COMPOSTING ANIMAL MORTALITIES:

A PRODUCER'S GUIDE

AGRICULTURE

LIVESTOCK

Introduction

The management of animal mortalities is an important consideration for livestock producers. Livestock producers have been challenged to discover innovative ways to manage livestock and poultry mortalities.

Composting is one option for managing mortalities. While there are benefits, producers must decide if composting fits into their operations. As with any other farm operation, successful composting requires a commitment to good management.

This manual describes the composting process and provides information on general planning considerations, building and managing the compost pile, and universal worksheets for sizing composting facilities for all types of animal mortalities. A troubleshooting guide is also included.

Composting Phases

Composting is a naturally occurring process in which bacteria, fungi and other microorganisms convert organic material into a stabilized product called compost. This means that the microorganisms do the composting work for you. Your role in managing the compost process is to make sure that the microorganisms have the environment they need in order to do their work quickly and effectively.

Mortality composting involves two phases. In the primary phase of mortality composting, the animal carcass is placed in a composting bin or windrow. A bulking agent that is high in carbon, such as sawdust or straw is placed around the carcass to completely surround it.

During this primary composting phase, anaerobic microorganisms (those not requiring oxygen) work in the carcass to degrade it, releasing fluids and odorous gases such as hydrogen sulfide and ammonia. These diffuse into the bulking agent where aerobic microorganisms (those requiring oxygen) degrade these materials to odour-free carbon dioxide (CO_2) and water (H_2O). The aerobic process produces considerable heat, causing the temperature of the compost pile to rise. The active bacteria in both the aerobic and anaerobic zones are heat-tolerant. However, the heat kills common viruses and bacteria that may be present in the carcass.

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Unlike traditional composting, in mortality composting the pile is left undisturbed until its temperature drops continuously for 10 to 14 days in a row. This means that the aerobic microorganisms are working less efficiently and have exhausted much of the food and air in their environment. By the end of the primary stage of composting, some large bones and hair may still be present, but no soft tissues.

The Mortality Composting Process	
Phase One	• Carcasses and bulk agent layered in pile • High rate of anaerobic and aerobic activity • Temperature increases • Temperature subsides • Breakdown of flesh and small bones
Phase Two	• Turning the pile initiates increased aerobic activity • Temperature increases • Breakdown of long bones, skull and pelvis • Stabilization of compost material

Table 1: The Mortality Composting Process

It is possible to accelerate the primary process by cutting open or mincing large carcasses. Using a bulking agent with smaller pieces, like fine sawdust, and turning the pile halfway through can also shorten the process. However, turning the pile part way through the primary decomposition of the carcasses will likely expose a number of large bones, so it is important to ensure that these are properly buried in the new pile. By accelerating the process, producers would require less space for the compost bins.

The second phase of the process involves regularly turning the pile and introducing air. Large bones and hair remaining from the primary phase will now decompose. At this stage the pile will need to be turned approximately once a week or more to introduce oxygen into the pile and increase aerobic activity. This increase in microbial activity will cause the temperature to rise again. The compost is finished and ready for storing or spreading on the field when the temperature of the pile has dropped to the ambient (outside air) temperature.

During the primary and secondary phases, the volume and weight of materials are reduced due to the loss of carbon dioxide and water to the atmosphere. The bulky raw materials are transformed into crumbly fine-textured compost. Properly finished compost should appear as a dark, nearly black granular material resembling humus or potting soil. It may have a slightly musty odour. Some resistant bones (skull parts, teeth) will be visible, but they should be soft and easily crumbled by hand.

Figure 2: Turning the compost pile. Courtesy of Starlite Hutterian Brethren Colony

The amount of time required to complete the entire composting process will depend on the type of bulking agent, temperature, moisture, management and carcass size. Normally, the second stage of composting will take the same length of time as the primary phase (Table 2). Turning the pile frequently to maintain aerobic activity could reduce the time required for the secondary phase by two thirds (i.e. 90 days can be reduced to 30 days.)

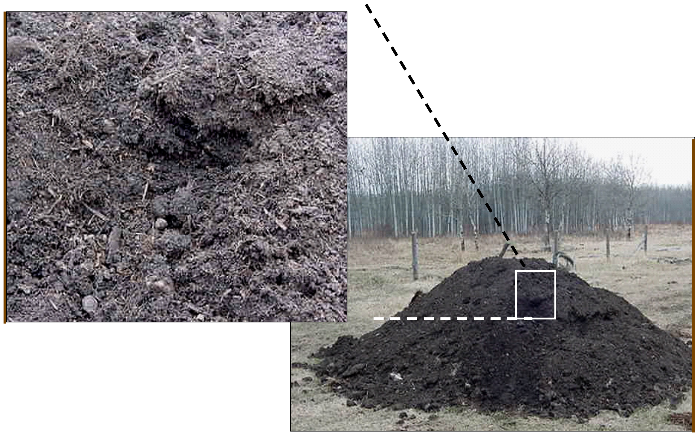

Figure 3: This compost pile is 13 months old and looks like a dark crumbly potting soil. *Courtesy: Birch Bay Pork.*

Carcass Size (kg.)	(lb.)	Primary Phase (Days)
0-5	0-10	15
5-10	10-25	30
10-135	25-300	90
135-340	300-750	120
340-635	750-1,400	180

Table 2: Average times for primary composting

What are the benefits of composting?

Biosecurity: Composting allows for immediate year-round management of mortalities so that disease is not spread. There is no entry of off-farm vehicles that could bring disease onto the farm from other operations. The high temperatures generated in the composting process kill pathogens.

Environmentally sound: Well-sited and managed composting operations will control risks to ground and surface water. Odours, flies and rodents are kept to a minimum. Composting turns a waste into a beneficial fertilizer and soil amendment resulting in on-farm recycling of nutrients.

Cost-effective: Composting has low to moderate start-up costs and minimal operating costs, although this will vary with the design of the facility. Volume and weight of the raw materials is reduced.

Easy to accomplish: Composting requires good management, but only minimal training. It requires little equipment that is not already available on-farm and utilizes readily available organic materials.

General Planning Considerations

There are two general approaches to composting mortalities: enclosed or bin system or an open-pile or windrow system. Producers should check with Saskatchewan Ministry of Agriculture staff to see what legislation and/or regulations pertain to the management of mortalities.

There are, however, some general planning considerations that relate to either type of composting.

Bins versus windrows: Bins may be preferred over windrows as they are contained and therefore somewhat screened. Covered bins are also more successful in variable climates as they simplify management and maximize the potential for success regardless of weather conditions. Covered bins can minimize the potential for seasonal odour problems caused by overly wet compost.

Bins use less space, improve heat retention in cold weather conditions and help to avoid problems with scavenging insects and animals. Bin systems do not have to be complicated or costly. Three-sided straw walled structures, open-front livestock buildings and other types of unused farm structures can be converted for composting at a relatively low cost.

The labour, material and management resources required to operate windrow systems during adverse weather conditions will be higher than for bin systems.

Site Selection: Good site selection is very important for the success of any type of composting site. Producers will need to consider soil type, topography, location of water sources, access for handling and hauling, distance from neighbours, wind direction and aesthetics. Some sites may be suitable for composting with only minimal development, whereas other sites may require more engineering.

Surface and Groundwater Protection: Avoid locating compost sites on slopes where runoff may be a problem or in depressions where the compost may become saturated with water. In general, the composting and curing site should be slightly sloped, clay-lined and have berms and runoff control structures.

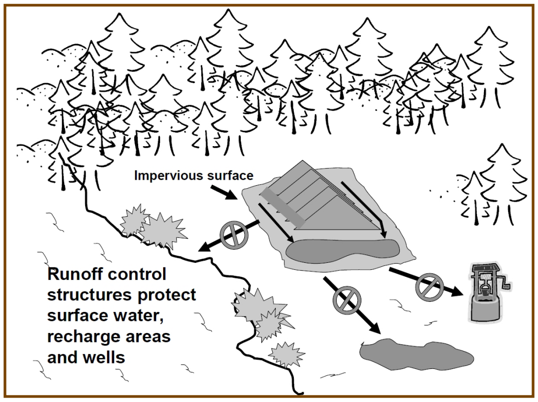

Figure 4: A properly planned composting structure.

Roofs: In areas with high rainfall, composting facilities may need to be covered in order to prevent excessive runoff or leaching. A roof is recommended to help control moisture levels. An open compost bin may receive too much rainfall in a given period or too much snow accumulation in winter.

There are two problems with excess moisture:

1. The pile may leach into underground water systems or runoff into your yard or surface water systems;

2. The pile may become anaerobic (without oxygen), deactivating the decomposer microbes and creating odour issues.

One drawback to having a roof is the need to add water to maintain appropriate moisture levels in hot, dry weather. In addition, roofed facilities will need to be designed with adequate head clearance, will require ongoing maintenance and may trap wind, creating issues related to temperature and dust.

Aesthetics: While offensive odours are not usually generated in a well-managed composting process, the handling of carcasses, manure and litter on a daily basis may not be aesthetically pleasing. Planting trees around the composting site improves its aesthetic appeal.

Size: It is important to size the composting facility properly. Inadequate facilities will force the compost through the operation before the process is complete, contributing to problems with odour and flies. The type of composting method chosen will influence the amount of space required. The windrow method requires the most land. Bin composting would require less space.

To size a composter, it is necessary to know or estimate the average daily weight of mortalities expected. Once the average daily mortality weight is known, the number and size of composters can be calculated.

Traffic Patterns: When locating a composter, consideration should be given to traffic patterns required for moving the mortalities and the required composting ingredients, and for removing the finished product from the composter. All-weather roads and work areas make access and movement easier.

Equipment: Equipment usually includes, at minimum, a front-end loader large enough to bring the carcasses to the compost bin and capable of turning the material.

Utilities: A freeze-proof hydrant at the composting facility is useful for wetting down the piles when moisture is required and for cleaning up and washing down equipment and the composting area.

A minimum 20 amp electrical circuit will allow the use of power tools, lights or other appliances that may be required at the compost facility.

Access: When using bin systems make sure that the front of the bin is removable, so that carcasses do not have to be lifted over. Removable dropboards that slide into a vertical channel on each side of the bin, doors that split horizontally, or gates can be used.

Bulking agent/cover material: The material used to cover the carcasses is an important part of the composting system. The ideal cover material retains heat, absorbs excess moisture and provides a barrier that helps discourage insects and scavengers. Cover materials also provide much of the carbon that is necessary for the microbes that decompose the mortalities. The physical characteristics of the bulking agent will affect how well the compost piles work.

In addition to choosing a bulking agent with an appropriate C:N ratio (see Composting Management section), you will want to find a bulking agent with a large enough particle size to let air flow, but not to the point that it cools the pile. Sawdust is generally considered the best cover material as it retains heat well and is very absorbent. However, as sawdust is not always available or may be too costly, alternative cover materials include chopped straw (2.5 cm or 1in. pieces) and small woodchips. You can also use finished compost as part of the bulking agent (up to 30 per cent). This has the advantage of inoculating the pile with microorganisms. Avoid using materials that are saturated with liquid or that contain high proportions of manure as these conditions may retard the composting process.

You can estimate the annual volume of bulking agent required using Table B in Appendix 2. This estimate is useful for planning purposes but it may need to be adjusted as you gain some experience with your particular bulking agent.

Availability and storage of cover material: Cover materials should be available from one or more sources in sufficient quantities throughout the year. Having sufficient amounts of ingredient such as sawdust, straw and litter present at the composting site greatly facilitates the day-to-day management of the process. When using a bin system, bins used for storage can double as primary composting bins if needed (e.g., during periods of high death loss), or they may facilitate the expansion of the composter if the farm is expanded. Ingredients do not have to be stored in bins, but the ingredient storage area should be roofed to keep the materials dry.

Figure 5: A hay moisture probe with a long stem works well to measure the moisture content of a compost pile. This pile is at the correct moisture level of about 45 per cent.

Composting Management

Compost piles have to be managed to ensure that the composting microorganisms have the right food and environment to be effective. There are four management considerations: C:N ratio; air flow; moisture content and temperature.

Carbon: Because animal carcasses are very high in nitrogen, you must add large amounts of carbon, in the form of the bulking agent, to the pile in order to provide the right environment and food for the composting microorganisms. The C:N ratio describes the amount of carbon compared to the amount of nitrogen in the pile. **A reasonable range is between 25:1 and 40:1.**

However, you don't need to be too worried about measuring the C:N ratio, since the composting process is fairly forgiving and will occur under a variety of C:N ratios, as long as you keep the overall C:N ratio in mind.

If you have too much carbon (a high C:N ratio) the low nitrogen supply can limit microbial activity. The temperature of the compost pile will decrease and the decomposition will be slowed. If you have too little carbon (a low C:N ratio) the high nitrogen supply is converted to ammonia and is emitted from the pile, resulting in increased odour. Leaching may also occur when there is excess nitrogen that converts to nitrate.

Air Flow (oxygen): Since aerobic microorganisms need oxygen to work, oxygen must be able to move into the pile and carbon dioxide and water vapour must be able to escape. This means that the bulking agent must have a particle size that allows air to move freely. **A particle size of 0.6 cm to 5 cm (1/4 in. to 2 in.) is reasonable.** Bulking agents such as newsprint can pack down, inhibiting air flow to the microorganisms, which will slow or even stop the composting process and produce odours. Large particles such as branches can let too much air in, cooling the pile and slowing down the work of the microorganisms. Ideally, 25 to 30 per cent free airspace is required.

Moisture Content: Microorganisms require water as a medium for chemical reactions, to transport nutrients and to move about. Compost with too little moisture will not supply sufficient water for microorganisms to survive. Too much moisture inhibits oxygen flow through the pile, causing aerobic microorganisms to slow down, which can lead to odours. **A moisture level of about 45 per cent will ensure a good composting environment.**

A hay moisture probe (a reasonably accurate probe is generally available at farm supply stores for approximately $250) can be used to monitor compost moisture levels. Several samples should be taken at random throughout the pile to get an average moisture reading. Recording the moisture readings will help you to make decisions on managing the pile, as moisture levels will affect temperature. Moisture content should not exceed 55 to 60 per cent. The compost should feel moist, but you should not be able to squeeze any liquid out. Covering a compost facility with a roof will reduce excess moisture accumulations, especially in areas of high rainfall, but may necessitate adding water to keep the pile active.

Temperature: Heat is required for the microorganisms to work and is also generated as a result of the composting process. The warmer the pile, the faster the microorganisms will work, the more heat they produce, the warmer the pile and so on. **Compost that is properly managed will have temperatures from 54 C to 71 C (130 F to 160 F).** Internal temperatures can be monitored using a 0.9 to 1.2 m (36 to 48 in.) temperature probe. For an accurate picture, it will be necessary to probe the pile in several locations (5 to10) to determine the average temperature.

It is quite normal to find hot and cool spots within the same bins. Recording the temperatures will allow you to track the level of activity in the pile. Temperatures lower than 49 C (120 F) indicate reduced microbial action, which means that decomposition is occurring slowly; this may affect the destruction of weed seeds and pathogens and may also result in odours. If temperatures reach 77 C (170 F) or higher, spontaneous combustion can occur. Temperatures should be maintained between 54 C to 71 C (130 F to 160 F), for several days or weeks to maximize the composting process and destroy weed seeds and pathogens. The troubleshooting guide in Appendix 1 is useful for identifying possible problems and solutions for your compost pile.

Figure 6: This pile is at an optimum temperature of 146 F (63 C)

Record keeping: A composting logbook is needed to record dates and weights of carcasses placed in the composter, temperature readings, amounts of bulking agent added, dates when compost is turned and amounts of finished compost.

Composting Bins

There are many different ways to build compost bins. Regardless of what system is used, the objective is to have enough capacity to manage all mortalities on-farm. Composting facilities can include wooden or concrete bins, hoop structures or bales. Alternatively, existing facilities like machine sheds can be adapted as long as the roof is high enough to allow the loader to lift and turn the compost.

Bins are usually laid out as three-sided enclosures with the open side wide enough (at least 0.6 m or 2 ft. wider than bucket width) to allow access with a front-end or skid-steer loader. Square bins are best, although length-to-width ratios of up to 2:1 are acceptable. Bins are usually filled to a depth of 1.5 to 1.8 m (5 to 6 ft.).


Figure 7: Design for 350-sow, farrow-finish system. ***Courtesy: Preun Farms.***

Layout should consider snow and wind loads. If problems with dogs or other animals occur, removable gates are helpful.

Size and number: The number and size of bins vary depending on the type and size of the operation. Bin dimensions depend on carcass size: large animals require more width than small animals to compost. Bin volume will depend on the size of the operation and the expected death loss. The worksheets for **Designing Your Bins** are provided in Appendices 3 and 4.

Figure 8: This bin has a concete base with a 4 in. curb. *Courtsey: Birch Bay Pork.*

In most cases, a minimum of three bins will be required, two of which are used for primary composting and the third for secondary composting. In a typical situation, one bin is full and composting while the other bin is being filled. Larger operations will require more than the minimum three bins. Experience has shown that having extra bins available for the storage of the bulking agent and finished compost is beneficial.

Base: It is recommended that the base should be a concrete pad with a 10 to 15 cm (4 to 6 in.) curb or lip to prevent leaching and runoff. A well-packed clay base is also appropriate. A buffer of crushed rock around the compost bin will discourage rodents. Due to its absorptive properties, sawdust is quite effective to control runoff and leaching.

Materials: Composting bins should be constructed of rot-resistant material including pressure-treated lumber, concrete or chain-link fencing. Bins are generally 2.1 to 2.4 m (7 to 8 ft.) high and solid to keep out scavengers. To avoid corrosion, ventilation is required and hot-dipped galvanized nails should be used. Field experience suggests that composting bins can be constructed using large round bales of hay (1.5 to 1.8 m or 5 to 6 ft. in diameter). Bales are placed end-to-end to form walls for three-sided enclosures or bins, as shown in Figure 9. A moveable gate (i.e. chain-link fencing) will keep scavengers out of the opening and allow easy access for disposal.

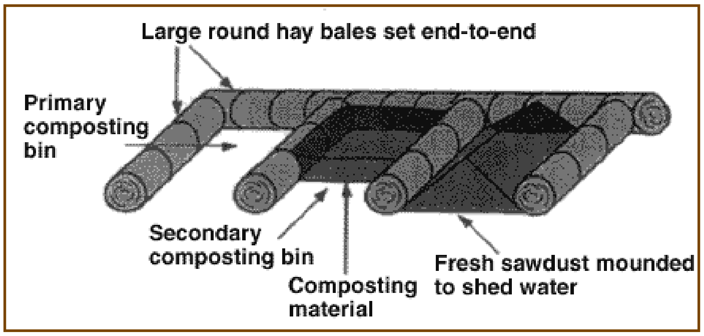

Figure 9: Compost bin made out of bales. Source: *Composting Dead Swine.* University of Missouri, 1999.

Building the Compost Pile

Start with a storage pile of sawdust or straw bales. Place a layer of material at least 0.45 to 0.6m (1.5 to 2 ft.) deep on the base of the first bin. This layer is necessary to provide good surface area contact with the carcass and to soak up any leachate. Lightly dampen the bulking agent. Pile on fresh mortalities, making sure they do not touch the bin sides.

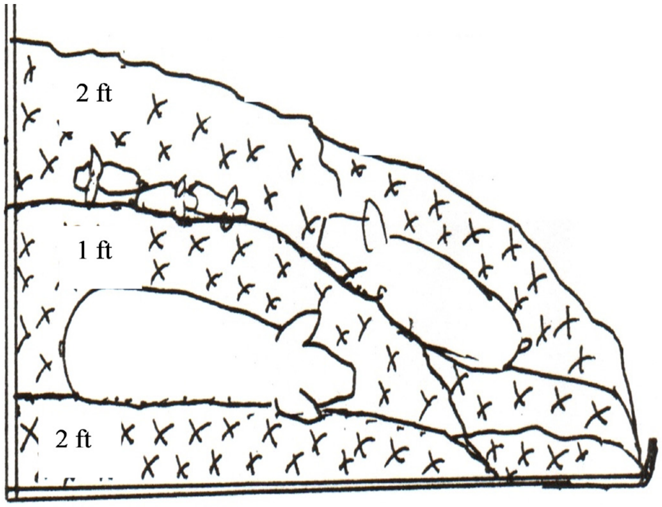

Figure 10: Simple cross-section of a compost pile.

Make sure you cover the carcass with a 0.45 to 0.6 m (1.5 to 2 ft.) layer of dry material. Proper coverage will reduce the odour and will prevent scavengers from digging up the carcasses. Start in one of the back corners of the bin and work your way forward slowly as the pile increases in height.

Lance the rumens to avoid bloating and possible explosions. Explosive releases of gases can result in odour problems and may blow the cover material off the composting carcasses.

For subsequent layers, scrape back the top dry portion of material leaving about one foot between carcasses, as shown in Figure 10. Continue layering mortalities and dry material, using either a shovel for small material or a tractor for heavy material.

Make sure new carcasses have adequate carbon material surrounding them. At no time should the carcasses be in contact with each other. When carcasses touch, you may have a rotting carcass rather than a composting one. Small animals may be grouped. Add fresh material occasionally, especially if the compost is becoming too soft or liquid.

The pile may need to be watered down occasionally, especially if conditions are dry or if it is covered with a roof. You will know this is necessary when the rate of decomposition begins to slow down.

When starting a new bin, 30 per cent of the dry matter can come from composted material. Advantages of recycling finished compost include: the need for less bulking agent; active bacteria and heat contained in finished compost; faster process; and less finished compost to be hauled for land spreading.

Windrow composting

Windrow composting can be used in conjunction with bin composting for the secondary stage where the pile is aerated. Alternatively, both the primary and secondary phase of composting can be done in a windrow rather than a bin. The costs for windrows may be somewhat less than for bins but the management requirements are often more intense, especially in adverse weather conditions which can affect the composting process.

When windrows are used, they should be constructed on an impervious surface and have proper runoff control. As with bin systems, windrows that are used to compost mortalities do not have to be turned during the primary stage of composting. However, the windrow will have to be turned (aerated) during secondary composting, so when designing the compost facility it is important to allow enough space between windrows for access by equipment.

Figure 11: Windrows

Building the Windrow

The worksheets for **Designing Your Windrows** appear in Appendices 3 and 4. The windrow volumes will be similar to the volumes required for bins.

The window should be properly sited on an impervious base with appropriate runoff control structures.

To prepare the windrow, first lay down a 0.3 to 0.45 m (12 to 18 in.) deep bed of the bulking agent (generally about 4.3 m or 14 ft. wide). This layer will absorb liquids from the decomposing carcasses. Mortalities are then put down in layers, with the bulking agent separating the layers. As with bins, lance the rumen to avoid bloat, explosions and odours. Layers are built until the pile is 1.5 to 2.1 m (5 to 7 ft.) tall.

The final layer should consist of the bulking agent and be at least 0.45 m (18 in.) deep. Using adequate material will ensure an adequate mass for composting, provide sufficient insulation, reduce odours and discourage scavengers. The calculation for estimating the amount of bulking agent required appears in Appendix 2.

As with bins, it is very important to completely cover the carcasses on all sides with bulking agent to a minimum of 0.3 to 0.45 m (12 to 18 in.) on all sides. Small animals may be grouped, but a minimum of 0.3 to 0.45 m (12 to 18 in.) of bulking agent should still be applied between layers. Never leave hooves, legs, ears or snouts sticking out of the pile. Most problems with composting mortalities occur when insufficient material is used to cover the carcasses.

Figure 12: covering a cow with material.

Use a pointed rod or dowel to measure the thickness of the bulking material. Large carcasses may need to be re-covered after a day or two, especially when using sawdust as it will tend to settle and may expose part of the carcass. The windrow should be shaped so that it will shed rainwater.

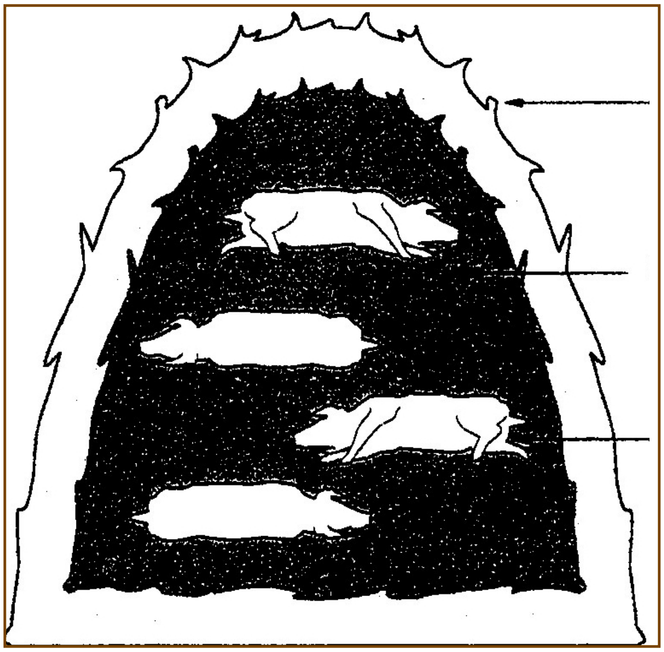

Figure 13: Layering the windrow.

To accelerate the composting process, especially in cold weather, the bulking agent can be warmed by adding extra material – over and above the 0.3 to 0.45 m (12 to 18 in.) layer, so that new carcasses are actually added to a warm bed. Alternatively, a 0.3 to 0.45 m (12 to 18 in.) layer of an absorbent material like sawdust or straw can be used to form the base of the pile and to this base a 0.3 m (12 in.) layer of hot (composting) manure can be added. The carcasses are then placed between the layers of hot manure, ensuring that they are covered on all sides with at least 0.3 to 0.45 m (12 to 18 in.) of material.

Emergency Composting

In the event of a catastrophic death loss, you may have too many carcasses to compost in your existing facility. Other arrangements will likely have to be made, or temporary facilities designed. For more information on emergency composting, livestock operators in Saskatchewan should contact the Agricultural Operations Unit with the Saskatchewan Ministry of Agriculture.

Composting Sick and Diseased Animals

Composting may not always be an appropriate method to manage dead animals. Animals that die as a result of a reportable disease should be disposed of according to guidelines provided by the Canadian Food Inspection Agency, Agriculture and Agri-Food Canada. When unsure of the appropriate action, contact your local veterinarian.

Appendix 1
Troubleshooting Guide

Problem	Probable Cause	Other Clues	Solution
Pile fails to heat	Materials too dry	Cannot squeeze water from material or moisture reading is below 20%	Add water, liquid manure or wet bulking agent
	Materials too wet	Materials look and feel soggy; pile slumps; or moisture reading is more than 60%	Add dry bulking agent
	Slow decaying, or not enough nitrogen	C:N ratio greater than 50:1; large amount of woody materials	Add more carcasses, perhaps cut or poke holes in the carcasses
	Poor pile structure or bulking agent used is too porous	Pile settles quickly while not excessively wet.	Add/mix existing bulking agent with sawdust
	Cold weather and/or small pile size	Pile height less than four feet	Enlarge or combine piles; add highly degradable materials (manure)
Failure to maintain temperature	Compost has dried out	Looks very dry; wind is blowing materials	Open pile and add water or liquid manure
	Cold weather		Ensure adequate cover with bulking agent and avoid adding frozen carcasses
	Too much moisture	Looks soggy; moisture reading is above 60%	Add fresh bulking agent to absorb moisture
Failure to decompose carcass tissues	Improper C:N ratio		Improper mix of ingredients or very old sawdust or straw
	Carcasses layered on top of each other	Carcass is intact even after two to three weeks from adding to the primary pile	Make sure 12 in. of bulking material between layers
	Carcasses placed on the outside edge of the pile		Maintain at least 1 ft. of space between carcass and outside edge of the bin
Smell of decaying flesh	Inadequate cover of bulking material over the carcass		Cover the carcass with at least 1ft. of bulking material
	Extended period of low temperature		Add manure and partially cut up the carcasses and cover with 2 ft. of bulking material
Pile overheating: temperature greater than 160 F (71 C.)	Insufficient aeration in the bulking material over the carcass	Pile is too moist	Add drier material and mix with the moist material
	Pile is too large	Height is greater than 7 ft.	Decrease pile size
	Low moisture		Add water or liquid manure

Problem	Probable Cause	Other Clues	Solution
Extremely high temperature: greater than 170 F (77 C)	Spontaneous combustion	Low moisture content; pile interior looks and/or smells charred	Decrease pile size; add water to charred or smoldering sections; break down pile.
High temperatures or odors in the curing (secondary) pile	Compost is not stable		Turn and mix pile till temperature and moisture are within limits
	Pile is too large	Higher than 7 ft.	Decrease pile size
Ammonia odors coming from pile	High nitrogen level		Add more bulking agent
	High ph level		Add manure
Rotten-egg odour coming from the pile	Anaerobic conditions; Materials too wet; poor pile structure; pile compacted	Low pile temperatures	Add dry bulking agent and mix top layer (if in primary bin) or the whole pile (if in secondary bin)
Run-off and/or leaching problems	Heavy rainfall		Build a roof over bin, make sure you have a curb on the base to catch run-off
	Too much moisture	Looks soggy; moisture reading is above 60%	Add fresh bulking agent to absorb moisture
Fly problems	Inadequate cover over the carcass		Maintain 1 ft. layer on top of carcass
	Poor sanitation conditions		Avoid having standing water around the facility - keep the surrounding site clean and free of garbage or debris
	Too high moisture	Looks and feels soggy	Add more cover of bulking material
Scavenging animals	Inadequate cover over the carcasses		Maintain 1 ft. cover on top of the carcasses
			Keep gates closed at all times
Pile doesn't reheat after turning in the secondary bin	Low moisture	Cannot squeeze water from material; moisture reading is below 20%	Add water and mix
	Composting near completion	Approaching expected composting time period	None required
Compost contains lumps of materials and large bones; texture is generally not uniform	Poor mixing of materials or insufficient mixing/turning in the secondary bin	Visible raw material; lumps of compost	You should have mixed the pile in the secondary bin as frequently and as thoroughly as possible!
	Active composting not complete	Curing pile heats or develops odours	Increase secondary composting time or improve composting conditions

Appendix 2

Table A: Annual Death Lost Estimates (%)

Type	Animal	Weight kg/lb.	Death Loss (%)	Cycle Length (days)
Beef Cattle	Cows and bulls	550/1,212	1	365
	Feeder cattle	450/992	1.5	120
	Replacement heifers	360/794	1	240
	Calves	135/298	4	200
Dairy Cattle	Cows/bulls	600/1,323	4	365
	Replacement heifers	450/992	4	365
	Calves	135/298	5	210
Hogs	Boars/sows	150/331	3	365
	Feeder pigs	100/220	1	126
	Weanling pigs	16/35	1.5	53
Poultry	Hens, cockerels, capons	1.8/4	5.5	294
	Chicks, broilers	1.5/3.3	6.5	40
	Hen turkeys, geese, ducks	8/18	9	92
	Heavy tom turkeys	12/26	11.5	114
Sheep	Rams and ewes	45/99	2	365
	Lambs	20/44	5	80
Goats	Does and Bucks	45/99	2	365
	Kids	20/44	5	180
Horses	Mares and studs	600/1,323	1	365
	Replacement horses	400/882	1	365
	Colts or ponies	135/298	4	365

Table B: Primary compositing phase, bin and bulking agent factors

Carcass Size		Primary Phase	Bin Factor		Bulking Agent Factor	
(kg)	(lb.)	(Days)	(m^3/kg/day)	(ft^3/lb./day)	(m3/100 kg)	(ft^3/100 lb.)
0-5	0-10	15	0.2	3	0.13	2
5-10	10-25	30	0.3	5	0.19	3
10-135	25-300	90	0.9	15	0.62	10
135-340	300-750	120	1.6	25	0.94	15
340-635	750-1,400	180	2.2	35	1.25	20

Designing Your Bins (Metric)

This worksheet is designed to calculate the number of bins required for your operation.

Example: A 1,200-sow farrow-to-finish operation containing 1,200 sows, 3,000 weanlings and 8,000 feeders.

1. Mass of carcasses composted (kg/cycle)

Number of animals in each cycle × average mass (kg) × death loss : Table A (%) ÷ 100 = (kg/cycle)	
EXAMPLE 1,200 sows × 150 kg × 3 % ÷ 100 = 5,400 kg/cycle 3,000 weanlings × 16 kg × 1.5 % ÷ 100 = 720 kg/cycle 8,000 feeders × 100 kg × 1 % ÷ 100 = 8,000 kg/cycle	**Your Numbers**

2. Mass of carcasses composted (kg/day)

(kg/cycle) ÷ number of days in each cycle : Table A = (kg/day)	
EXAMPLE Sows: 5,400 kg/cycle ÷ 365 days = 15 kg/day Weanlings: 720 kg/cycle ÷ 53 days = 14 kg/day Feeders: 8,000 kg/cycle ÷ 126 days = 64 kg/day	**Your numbers**

3. Total weight of carcasses composted (kg/day)

(kg/day) + (kg/day) + (kg/day) = Total (kg/day).
EXAMPLE (Sows) 15 kg/day + (Weanlings) 14 kg/day + (Feeders) 64 kg/day = 93 kg/day
Your numbers

4. Total bin volume (m^3)

$\text{Total (kg/day)} \times \text{Bin factor : Table B } (m^3/\text{kg/day}) = \text{Bin volume } (m^3)$	
EXAMPLE $93 \text{ kg/day} \times 0.9 \text{ m}^3/\text{kg/day} = 84 \text{ m}^3$	Your numbers

5. Total bin area (m^2)
- Assume each bin will be 1.5 to 1.8 m in height.

$\text{Bin volume } (m^3) \div \text{Bin height(m)} = \text{Total bin area}(m^2)$	
EXAMPLE $84 \text{ m}^3 \div 1.5 \text{ m} = 56 \text{ m}^2$	Your numbers

6. Individual bin size

Between 10 and 20 m^2
Ideally, bins should be between10 and 20 m^2. To complete the calculations, you must pick a bin size between 10 and 20 m^2 that works for you and results in an even number of bins (i.e. 3 bins or 6 bins, but not 4.9 bins, see example in #7).

7. Number of primary bins

$\text{Total bin area } (m^2) \div \text{Individual bin area } (m^2) = \text{Number of primary bins}$	
CORRECT EXAMPLE $56 \text{ m}^2 \div 14.0 \text{ m}^2 = 4 \text{ bins}$ NOT CORRECT 56 m^2 ÷ 15 m^2 = 3.7 bins rounding up or down does not work	Your numbers

Note: An equal number of *secondary* bins are also required.

8. Bin width

- Bin width should be at least the width of the loader bucket plus 0.6 m

Bucket width (m) + 0.6 m = Bin width (m)	
EXAMPLE $1.8\text{ m} + 0.6\text{ m} = 2.4\text{ m}$	Your numbers

9. Bin length (m)

Individual bin area (m^2) ÷ Bin width (m) = Bin length (m)	
EXAMPLE $14.0\text{ m}^2 \div 2.4\text{ m} = 5.8\text{ m}$	Your numbers

The result is now four primary bins; each bin is 2.4 m x 5.8 m in size. As somewhat square bins have been found to be more efficient for management and composting, you can adjust the dimension of the bins (width x length) to result in a more square design. An example is provided below.

10. Adjusting the bin width (m)

Bin width is usually no greater than twice the width of the bucket.	
EXAMPLE $2.4\text{ m} + 0.6\text{ m} = 3.0\text{ m}$ = revised bin width	Your numbers

11. Adjusting the size of the bin length (m). Divide the individual bin area by the bin width to find bin length.

Individual bin area (m^2) ÷ bin width (m) = adjusted bin length (m)	
EXAMPLE $14.0\text{ m}^2 \div 3.0\text{ m} = 4.7\text{ m}$	Your numbers

- The result is now four primary bins; each bin is 3.0 m x 4.7 m in size.

12. Total number of bins

As noted earlier, an equal number of *secondary* bins of the same size is required. In addition, one extra bin is required to accept new carcasses.

Total number of bins = (Number of primary bins x 2) + 1	
EXAMPLE (4 x 2) + 1= 9	Your numbers

- In most cases, a minimum of three bins will be required, two of which are used for primary composting, and the third for secondary composting. In a typical situation, one bin is full and composting while the other bin is being filled. Larger operations will require more than the minimum three bins. Additionally, it is beneficial to have extra bins available for the storage of bulking agent and finished compost.
- Throughout this example, all animal sizes were composted together. Consider separate facilities for animals of different ranges of weight.
- Refer to Table B to determine primary composting time. Secondary composting time will be similar to (or less than) the number of days in the primary phase.

Estimating the Volume of Bulking Agent (Metric)

This worksheet is designed to estimate the volume of bulking agent required for your operation.

Example: A 1,200-sow farrow-to-finish operation using bulking agent.

1. Weight of carcasses composted annually (kg/year).
Multiply the total weight of carcasses composted daily by 365. The daily weight of carcasses composted was determined in step three of the previous example.

(kg/day) x 365 days/year = kg/yr	
EXAMPLE 93 kg/day x 365 days/year = 33,945 kg/year	Your numbers

2. Volume of bulking agent required annually (m^3/year).
Refer to Table B to find a "bulking agent factor" for the expected carcass size. Multiply the weight of carcasses composted annually by the factor, and divide by 100.

$\frac{\text{(kg/yr) x bulking agent factor (Table B)}}{100} = (m^3/yr)$	
EXAMPLE $\frac{33{,}945 \times 0.62}{100} = 210\ m^3/yr$	Your Numbers

This example finds that approximately 233 m^3 of bulking agent is required each year. Remember, this is only an estimate. New bins could be started with about 30 per cent finished compost. The amount of bulking agent will therefore vary with the amount of finished compost recycled.

Designing Your Windrows (Metric)

This worksheet is designed to calculate your windrow requirements.

Example: 5,000-head feedlot.

1. Mass of carcasses composted (kg/cycle).

Number of animals in each cycle × Average mass (kg) × Death loss : Table A (%) ÷ 100 = (kg/cycle)	
Example	Your Numbers
5,000 feeders × 450 kg × 1.5 % ÷ 100 = 33,750 kg/cycle	

2. Mass of carcasses composted (kg/day)

(kg/cycle) ÷ Number of days in each cycle = (kg/day)	
EXAMPLE	Your numbers
33,750 kg/cycle ÷ 120 days = 281 kg/day	

3. Total mass of carcasses composted (kg / day)

(kg/day) + (kg/day) + (kg/day) = Total (kg/day)
EXAMPLE 281 kg/day (only one type of animal in this example)
Your numbers

4. Total windrow volume (m^3)

Total (kg/day) × Bin factor : Table B (m^3/kg/day) = Windrow volume (m^3)	
EXAMPLE 281 kg/day × 2.2 m^3/kg/day = 618 m^3	Your numbers

5. Windrow height (m).
Ideally, each windrow will be 1.5 to 2.1 m in height. Select the windrow height from the table below to give you the windrow base width and the cross sectional area. Assume the side slopes are 1:1 and the top width is 0.3 m.

Windrow Height (m)	Cross Sectional Area (m^2)	Base Width (m)
1.5	2.7	3.3
1.8	3.8	3.9
2.1	5.0	4.5

6. Windrow length (m).

$$\text{Windrow volume}\,(m^3) \div \text{Cross sectional area}\,(m^2) = \text{Total length}\,(m)$$

EXAMPLE	Your numbers
$618\,m^3 \div 5.0\,m^2 = 124\,m$	

This example finds a total windrow length of 124 m; the windrows are 2.1 m in height and 4.5 m in width. Depending on the site and equipment, five windrows each 25 m in length may be easier to manage than one long windrow.

Designing Your Bins (Imperial)

This worksheet is designed to calculate the number of bins required for your operation.

Example: A 1,200-sow farrow-to-finish operation containing 1,200 sows, 3,000 weanlings and 8,000 feeders.

1. Weight of carcasses composted (lb./cycle)

Number of animals in each cycle × average weight (lb.) × death loss : Table A (%) ÷ 100 = (lb./cycle)	
EXAMPLE 1,200 sows × 331 lb. × 3 % ÷ 100 = 11,916 lb./cycle 3,000 weanlings × 35 lb. × 1.5 % ÷ 100 = 1,575 lb./cycle 8,000 feeders × 220 lb. × 1 % ÷ 100 = 17,600 lb./cycle	Your Numbers

2. Weight of carcasses composted (lb./day)

(lb./cycle) ÷ number of days in each cycle : Table A = (lb./day)	
EXAMPLE Sows: 11,916 lb./cycle ÷ 365 days = 33 lb./day Weanlings: 1,575 lb./cycle ÷ 53 days = 30 lb./day Feeders: 17,600 lb./cycle ÷ 126 days = 140 lb./day	Your numbers

3. Total weight of carcasses composted (lb./day)

(lb./day) + (lb./day) + (lb./day) = Total (lb./day).
EXAMPLE (Sows) 33 lb./day + (Weanlings) 30 lb./day + (Feeders) 140 lb./day = 203 lb./day
Your numbers

Appendix 3 cont'd.

4. Total bin volume (ft^3)

$$\text{Total (lb./day)} \times \text{Bin factor : Table B } (ft^3/\text{lb./day}) = \text{Bin volume } (ft^3)$$

EXAMPLE	Your numbers
$203 \text{ lb./day} \times 15 \text{ ft}^3/\text{lb./day} = 3{,}045 \text{ ft}^3$	

5. Total bin area (ft^2)

- Assume each bin will be 5 to 6 feet in height.

$$\text{Bin volume } (ft^3) \div \text{Bin height(ft.)} = \text{Total bin area} (ft^2)$$

EXAMPLE	Your numbers
$3{,}045 \text{ ft}^3 \div 5 \text{ ft.} = 609 \text{ ft}^2$	

6. Individual bin size

Between 100 and 200 ft^2
Ideally, bins should be between100 and 200 ft^2. To complete the calculations, you must pick a bin size between 100 and 200 ft^2 that works for you and results in an even number of bins (i.e. 3 bins or 6 bins, but not 4.9 bins, see example in #7)

7. Number of primary bins

$$\text{Total bin area} (ft^2) \div \text{Individual bin area} (ft^2) = \text{Number of primary bins}$$

CORRECT EXAMPLE	Your numbers
$609 \text{ ft}^2 \div 122 \text{ ft}^2 = 5 \text{ bins}$ NOT CORRECT $609 \text{ ft}^2 \div 124 \text{ ft}^2 = 4.9$ bins rounding up or down does not work	

Note: An equal number of *secondary* bins are also required

8. Bin width
   - Bin width should be at least the width of the loader bucket plus two feet.

$\text{Bucket width(ft.)} + 2 \text{ feet} = \text{Bin width(ft.)}$	
EXAMPLE $6 \text{ ft.} + 2 \text{ ft.} = 8 \text{ ft.}$	Your numbers

9. Bin length (ft.)

$\text{Individual bin area(ft}^2) \div \text{Bin width(ft.)} = \text{Bin length(ft.)}$	
EXAMPLE $122 \text{ ft}^2 \div 8 \text{ ft.} = 15 \text{ ft.}$	Your numbers

The result is now five primary bins; each bin is 8 ft. x 15 ft. in size. As somewhat square bins have been found to be more efficient for management and composting, you can adjust the dimension of the bins (width x length) to result in a more square design. An example is given below.

10. Adjusting the bin width (ft.)

Bin width is usually no greater than twice the width of the bucket.	
EXAMPLE $8 \text{ ft.} + 2 \text{ ft.} = 10 \text{ ft.}$ = revised bin width	Your numbers

11. Adjusting the size of the bin length (ft). Divide the individual bin area by the bin width to find bin depth.

Individual bin area (ft^2) ÷ bin width (ft.) = adjusted bin length	
EXAMPLE $122 \text{ ft}^2 \div 10 \text{ ft.} = 12 \text{ ft.}$	Your numbers

- The result is now five primary bins; each bin is 10 ft. x 12 ft. in size.

12. Total # of bins

As noted earlier, an equal number of *secondary* bins of the same size is required. In addition one extra bin is required to accept new carcasses.

Total number of bins = (# of Primary bins x 2) + 1	
EXAMPLE (5 x 2) + 1= 11	**Your numbers**

- In most cases, a minimum of three bins will be required, two of which are used for primary composting and the third for secondary composting. In a typical situation, one bin is full and composting while the other bin is being filled. Larger operations will require more than the minimum three bins. Additionally, it's beneficial to have extra bins available for the storage of bulking agent and finished compost.
- Throughout this example, all animal sizes were composted together. Consider separate facilities for animals of different ranges of weight.
- Refer to Table B to determine primary composting time. Secondary composting time will be similar to (or less than) the number of days in the primary phase.

Estimating the Volume of Bulking Agent (Imperial)

This worksheet is designed to estimate the volume of bulking agent required for your operation.

Example: A 1,200-sow farrow-to-finish operation using bulking agent.

1. Weight of carcasses composted annually (lb./year).

Multiply the total weight of carcasses composted daily by 365. The daily weight of carcasses composted was determined in step three of the previous example.

(lb./day) x 365 days/year = lb./yr	
EXAMPLE 203 lb./day x 365 days/year = 74,095 lb./year	Your numbers

2. Volume of bulking agent required annually (ft^3/year).

Refer to Table B to find a "bulking agent factor". Multiply the weight of carcasses composted annually by the factor and divide by 100.

$\frac{\text{(lb./yr) x bulking agent factor (Table B)}}{100} = (ft^3/yr)$	
EXAMPLE $\frac{74{,}095 \times 15}{100} = 11{,}114$	Your Numbers

This example finds that approximately 11,100 ft^3 of bulking agent is required each year. Remember that this is only an estimate. New bins could be started with about 30 per cent finished compost. The amount of bulking agent will therefore vary with the amount of finished compost recycled.

Table B: Primary composting phase, bin and bulking agent factors

Carcass Size		Primary Phase	Bin Factor		Bulking Agent Factor	
(kg)	(lb.)	(Days)	(m^3/kg/day)	(ft^3/lb./day)	(m^3/100 kg)	(ft^3/100 lb.)
0-5	0-10	15	0.2	3	0.13	2
5-10	10-25	30	0.3	5	0.19	3
10-135	25-300	90	0.9	15	0.62	10
135-340	300-750	120	1.6	25	0.94	15
340-635	750-1400	180	2.2	35	1.25	20

Designing Your Windrows (Imperial)

This worksheet is designed to calculate your windrow requirements.

Example: 5,000-head feedlot.

1. Weight of carcasses composted (lb./cycle).

$$\text{Number of animals in each cycle} \times \text{Average weight (lb.)} \times \text{Death loss : Table A (\%)} \div 100 = \text{(lb./cycle)}$$

EXAMPLE	Your Numbers
$5{,}000 \text{ feeders} \times 992 \text{ lb.} \times 1.5\,\% \div 100 = 74{,}400 \text{ lb./cycle}$	

2. Weight of carcasses composted (lb./day)

$$\text{(lb./cycle)} \div \text{Number of days in each cycle} = \text{(lb./day)}$$

EXAMPLE	Your numbers
$74{,}400 \text{ lb./cycle} \div 120 \text{ days} = 620 \text{ lb./day}$	

3. Total weight of carcasses composted (lb./day)

$$\text{(lb./day)} + \text{(lb./day)} + \text{(lb./day)} = \text{Total (lb./day)}$$

EXAMPLE
620 lb./day (only one type of animal in this example)
Your numbers

4. Total windrow volume (ft^3)

$$\text{Total (lb./day)} \times \text{Bin factor : Table B } (ft^3\text{/lb./day}) = \text{Windrow volume } (ft^3)$$

EXAMPLE	Your numbers
$620 \text{ lb./day} \times 35 \ ft^3\text{/lb./day} = 21{,}700 \ ft^3$	

Designing Your Windrows (Imperial) cont'd.

5. Windrow height (ft).

Ideally, each windrow will be five to seven 7 feet in height. Select the windrow height from the table below to give you the windrow base width and the cross sectional area. Assume the side slopes are 1:1 and the top width is 1 ft.

Windrow Height (ft.)	Cross Sectional Area (ft^2)	Base Width (ft.)
5	30	11
6	42	13
7	56	15

6. Windrow length (ft).

$\text{Windrow volume } (ft^3) \div \text{Cross sectional area } (ft^2) = \text{Total length (ft.)}$	
EXAMPLE	Your numbers
$21{,}700\ ft^3 \div 56\ ft^2 = 388\ ft.$	

This example finds a total windrow length of 388 ft.; the windrows are 7 ft. in height and 15 ft. in width. Depending on the site and equipment, five windrows each 78 ft. in length may be easier to manage than one long windrow.

Appendix 5
Metric Conversion Factors * (Approximate)

Metric to Imperial			Imperial to Metric	
Metric Unit	**Multiply By**	**Imperial Unit**	**Multiply By**	**Metric Unit**
LINEAR				**LINEAR**
centimetre (cm)	x 0.39	inch	x 2.54	centimetre (cm)
AREA				**AREA**
square metre (m2)	x 1.2	square yard	x 0.84	square metre (m2)
hectare (ha)	x 2.5	acres	x 0.4	hectare (ha)
VOLUME				**VOLUME**
litre (L)	x 0.22	gallon	x 4.55	litre
PRESSURE				**PRESSURE**
kilopascals (kPa)	x 0.14	psi	x 6.9	kilopascals (kPa)
WEIGHT WEIGHT				
gram (g)	x 0.04	oz	x 28.35	gram (g)
kilogram (kg)	x 2.2	lb	x 0.454	kilogram (kg)
AGRICULTURAL				**AGRICULTURAL**
litres per hectare (L/ha)	x 0.089	gallons/acre	x 11.23	litres per hectare (L/ha)
litres per hectare (L/ha)	x 0.357	quarts/acre	x 2.81	litres per hectare (L/ha)
litres per hectare (L/ha)	x 0.71	pints per acre	x 1.41	litres per hectare (L/ha)
millilitres per hectare (mL/ha)	x 0.014	fl.oz per acre	x 70.22	millilitres per hectare (mL/ha)
kilograms per hectare (kg/ha)	x 0.89	lb per acre	x 1.12	kilograms per hectare (kg/ha)
grams per hectare (g/ha)	x 0.014	oz/acre	x 70	grams per hectare (g/ha)

*EXAMPLE: To convert centimetres to inches, multiply by 0.39; conversely, to convert inches to centimetres, multiply by 2.54. CAUTION: Herbicide labels are in metric units only. Conversion between the Metric and Imperial system may result in confusion. It is recommended to use metric units only.

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