrict its movements in order to facilitate effective management.

Root mean square

A means of calibrating alternating current to a direct current signal.

Stock handling

Good stock handling means a professional and positive response to an animal's welfare requirements.

Stunning

Any mechanical, electrical, chemical or other procedure that causes immediate loss of consciousness. When used before slaughter, the loss of consciousness lasts until death from the slaughter process; in the absence of slaughter, the procedure could allow the animal to recover consciousness.

World Organisation for Animal Health *Ad hoc* Group

In 2003, the World Organisation for Animal Health (OIE) established an *Ad hoc* Group on humane killing for disease control purposes. The members of the group were Drs John Galvin (chair), Harry Blokhuis, Micus Chimbombi, De-shien Jong and Steve Wotton. The group met twice in 2003 and 2004, with the following terms of reference:

– first output: draft guiding principles (rather than a prescriptive approach to procedures) specifically addressing depopulation for disease control purposes, based on the generic OIE guiding principles and policies for animal welfare

– final output: draft standards/guidelines for the OIE *Terrestrial Animal Health Code* based on these guiding principles

– appropriately address religious and cultural dimensions and the needs of pregnant animals

– identify future directions in which the *Ad hoc* Group might need to move

– produce drafts for review by the Animal Welfare Working Group and then by the Terrestrial Code Commission.

At its 2003 and 2004 meetings, the group covered humane killing methods for cattle, sheep, goats, pigs and poultry.

Introduction

The animal welfare aspects of disease control procedures need to be addressed within broader constraints, including those imposed by human safety and biosecurity considerations (3). Within this scope, this paper considers methods for the killing of animals, and the required competencies of personnel, to minimise adverse welfare impacts. The paper is confined to the procedures that need to occur from the time that the decision is taken to kill animals for disease control purposes until the animals are dead, and to the killing of cattle, sheep, goats, pigs and poultry. These methods may also be applied when animals need to be killed for other purposes such as after natural disasters and in emergency slaughter situations.

The descriptions in this paper do not contain detailed, specific operating procedures as these are available elsewhere in emergency disease control plans and the recommendations of equipment manufacturers. This level of detail was considered beyond the scope of the *Ad hoc* Group's terms of reference and of this paper.

The methods aim to give those personnel responsible for the killing of animals, information on which to decide the most humane procedures applicable to the particular circumstances they face, noting that circumstances will vary and usually be less than ideal, and operations will generally need to be conducted within short time-frames.

The methods and procedures described in this paper are part of the Guidelines for the humane killing of animals for disease control purposes, approved by the International Committee during the OIE 73rd General Session, May 2005.

Planning and preparedness

For an effective response to an animal disease emergency, contingency plans should be in place at a national level and should contain details of management structure, disease control strategies and operational procedures (1). Animal welfare considerations should be addressed within the disease control contingency plans. Animal disease emergency plans should be flexible, timely and regularly tested (1). The involvement of farmers' organisations in emergency disease preparedness and response is important, especially where veterinary resources are limited (1).

An additional consideration is that controls over the movement of animals will usually be necessary to contain the disease, and these may create animal welfare problems, especially for intensively housed animals. Disease control strategies should therefore also address the animal welfare issues that may result from movement controls.

Organisational arrangements

Operational activities should be led by an official veterinarian who has the authority to ensure that high animal welfare standards are maintained and that the personnel involved have the required competencies. The official veterinarian should be responsible for all activities (1) across one or more affected premises, and provide overall guidance to personnel and logistic support for operations on all affected premises to ensure consistency in adherence to animal welfare standards.

A specialist team, led by a designated team leader and supported by personnel with the skills and competencies to conduct all required operations, should be deployed to work on each affected site (1). The team leader requires specialised training in relevant skills and procedures, including skills to manage all activities on the premises and deliver outcomes on time, awareness of psychological effects on the farmer, team members and general public, and effective communication skills. The team leader has responsibility for:

– planning overall operations on an affected site

– determining, implementing and monitoring operations to ensure that animal welfare, operator safety and biosecurity requirements are met

– organising, briefing and managing a team of people to facilitate humane killing of the relevant animals on the premises in accordance with national regulations and animal welfare standards

– determining and managing the logistics required

– reporting on progress and problems, including provision of a written report at the conclusion of the killing, describing the practices adopted and their effect on animal welfare.

Veterinarians on affected premises require the ability to assess animal welfare, especially the effectiveness of stunning and killing, and the ability to assess biosecurity risks. They have responsibility for:

– planning, implementing and monitoring the most effective killing method to ensure that animals are killed without avoidable pain and distress

– determining, implementing and continuously monitoring the requirements for animal welfare, including the order of killing the animals

– minimising the risk of disease spreading within and from the premises through the supervision of other biosecurity personnel

– in cooperation with the team leader, preparing a written report at the conclusion of the killing, describing the practices adopted and their effect on animal welfare.

Animal handlers require skills that include good stock handling, awareness of animal behaviour, and experience of working with animals in emergency situations and in close confinement. They have responsibility for:

– reviewing on-site facilities in terms of their appropriateness

– designing and constructing temporary animal handling facilities when required

– moving and restraining animals.

Slaughterers are responsible for ensuring humane killing of animals through effective stunning and killing. They require competence in the use and maintenance of relevant equipment, the appropriate techniques for the species involved, and assessment of effective stunning and killing. When required by regulations, they must be licensed to use necessary equipment or to be slaughterers.

The farmer/owner/manager can provide specific knowledge of his/her animals and their environment, which may be of great assistance to the team leader and veterinarian.

Carcass disposal personnel may be working on affected premises during the killing operations. They need to ensure efficient carcass disposal so that killing operations are not hindered.

Biosecurity

Disease control operations aim to contain the agent within the affected premises or area and then eliminate it. As live animals present the major risk of spreading infectious agents, they need to be killed quickly. The nature of the agent and disposition of other susceptible animals in the area will determine how quickly the animals should be killed; for example there would be more urgency in the case of foot and mouth disease than of bovine spongiform encephalopathy. A biosecurity plan should include consideration of securing the premises and preventing the escape of the agent on animals, animal products, personnel or equipment, or environmentally (e.g. by wind) (1, 3).

Human safety

Risks to human safety can arise from the agent, the killing method and/or on-farm hazards, where personnel are working in an unfamiliar environment. Involving personnel with human safety expertise in the planning of operations on affected premises should be considered.

Personnel may be exposed to zoonotic agents when moving and handling infected animals or where the killing method causes the spillage of potentially infectious body fluids. These risks can be minimised by providing appropriate personal protective equipment and minimising the exposure to and handling of animals.

Some killing methods present risks to operators and other persons in the area, as does operating in an unfamiliar environment. It is essential to ensure that personnel involved in the killing of animals have appropriate skills, training and competencies and that all operations are

constantly monitored. Equipment used should be in excellent working order and regularly maintained. Back-up equipment should be provided.

Training

Competent personnel who have the relevant skills are critical to ensuring the highest possible animal welfare standards (1). Veterinarians are the best-qualified generalists in animal welfare matters, but specialist knowledge is required when supervising the humane killing of livestock for disease control purposes. The official veterinarian needs to be aware of the welfare attributes of the available killing methods that can be selected to meet the circumstances on each affected site. Continual professional development programmes (covering elements of animal welfare and the scientific research that underpins the preferred killing methods) should be available for official veterinarians.

Team leaders and veterinarians require a training and evaluation programme that is explicit to the operation of the team and their defined roles. Detailed training should include humane killing methods and focus on the welfare considerations of the killing methods for cattle, sheep, goats, pigs and poultry. Formal training and assessment of competence should be in place for animal handlers and slaughterers.

Planning humane killing

Many activities will need to be conducted on affected premises, including the humane killing of animals. The 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 as non-aversive as possible and should minimise anxiety, pain, distress or suffering in the animals. The method chosen needs to be consistently reliable to ensure that all animals are humanely and quickly killed.

For animal welfare considerations, young animals should be killed before older ones. For biosecurity considerations, infected animals should be killed first, followed by in-contact animals, and then the remaining ones. There should be continuous monitoring of the procedures to ensure they are consistently effective with regard to animal welfare, operator safety and biosecurity.

A plan for humanely killing animals on a site needs to be developed to allow for the specific circumstances operating on that site and should include consideration of:

– minimising the handling and movement of animals (animal restraint should be sufficient to facilitate effective killing, in accordance with animal welfare and operator safety requirements; when restraint is required, killing should follow with minimal delay)

– ensuring wherever possible that animals are killed on the affected premises (however, there may be circumstances where the animals need to be moved to another location for killing) (3)

– the species, number, age and size of animals to be killed, and the order of killing them

– methods of killing the animals, and their cost

– the housing and location of the animals

– the availability and effectiveness of equipment needed for killing the animals

– the facilities available on the premises that will assist with the killing

– biosecurity issues

– the health and safety of personnel conducting the killing and of other persons in the area

– any legal issues that may be involved, for example where restricted veterinary drugs may be used, or where the process may have an impact on the environment

– the presence of other nearby premises holding animals

– the need for killing of animals and carcass disposal to be carried out away from public view where possible, so as to minimise public distress.

Following the decision to kill the animals, killing should be conducted as quickly as possible and normal husbandry should be maintained until the animals are killed. When the operational procedures are concluded, there should be a written report describing the practices adopted and their effect on animal welfare, operator safety and biosecurity.

Killing methods

The various methods for causing death (Table I) act by first causing loss of consciousness, followed by cardiac and/or respiratory arrest, leading to complete loss of brain function. The three key methods for causing death are:

– hypoxia: causes unconsciousness and depression of the respiratory centre in the central nervous system (CNS), followed by complete loss of brain function

– depression of neurones necessary for life functions: depression of the CNS respiratory centre leading to cardiac arrest

– physical disruption of the brain (2).

Mechanical killing methods

Mechanical methods cause physical disruption to the brain or neck, leading to unconsciousness and death. Some may only cause unconsciousness, so pithing or bleeding should follow immediately to ensure the death of the animal.

Free bullet

A free bullet is a projectile fired from a shotgun (most commonly 12, 16, 20, 28 bore and 410), rifle (most commonly 22 rimfire and 243, 270 and 308 for large animals and long-range use), handgun (various calibres from 32 to 45) or purpose-made humane killer. A free bullet should be aimed to penetrate the skull or soft tissue at the top of the neck of the animal, to cause irreversible concussion and death (1, 3, 4). A heart shot may achieve a rapid, effective and humane kill and may allow better accuracy in some circumstances. The correct cartridge, calibre and type of bullet for the different species, age and size should be used. Ideally, the ammunition should expand on impact and dissipate its energy within the cranium (1, 2, 3). The marksman should ensure that the animal is in a position that enables accurate targeting. While free bullets can be used to kill animals at a distance (e.g. using a telescopic device), this increases the risk of a failed shot (2). The firearm should not be touching the head of the animal when fired. Shot animals should be checked to ensure the absence of brain stem reflexes. The marksman should take account of human safety in the area in which he or she is operating.

When used properly by competent personnel, use of a free bullet provides a quick and effective method for killing, requiring minimal or no restraint, and can be used to kill from a distance. It is suitable for killing agitated animals in open spaces (4). However, it is potentially dangerous to humans and other animals in the area and there is the potential for non-lethal wounding of target animals (2). Destruction of brain tissue may preclude diagnosis of some diseases and leakage of bodily fluids may present

Table I
Killing methods for various species

Method	Procedure	Cattle	Sheep and goats	Pigs	Poultry
Mechanical	Free bullet	Y	Y	Y	Y
	Penetrating captive bolt – followed by pithing or bleeding	Y	Y	Y (except neonates)	N
	Non-penetrating captive bolt	Y (adults only)	Y	Y (neonates only)	Y
	Cervical dislocation (manual and mechanical)	N	N	N	Y (small numbers of poultry species)
	Maceration	N	N	N	Y (neonates and eggs)
Electrical	Two stage application	Y (calves only)	Y	Y (over one week of age)	N
	Single application (including water bath)	Y (calves only)	Y	Y (over one week of age)	Y
Gaseous	CO_2 air mixture	N	Y (neonates only)	Y (neonates only)	Y
	Nitrogen/inert gas mixed with CO_2	N	Y (neonates only)	Y (neonates only)	Y
	Nitrogen and/or inert gases	N	Y (neonates only)	Y (neonates only)	Y
	CO	N	Y (neonates only)	Y (piglets only)	Y
Lethal injection	Barbiturates and others	Y	Y	Y	Y
Addition of anaesthetics to feed or water	Barbiturates and others	N	N	N	Y
Killing unconscious animals	Decapitation	N	N	N	Y
	Pithing	Y	Y	Y	N
	Bleeding	Y	Y	Y	Y

CO: Carbon monoxide
CO_2: Carbon dioxide
N: No
Y: Yes

a biosecurity risk (3). Legal requirements may preclude or restrict the use of firearms (2). Using a free bullet is a suitable method for killing cattle, sheep and goats, pigs and poultry, including large animals in open spaces.

Penetrating captive bolt

A penetrating captive bolt is fired from a gun powered by either compressed air or a blank cartridge. There is no free projectile. The captive bolt should be held in contact with or slightly away from the head and aimed at right angles to the skull in a position to penetrate the cortex and mid-brain of the animal (1, 2, 3). The impact of the bolt on the skull produces unconsciousness (3). Physical damage to the brain caused by penetration of the bolt may result in death; however pithing or bleeding should be performed immediately after the shot in order to ensure the death of the animal, as demonstrated by the absence of brain stem reflexes (1). In some situations, the use of a sedative such as xylazine may enhance animal welfare.

The cartridge strength and calibre, and the length of the bolt should be appropriate to the species and type of animal, in accordance with the manufacturer's recommendations (3). Animals should be restrained (4), as a minimum free-standing in a pen, so the operator can ensure that the animal's head is accessible. A back-up gun should be available in the event of an ineffective shot and guns should be frequently cleaned and maintained in good working condition.

Captive bolt guns are mobile, cause immediate onset of a sustained period of unconsciousness and offer improved operator safety over the use of a free bullet. However, misfirings and inaccuracies may result in poor animal welfare, especially when dealing with agitated animals, while post-stun convulsions may make pithing difficult and hazardous (3). As with using a free bullet, destruction of brain tissue may preclude diagnosis of some diseases and leakage of bodily fluids may present a biosecurity risk (3). This is a suitable method for killing cattle, sheep, goats and pigs (except neonates), when followed by pithing or bleeding (4).

Non-penetrating captive bolt

Non-penetrating captive bolts are used in some poultry slaughterhouses as well as for mammals (3). They are fired from a gun powered by compressed air or a blank cartridge and there is no free projectile. The bolt is designed and constructed to deliver a percussive blow to the head, which in birds results in immediate unconsciousness and death through profound brain dysfunction and physical damage, and in mammals causes unconsciousness. In mammals (especially neonates), bleeding should be carried out as soon as possible after the blow to ensure the death of the animal. Bolt velocity should be appropriate to the species and type of animal, as stipulated in the manufacturer's recommendations (3).

Birds should be restrained in cones, shackles, crushes or by hand (provided operator safety is not compromised by the design of the gun). The comb or sides of the beak should be held between thumb and forefinger. The gun barrel should be placed firmly onto the rear of the head behind the comb before firing. The bird's head should be allowed to be propelled out of the hand upon firing. This method can produce post-stun/kill convulsions. Mammals should be restrained in a pen or race.

Air-powered devices are inexpensive to operate and require minimum training of operators to minimise risks to operator safety. Multiple air-powered devices can be powered by a single compressor and used to humanely kill large numbers of birds, following their manual removal from the house or yard. The guns should be frequently cleaned and maintained in good working condition. Using a non-penetrating captive bolt is a suitable method for killing poultry, cattle (adults only) and neonate sheep, goats and pigs.

Cervical dislocation (manual and mechanical)

Poultry may be killed by either manual cervical dislocation (stretching) or mechanical neck crushing using a pair of pliers (1). Both methods result in death from asphyxiation and/or cerebral anoxia (3), but neither is likely to produce immediate unconsciousness. The operation of cervical dislocation should be performed in one action to sever the spinal cord. Mechanical pliers should be used to crush the cervical vertebrae with consequent major damage to the spinal cord; breathing should then stop and pupils should be dilated.

Poultry need to be handled and restrained. Consistent results require strength and skill, so personnel should be rested regularly to ensure consistently reliable results, and operations should be closely monitored. While this may be the cheapest method for killing poultry, death caused by cerebral anoxia in poultry takes a longer time (more than a minute), poultry are not immediately rendered unconscious and there may be pain and/or distress during the process (2). Consistent and reliable results are difficult to achieve if large numbers of poultry need to be killed.

Regulations may prohibit the use of this technique in some countries. Cervical dislocation should only be applied on small numbers of birds (such as ducks and geese with long necks) where the use of gaseous killing agents can be more difficult and where other methods are unavailable.

Maceration

Maceration causes immediate death through the introduction of animals to a high-speed grinder fitted with

rotating blades (6,000 or more revolutions per minute), resulting in the destruction of the brain and other tissues. This method requires trained personnel using specialised equipment that must be kept in excellent working order. Neonate poultry and eggs are fed into the macerating equipment via a hopper. The rate of introducing the birds should not allow the equipment to jam, birds to rebound from the blades or the birds to suffocate before they are macerated. This is only recommended for the killing of neonatal poultry and fertile eggs (4).

Electrical killing methods

Electrical killing methods cause depression of the CNS respiratory centre and/or ventricular fibrillation, leading to unconsciousness, cardiac arrest and death (2, 3).

Electric current: two-stage application

The two-stage application of an electric current comprises the application of current to the head by scissor-type tongs, immediately followed by an application of the tongs across the chest in a position that spans the heart. The application of sufficient electric current to the head will induce 'tonic/clonic' epilepsy and unconsciousness. Once the animal is unconscious, the second-stage low-frequency electric current applied across the chest will induce ventricular fibrillation (cardiac arrest) resulting in death. To prevent unacceptable levels of pain, the second application should only be applied to unconscious animals.

Animals should be restrained, as a minimum free-standing in a pen, close to an electrical supply. Two operators are required, the first to apply the electrodes and the second to manipulate the position of the animal to allow the second application to be made. Appropriate protective clothing (including rubber gloves and boots) should be worn. The stunner control device should generate a low-frequency (50 Hz) (3) current with a minimum voltage of 250 volts true root mean square (RMS) under load. A stunning current should be applied via scissor-type stunning tongs in a position that spans the brain for a minimum of three seconds (3). Immediately following the application to the head, the electrodes should be transferred to a position that spans the heart and the electrodes applied for a minimum of three seconds. Animals should be monitored to ensure the absence of brain stem reflexes. Electrodes should be cleaned regularly and after use to enable optimum electrical contact to be maintained.

This method is immediate in action and particularly effective with pigs, as it minimises post-stun convulsions. It is a non-invasive technique that minimises biosecurity risks. The electrodes must be applied and maintained in the correct positions to produce an effective stun and kill. The procedure may be physically demanding, leading to operator fatigue, and there is the potential for painful and even lethal shocks to the operator. This is a suitable method for killing calves, sheep and goats, and especially for pigs (over one week of age). Ventricular fibrillation and circulatory collapse may not persist after the cessation of current flow in pigs of less than 5 kg.

Electric current: single application

There are several methods of administering a single application of current. Method 1 comprises the single application of sufficient electrical current (either head-to-back or head-to-body) (3) to simultaneously stun the animal and fibrillate the heart, causing cardiac arrest. Provided sufficient current is applied in a position that spans both the brain and heart, the animal will not recover consciousness. This method is immediate in action and particularly effective with pigs, because post-stun convulsions are minimised. Animals must be individually restrained close to an electrical supply, as the maintenance of physical contact between the stunning electrodes and the animal is necessary for effective use. A single operative is required to apply the electrodes mounted on a handset in a position that spans both the brain and the heart. Appropriate protective clothing (including rubber gloves and boots) should be worn.

A low-frequency (50 Hz) stunner control device should generate a minimum voltage of 250 volts true RMS under load (3). The front electrodes should be applied in a position that is forward of the eyes and the rear electrode to the back, above or behind the heart, with current applied for a minimum of 10 s. An effective stun/kill should be verified by the absence of brain stem reflexes. Where sheep are stun/killed, water or saline solution should be used to improve electrical contact with the animal (3). Electrodes should be cleaned regularly between animals; regular maintenance and testing of the handset, electrodes, connecting cable and control unit are essential for both operator safety and animal welfare. This method is suitable for killing calves, sheep and goats, and pigs (over one week of age). Ventricular fibrillation and circulatory collapse may not persist after the cessation of current flow in pigs of less than 5 kg.

Method 2 immediately stuns/kills by drawing inverted and shackled poultry through an electrified water bath stunner. Electrical contact is made between the 'live' water and the earthed shackle and, when sufficient current is applied, poultry will be stunned and killed. Appropriate protective clothing (including rubber gloves and boots) should be worn.

A mobile water bath stunner and a short loop of processing line are required. Birds need to be manually removed from their cage, house or yard, inverted and shackled onto a line that conveys them through a water bath (3). A low-frequency (50 Hz) (3) current applied for a minimum of three seconds is necessary to stun/kill the birds. Minimum currents required to stun/kill are: for quail, 100 mA; chickens, 160 mA; ducks and geese, 200 mA; and turkeys, 250 mA (3). An effective stun/kill should be verified by the absence of brain stem reflexes. This method is capable of killing large numbers of birds reliably and effectively; however it requires a relatively high capital investment and a supply of mains or generator electricity. This is a suitable method for stunning/killing large numbers of birds.

Method 3 comprises the single application of sufficient electrical current to the head of poultry in a position that spans the brain, causing unconsciousness, followed by a killing method such as decapitation, pithing or bleeding.

The birds should be restrained, as a minimum manually, close to an electricity supply. The stunner control device should generate sufficient current (more than 300 mA/bird). A stunning current should be applied to a position that spans the brain for a minimum of three seconds; immediately following this, the birds should be killed. Birds should be monitored after stunning until death to ensure the absence of brain stem reflexes. Electrodes should be cleaned regularly and after use, to enable optimal electrical contact to be maintained. This is a suitable method of stunning (prior to killing) small numbers of birds.

Gaseous killing methods

Gas killing is performed by exposing animals to a predetermined gas mixture, either while being held within a container/chamber or with the gas being passed into the animal house. The requirements applying to the following gaseous killing methods include:

– containers or poultry houses should allow the required concentration of gas to be maintained and accurately measured

– when animals are exposed to the gas individually or in groups, the equipment used should be designed, constructed and maintained in such a way as to avoid injury to the animals and allow them to be observed

– equipment should be capable of rapid delivery of the gaseous agent without it freezing

– animals should be introduced into the container after it has been filled with the required concentration of gas, and held in this atmosphere until death is confirmed; or held in their normal housing which is sealed and the gaseous agent introduced and maintained until all animals are dead (gas should be introduced to fill the house well above the level of the heads of the animals or birds)

– team members should ensure that sufficient time is allowed for each batch of animals to die before subsequent ones are introduced into the container

– containers should not be overcrowded and measures are needed to avoid animals suffocating by climbing on top of each other.

Carbon dioxide/air mixture

Inhalation of carbon dioxide (CO_2) induces respiratory and metabolic acidosis and hence reduces the pH of cerebrospinal fluid and neurones, thereby causing unconsciousness and, after prolonged exposure, death.

Method 1 is performed by exposing animals to a concentration of > 40% CO_2 (1) by placing them in a container/chamber. Animals should be introduced into the container after it has been filled with the required CO_2 concentration.

While CO_2 is readily available and application methods are simple, there may be welfare problems in the induction phase due to the aversive nature of high CO_2 concentrations. This method is suitable for killing poultry and neonatal sheep, goats and pigs.

Method 2 is performed by introducing the gas into a poultry house at a concentration of > 40% CO_2. The poultry house should be effectively sealed to minimise escape of gas and maintain CO_2 concentrations. As the gas is applied *in situ*, this method eliminates the need to manually handle and move live birds. If gas mixtures are used to kill animals *in situ*, they should be administered in such a way that they gradually fill the houses from the floor to a level well above the heads of the birds. There may be difficulty in achieving and maintaining adequate concentrations of CO_2 in some poultry houses, especially 'high-rise' houses, and difficulty in verifying death. This is a suitable method for killing poultry, especially in closed-environment sheds.

Nitrogen/inert gas mixed with carbon dioxide

The CO_2 may be mixed in various proportions with nitrogen or an inert gas (e.g. argon). The inhalation of such mixtures causes hypercapnic-hypoxia and death when the oxygen concentration by volume is ≤ 2% (2). This method involves the introduction of animals into a container/chamber containing the gases. Using CO_2 in combination with nitrogen or an inert gas induces

unconsciousness more quickly than use of CO_2 alone. However, as such mixtures do not induce immediate loss of consciousness, the aversiveness of various gas mixtures and the respiratory distress occurring during the induction phase are important animal welfare considerations. Pigs and poultry appear not to find 30% by volume of CO_2 strongly aversive, and a mixture of nitrogen and/or argon with up to 30% CO_2 by volume and $\leq$ 2% O_2 by volume has therefore been used for killing poultry and neonatal sheep, goats and pigs (2, 3).

If gas mixtures are used to kill pigs or poultry in their houses, the gases should be administered in such a way that they gradually fill the houses from the floor to a level well above the heads of the animals. Specialised equipment is required to administer gas mixtures that may be aversive to animals. Some mixtures may not lead to immediate loss of consciousness, and exposure times required to kill pigs and poultry are considerable, while the maintenance of gas mixtures to produce less than 2% O_2 is difficult in houses. This is a suitable method for killing poultry and neonatal sheep, goats and pigs.

Nitrogen and/or inert gases

This method involves the introduction of animals into a container/chamber containing nitrogen or an inert gas such as xenon, krypton or argon, all of which have anaesthetic properties. The technique leads to unconsciousness and death from hypoxia. The hypoxia does not seem to be aversive to pigs and poultry (as animals are unable to detect nitrogen or inert gases) and does not induce any signs of respiratory distress prior to loss of consciousness. However, prolonged exposure to these gases can be harmful to humans.

Xenon is an anaesthetic gas under normal atmospheric pressure, whereas argon and krypton have anaesthetic properties only under hyperbaric conditions (3). There is a high cost and possibly limited availability associated with using xenon and krypton. Argon- or nitrogen-induced hypoxia at normobaric conditions is commercially used to stun or stun/kill poultry. If the animals are introduced into the chamber, it should be only after it has been filled with 100% of inert gases. The concentration of residual oxygen in the chamber should be continuously monitored to ensure that it remains at less than 2% by volume (2). This method is suitable for killing poultry and neonatal sheep goats and pigs, in chambers or in their houses. However, the likely limited availability of the gases may make their application in killing animals for disease control purposes impractical.

Carbon monoxide

Carbon monoxide (CO) combines with haemoglobin to form carboxyhaemoglobin, which prevents the carriage of oxygen by red blood cells, inducing unconsciousness and death through cerebral anoxia. The CO can be obtained from commercial CO supplies, produced by the chemical interaction of sodium formate and sulphuric acid, or produced by internal combustion engines (2). If the CO is produced by a combustion engine, the gas should be cooled to ambient temperature and filtered to remove impurities, as these will cause respiratory distress to animals.

In closed-environment poultry houses, using CO is a relatively easy way to kill poultry without moving and handling the animals. If the animals are introduced into a chamber, it should be only after it has been filled with a CO concentration of at least 1% by volume. As CO is a highly toxic gas, an efficient exhaust and/or ventilation system needs to be provided. The risks to human health and safety need to be assessed, all personnel must be advised of the dangers and actions taken to mitigate them. Carbon monoxide should only be used after a careful assessment of all hazards and in a well ventilated area. It is suitable for use on poultry and neonatal sheep, goats and pigs, especially when applied *in situ* to poultry housed in closed-environment sheds.

Injectable killing methods

Lethal injection

A lethal injection using high doses of anaesthetic and sedative drugs causes CNS depression, unconsciousness and a smooth death (1, 2). In routine veterinary practice, barbiturates (e.g. sodium pentobarbital) and combinations of other drugs are commonly administered as an overdose for euthanasia of animals. Doses and routes of administration that cause rapid loss of consciousness followed by death should be used. Prior sedation may be necessary for some formulations and fractious animals. Animals should be suitably restrained. Intravenous administration is preferred. Intraperitoneal administration may be appropriate, providing the agent is non-irritating. Intra-cardiac injections should only be applied to heavily sedated or comatose animals (2). Other routes of administration including intramuscular, subcutaneous, intrathoracic and intrapulmonary are not recommended. Animals should be restrained to allow effective administration and then monitored to ensure the absence of brain stem reflexes.

For practical reasons, this method may be most applicable for use in small animals or small numbers of large animals. Highly trained personnel are required for administration to restrained animals and legal requirements may allow only veterinarians to use lethal injections. This is a suitable method for killing cattle, sheep, goats, pigs and poultry.

Oral killing methods

Addition of anaesthetics to feed or water

An anaesthetic agent mixed with poultry feed or water may be used to anaesthetise or kill poultry in their houses. Where birds are not killed by the oral agent, they may then need to be killed by another method. These agents can be expensive, may have an adverse flavour and their use may be regulated or restricted to veterinarians.

Sufficient quantities of anaesthetic need to be ingested rapidly for effective response. Intake of sufficient quantities can be facilitated if the animals are fasted. However, the dose taken by individual animals cannot be regulated and variable results may be obtained. This method can be used for wild species that could not otherwise be killed; however, non-target species may accidentally ingest the medicated feed or water when it is provided in an open environment. Care is essential in the preparation and provision of treated feed or water, and in the disposal of uneaten feed/water and contaminated carcasses. This is a suitable method for killing large numbers of poultry in houses.

Addition of toxic agents/poisons to food or water

A number of toxic agents/poisons could be added to food or water to kill animals. These include the organophosphates and fluoroactetates. The *Ad hoc* Group examined the use of these agents but considered that such use involved serious animal welfare and environmental concerns, and risks to non-target species. The group did not recommend their use in killing of animals for disease control purposes.

Killing methods for unconscious animals

A number of the methods discussed above cause unconsciousness but not (reliably) the death of animals. If a killing method is not applied effectively or a stunning method is used, the stunned animals will be able to regain brain and body functions. The following methods should be applied to kill unconscious animals effectively (2).

Decapitation

Decapitation results in death by cerebral ischaemia. This method should be considered only for killing poultry. Decapitation requires the rapid severing of the head from the body, using a guillotine or sharp blade. Blood contaminates the working area, which may create biosecurity concerns. This method is not aesthetically pleasing and may distress personnel. Decapitation is a suitable method for killing unconscious poultry.

Pithing

Pithing is a method of killing animals that have been stunned with a penetrating captive bolt. Pithing results in the physical destruction of the brain and upper regions of the spinal cord, as a result of the insertion of a rod or cane through the bolt hole (1). Conducted immediately after application of the captive bolt, it is an effective technique in producing immediate death. Post-stun convulsions may lead to delayed or ineffective pithing, and contamination of the working area with body fluids may lead to concerns about biosecurity or operator safety. This is a suitable method for killing unconscious animals that have been stunned by a penetrating captive bolt.

Bleeding

Bleeding is a method of killing animals through the severance of the major blood vessels in the neck or chest, which results in a rapid fall in blood pressure, leading to cerebral ischaemia and death (2). The technique is effective in producing death after an effective stunning method that does not permit pithing (3). A sharp knife, trained operators and safe access to the neck or chest are required. Animals should be monitored continuously until death, as demonstrated by the lack of brain stem reflexes.

Élimination des animaux à des fins sanitaires

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Résumé
En cas d'apparition de foyers de maladie impliquant le recours à des mesures d'urgence, il peut s'avérer nécessaire d'éliminer un grand nombre d'animaux à des fins de contrôle, de confinement et/ou d'éradication. Les stratégies de lutte contre les maladies impliquent généralement le dépeuplement total des élevages et peuvent aller jusqu'au dépeuplement dans des zones désignées. Comme les animaux vivants risquent de propager des agents infectieux, leur abattage doit être entrepris aussi rapidement que possible, en cherchant à épargner les animaux de la douleur et de la détresse. La méthode choisie doit permettre l'abattage des animaux dans des conditions décentes. Elle doit être efficace et sans danger pour les populations humaines et pour l'environnement. Les opérations doivent être conduites sous le contrôle d'un vétérinaire officiel, assisté par un nombre suffisant d'agents compétents ayant reçu une formation appropriée. Il est essentiel de s'assurer de la mort de tous les animaux, mise en évidence par l'arrêt des contractions cardiaques et des mouvements respiratoires. Le présent article passe en revue les méthodes permettant l'élimination des animaux à des fins sanitaires.

Mots-clés
Abattage – Animal – Contrôle – Condition décente d'abattage – Élimination – Maladie.

Matanza de animales por motivos sanitarios

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Resumen
Las medidas de emergencia que deben adoptarse para controlar, circunscribir y erradicar un foco de enfermedad pueden incluir la matanza de grandes cantidades de animales. Por lo general, las estrategias de control de enfermedades implican la eliminación de todos los animales de los rebaños o bandadas, que incluso puede extenderse a todos los animales de una zona determinada. El grave peligro que entrañan los animales vivos radica en que pueden convertirse en vectores de agentes infecciosos; por ello, han de sacrificarse a la mayor brevedad, infligiéndoles el menor dolor y angustia posible. El método escogido para la matanza ha de ser clemente, eficaz y seguro, tanto para las personas como para el medio ambiente. La matanza debe efectuarse bajo la supervisión de un veterinario oficial que ha de contar con la asistencia de personal suficiente, correctamente capacitado y competente. Es indispensable asegurarse de que todos los animales han muerto; para ello será preciso comprobar la desaparición de los movimientos cardíacos y respiratorios. En este artículo se examinan los métodos de matanza con fines sanitarios.

Palabras clave
Animal – Compasión – Control – Enfermedad – Matanza – Sacrificio.

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