ENVIRO FACT SHEET

Composition and Value of Layer Manure

Manure from poultry layer systems can be a valuable plant nutrient resource for grazing and cropping systems. There are two main types of layer manure; manure from caged systems and litter from barn laid or free range systems. Generally, manure from caged systems has a higher nutrient content and less carbon than litter. However, both of these by-products usually have a higher nutrient content than other animal manures.

Layer manure supplies essential plant nutrients in a 'slow release' form, which can boost plant growth for a period of weeks after application. Sufficient manure for two or more seasons may be spread in one application as nutrients such as a phosphorus will be released over time.
Like other manure and litter by-products, layer manures are not a balanced nutrient source. They have a high ratio of phosphorus to nitrogen and for this reason they are best used primarily as a phosphorus source. It is important to carefully manage the reuse of manure, as over application and poor reuse practices can cause environmental harm. To read more about application rates, see the fact sheet in this series called *Layer Manure – Spreading Layer Manure*.

Composition

The composition of layer manure varies between different layer farms because of differences in diets fed and management systems (caged layers, barn laid or free range). Manure composition also depends on the length of time the manure has been stockpiled. Generally, the amount of carbon and nitrogen will decline as the stockpiling time is extended, while other conservative nutrients such as phosphorus are concentrated due to the loss of carbon and nitrogen.

Consequently, the nutrient profile of layer manure is variable, and the figures presented in *Table 1* are indicative only. A chemical analysis of the manure is needed to accurately determine the composition.

Table 1. Average composition of layer manure

Parameter	Units	Belt Average*	Spent Litter Average*	Composted manure, range and average.+
Moisture	%	58.9	20.8	20.5 – 43.6 (34.4)
pH – water		6.3	6.9	7.3 - 8.7 (8.3)
Electrical conductivity	dS/m	12.3	9.5	8.4 – 12.7 (11.5)
Organic carbon	%	37.8	32.3	20.2 – 35.6 (25.5)
Nitrogen	%	6.0	2.7	1.6 - 4.9 (3.5)
Ammonium nitrogen	mg/kg	6449	1941	485 – 7455 (3863)
Nitrate-N	mg/kg	<200	384	66.2 – 152.1 (136.3)
Phosphorus	%	2.3	1.6	1.6 - 1.8 (1.7)
Ortho-phosphorus	mg/kg	3224	2052	4526 – 4660 (4593)
Potassium	%	1.9	1.5	**

* Values derived from Wiedemann et al. (2008)
+ Values derived from those reported in the *Egg Industry Environmental Guideline* (Edition II, McGahan et al., 2018)
** Not reported.

Environmental management

Layer manure is a valuable resource, but reuse needs to be managed in a sustainable way to overcome potential environmental threats, such as nutrient losses. For more information on determining the risk of nutrient losses refer to the *Egg Industry Environmental Guidelines* (Edition II, McGahan et al., 2018).

Metal and pathogen contaminants can be managed using a range of approaches. The first step is to determine the risk of metal contamination.

Table 2 shows the different elements that may be present at low concentrations in layer manure. Several of these elements are necessary for plant growth, but may become toxic to plants at high concentrations.

Table 2. Composition of layer manure – potential environmental contaminants (Wiedemann et al., 2008)

Contaminant	Layer Manure Concentration (mg/ kg), range and average.
Arsenic (As)	1–1 (1)
Copper (Cu)	31–82 (58)
Zinc (Zn)	280–540 (398)

Table 3 shows the recommended upper limits for several potential contaminants that may be found in layer manure. The maximum concentrations for arsenic, copper and zinc in layer manure are typically lower than the limits suggested by the Natural Resource Management Ministerial Council (NRMMC 2004).

Table 3. Limits for contaminants in compost, soil conditioners and mulches for agricultural land application (mg/kg) Sources: NRMMC (2004), NSW EPA (2000), VIC EPA (2004)

Contaminant	NMRCC	NSW EPA	VIC EPA
Arsenic (As)	60	20	60
Copper (Cu)	2500	2000	2000
Zinc (Zn)	2500	2500	2500

While the levels of contaminants in layer manure are generally well below the guideline upper limits, it is recommended that users of layer manure monitor soils to ensure elements do not build up to levels where toxicity becomes limiting to plant growth. If other metals are a concern, chemical analysis of the manure before use is advised.

Pathogens can also exist in layer manure and this may be a concern if applying manure directly to horticultural crops. Some pathogens potentially present in layer manure are *Campylobacter jejuni/coli, Clostridium perfringens, Clostridium botulinum, Enterococcus spp, Listeria monocytogenes, Salmonella spp*. Use of appropriate health and safety precautions will protect worker health. Refer to www.biosolids.com.au for more details on biosolids regulations in your state.

Calculating potential manure value

It is possible to roughly estimate of the value of layer manure by comparing the value of the macro nutrients (nitrogen, phosphorus and potassium) in the manure with the cost of commercial inorganic fertilisers (see *Table 4*). This provides a starting point for assessing the value of manure as a nutrient resource.

Table 4. Value of nutrients in layer manure (Belt system) compared to inorganic fertilisers

	Manure Analysis *(%dry basis)	kg / m3	Inorganic Fertiliser product ($/t ex GST)	Value of Layer Manure
Moisture content	58.9	501.6		
Nitrogen (N)	5.95	20.1	Urea (46% N) $420	$19.00
Phosphorus (P)	2.3	8.1	MAP (21% P) $660	$24.26
Potassium (K)	1.9	6.65	MOP (50% P) $595	$7.91
Calcium	11.3	39.55	Gypsum (23% Ca)	$8.60
Maximum value of N,P,K and Ca per m3				$59.79

1m^3 is assumed to contain 350kg of solids
*Values from Wiedemann et al. 2008

To do this, the kilograms of nutrient per cubic meter (the most common measurement) need to be calculated. These calculations are provided in the *Layer Manure – Spreading Layer Manure* fact sheet in this series. In addition to nitrogen, phosphorus and potassium (N, P, K), there are significant amounts of calcium, sulphur and trace elements in layer manure. Comparing the value of manure with lime as a source of calcium, layer manure may be valued at around $8.60/m3 if compared to agricultural lime at $50/t, though in practice the amount in manure is lower than typical application rates for lime.

The trace elements in layer manure include magnesium, manganese, iron, boron, copper and zinc. Where required, these trace elements are highly valuable and will increase the reuse value of layer manure.

How much is layer manure worth?

Typically, layer manure is sold for $10 – 15/m3 (1m3 = approx. 850kg with 59% moisture). This is considerably less than the value of the nitrogen, phosphorus and potassium in the manure. Also, manure has the added value of organic matter (approximately 30% of dry weight) which is beneficial to soil, improving soil structure and water holding capacity. However, there are also reasons why manure value will be lower than the maximum value of the nutrients, caused by difficulty in handling and application of manure compared to fertilisers.

Manure can be difficult to handle compared to conventional fertiliser, requiring specialised equipment and management. Manure also contains several nutrients that need to be balanced with plant requirements, which requires understanding of the attributes of the manure product as well as the fertiliser requirements of the crop being grown. Nutrients within the manure may not be in a form that is immediately available for plant growth, increasing the need for nutrient monitoring of soils and crops. These factors increase the management and handling requirements compared to conventional fertilisers.

Because of these factors, it may be reasonable to value manure at approximately 50% of the value of the N, P and K it contains. This would give a value of approximately $28/m3 at 2018 fertiliser values.

Getting maximum value from layer manure requires a good understanding of the product and the best ways to manage this product in a farming system. Several other fact sheets in this series have been produced to provide information on setting application rates and spreading. These fact sheets are designed to help producers to get the maximum value out of layer manure in farming systems.

References and Further Reading

Wiedemann, S., McGahan, E. and Burger, M. (2008) *Layer Hen Manure Analysis Report*. Australian Egg Corporation Limited.

McGahan, E., Wiedemann, S. G., & Gould, N. (2018) *Egg Industry Environmental Guidelines, Edition II*. Australia, Australian Eggs Limited.

NRMMC (2004) *Australian Guidelines for Sewerage Systems-Biosolids Management*, Australian Water Association, NSW, and the Natural Resource Management Ministerial Council.

NSW EPA (1997) *Environmental Guidelines for Use and Disposal of Biosolid Products*, Department of Environment and Conservation, Sydney and the New South Wales Environmental Protection Agency (NSW EPA).

VIC EPA (2004) *Guidelines for Environmental Management-* Biosolids Land Application. Southbank, VIC: Victorian Environmental Protection Agency (VIC EPA).

ENVIRO FACT SHEET

Composting By-products on Egg Farms

Composting is a useful way to manage a range of wastes and by-products from egg farming, including layer manure (caged layer manure and barn litter), egg waste and spent hens. In addition to this, the end product can be valuable as a nutrient source and soil amendment for spreading on grazing and cropping land (refer to the factsheet in this series "Spreading Layer Manure").

Composting is a natural process involving the breakdown of organic matter by microorganisms. The resulting product is a humus like material that is a valuable soil conditioner and nutrient source. There are many benefits to using a composting process to manage wastes and by-products, including the reduction of bulk, moisture content and pathogens and the production of a stable, uniform product that does not produce offensive odour when applied to land.

Composting requires careful management of three key components:

1. The Carbon:Nitrogen ratio (C:N)
2. Oxygen supply
3. Moisture level

There are many other management factors that need to be considered when trying to get the most out of a composting process, but most relate to the above components.

C:N ratio

Carbon (C) and nitrogen (N) are the two elements most likely to limit the composting process if they are not supplied in the correct ratio.

Generally, a C:N ratio of between 15:1 and 40:1 will provide for effective composting. Where the C:N ratio is less than 15:1 (not enough carbon), the carbon is consumed without necessarily stabilising the nitrogen in the biological matter. The excess nitrogen can be lost to the atmosphere as ammonia (NH_3) and odour can become a problem. If the C:N ratio is higher than about 40:1, the composting process takes longer to consume the carbon or stalls, because microbial growth is limited by a lack of nitrogen.

Carbon naturally occurs in a range of forms, and this can influence the efficiency of composting as some forms are more readily degraded than others. For example, the carbon found in straw is readily degradable and will compost quickly, while cellulose or lignin fibres found in paper or wood will take longer to compost.

Layer manure, egg waste and carcasses have a very low C:N ratio. For this reason, it is necessary to add a carbon source (i.e. sawdust, straw or cardboard from egg processing) at a ratio of about 1 part manure/waste to 2 to 3 parts of a carbon source material (by volume). If using cardboard, the process will be helped by shredding the cardboard before composting to increase the surface area.

Oxygen supply

Composting is a process carried out by living organisms in the presence of oxygen. Under aerobic conditions, organisms break down organic matter, producing carbon dioxide as a by-product and very little odour. However, if oxygen is not present (anaerobic conditions) a compost pile may produce offensive odours.

Oxygen supply in a compost windrow or pile is influenced by the size and shape of the pile, the pore space in the material (porosity), the water content of the compost and the frequency of turning. Aeration is usually supplied by frequently turning a pile or windrow, or by using forced aeration in a static pile. Windrows can also aerate as convection forces draw air into the pile when temperatures increase.

Moisture level

Water is a key component in the composting process. Organisms require moisture to survive and increase and the composting process will slow or stop altogether if the moisture level drops too low. However, if moisture levels are too high and the material is too dense (low porosity) there may not be enough oxygen for the beneficial aerobic organisms.

Generally, the preferred moisture content for a compost mix is about 40–65%. Depending on the materials used in the initial compost mix, water may need to be added to achieve the ideal level.

Composting will 'use' water during the process, as moisture is evaporated from the windrows or piles. For this reason, moisture levels should be monitored to keep the material between 40–65% (about field capacity) where the product is moist to touch but does not drip when gently squeezed. One exception to this is for composting of mortalities and spent hens. In general birds have adequate moisture to begin the composting process and may only require a small amount of moisture to wet down the feathers. At later stages in the composting process water may need to be added to ensure the process is successful.

If the windrow becomes too wet odour may be produced. In this case, drying can be hastened by turning the pile or adding more dry bulking material.

Temperature

Composting produces heat, coming from the biological activity of the organisms as they break-down organic matter. The process has a general pattern of temperature fluctuations that can be used to monitor the process.

After initial mixing, the temperature in the centre of the pile generally starts to rise within a few hours. Provided windrows are large enough to maintain the heat generated, temperatures in the range of 55°–60°C will be reached within a few days of start-up. Under ideal conditions these temperatures will be maintained for several weeks before dropping gradually to ambient temperature, at which time the compost process is complete.

Temperature will be self-regulating provided that there is sufficient nitrogen, carbon and moisture for microbial breakdown. Because of this, temperature is a useful indicator for the composting process. Composting is most rapid when the temperature is maintained between 40°–60°C. During the initial phase, a drop in temperature will usually indicate insufficient water, oxygen supply or possibly nitrogen. When the composting process is complete, temperatures within the pile will not rise after being watered and turned.

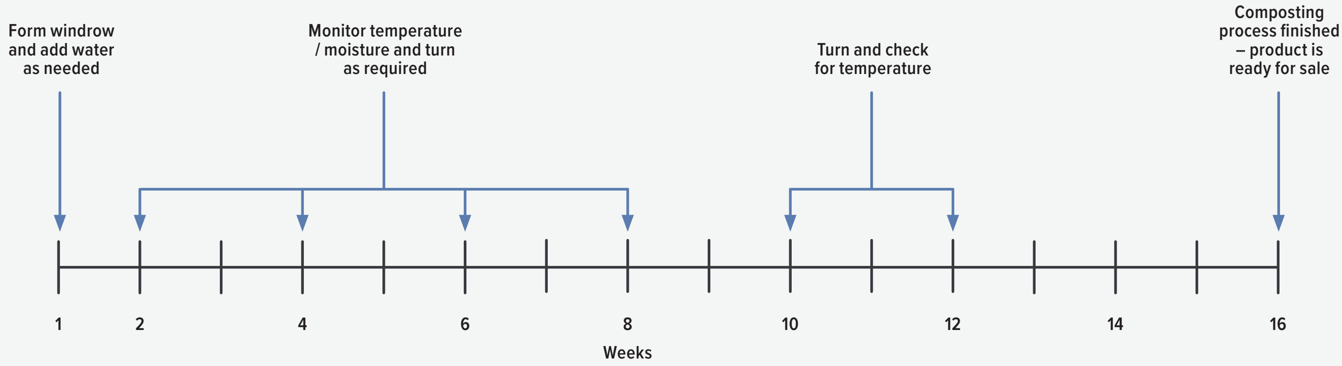

Figure 1. Key time periods during composting

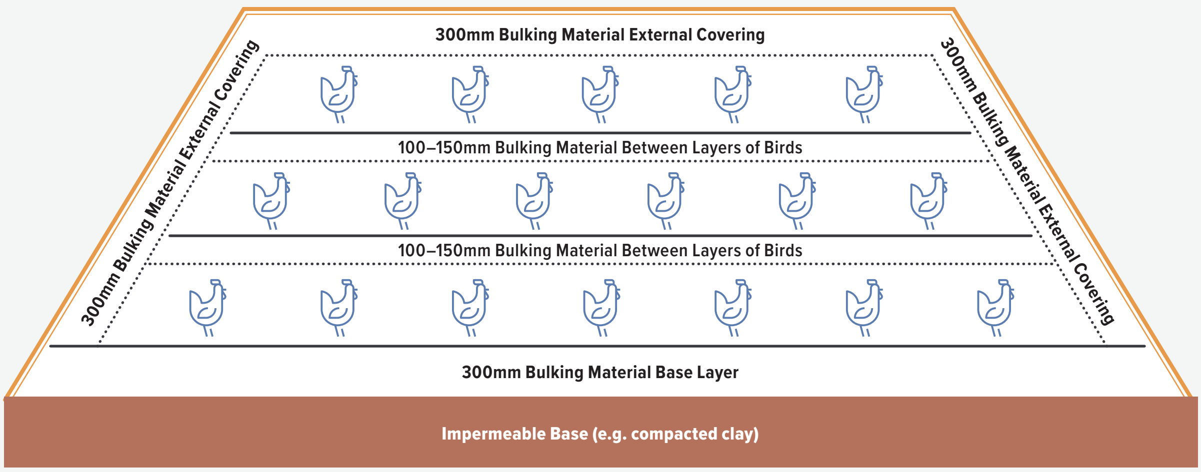

Figure 2. Carcass composting heap design

High temperatures (above 55°C) are essential to destroy weed seeds and pathogens. Turning windrows is important to ensure all of the material is subjected to the high temperatures in the pile centre. This will ensure that weed seeds and pathogens are killed.

General compost management

Composting is generally conducted in windrows 1.5–2m high and 3–4m wide at the base. To maintain enough oxygen, the windrows need to be turned regularly during the initial phase. The process should be complete in about 8–12 weeks, with an additional 4 weeks of curing time. *Figure 1* shows key time periods during the composting process.

Refer to the factsheet in this series "Composting Equipment" for more information on equipment used in composting.

Advantages of composting:

- Produces a consistent product that is safe for reuse in agricultural and residential areas.
- Reduces the weight and volume of the manure and processing wastes by 30–50%.
- Heat generated in the process destroys most pathogens and weed seeds, providing a safer and more widely useable end product.

Disadvantages of composting:

- Adds an additional cost to the treatment process (machinery and labour).
- Nitrogen may be lost via volatilisation and a smaller proportion is typically plant-available compared to un-composted manure.

Carcass composting

Composting is an effective way to dispose of daily mortalities and spent hens. In general, carcass composting follows the same principles as manure composting. However, some differences are apparent. See *Figure 2* for typical carcass composting heap design.

Poultry carcasses have a high moisture and nitrogen content compared to many organic materials. For successful composting, it is necessary to add a carbon source (such as sawdust or chopped straw) to soak up moisture and provide an additional carbon source for the process.

The first step to setting up the compost is calculating the number of mortalities or spent hens for composting To calculate daily mortalities, this will equal the total number of birds multiplied by the mortality rate and divided by the days of occupancy, for example:

10,000 birds x 3% mortality = 300 birds

300 / 365 = 0.8 birds/ d, or = 6 birds / wk.

This gives a total mass of about 12 kg of carcass per week, which will require about 25kg of bulking material (i.e. 0.1m3 of sawdust). Annually, this amounts to about 5m3 of sawdust to compost the 300 birds. Some or all of the completed compost material may be reused for 2–3 years to reduce cost.

Because of the odour and pest potential with carcass composting, it is important that all carcasses are adequately covered with bulking material. This requires coverage with approximately 300 mm of carbon bulking material (i.e. sawdust) to ensure that odours do not escape, and scavengers do not discover the carcasses. One very important consideration with carcass composting is to ensure the process has adequate oxygen at all times during the process. This will reduce the risk of botulism, which is caused by the Clostridium botulinum organism.

Another essential step to reduce the risk of botulism is to ensure that mortalities are managed to avoid anaerobic decomposition occurring before the composting process begins. This can be done by composting mortalities every day or storing mortalities in a fridge / freezer if daily composting cannot be done.

Carcass composting can be done successfully with 1–2 turns of the compost. Unlike regular composting, it is advisable to leave a carcass compost pile for a minimum of 4 weeks before turning the pile to allow time for breakdown of the carcasses. After this time the pile can be turned, but it must be re-covered with about 300 mm of an inert material to ensure carcasses are not exposed on the outside of the pile. An ideal material to use for this is 'finished' compost that has been through the cycle once already.

Like all composting, carcass composting needs a good source of carbon. The ideal materials are sawdust / shavings, barn litter or finely chopped straw.

Finely mulched green waste may also be used but wood chips or coarse green waste are not ideal. Layer manure may also be used, but this should be used at less than 25% of the total mix as it does not contain adequate amounts of carbon for effective carcass composting.

To minimise pathogen levels in carcass compost, the compost should be turned three times and reach temperatures of 55°C for three consecutive days after each turning. These temperatures should be monitored, and records maintained.

Compost area design considerations

Carcass composting can be done in many ways; however the simplest option is to construct bays or a windrow with a compacted base, and turn piles one month after the last carcass was added.

Some important factors to consider when designing a compost area include:

- Forming an impermeable base to avoid leaching and improve machinery access,
- Good site drainage to avoid muddy conditions and excessive moisture in the compost. The site may also require bunding to reduce runoff from the site.
- Collect nutrient rich runoff in a sump / dam; this can then be re-used for composting.
- Check licence requirements as some states require a separate licence for composting.

Composting Check List

- ☐ Construct pad for composting operations ensuring the base is impermeable to control drainage, and ensure that runoff is contained.
- ☐ Add manure or spent litter to the pad with additional bulking material.
- ☐ Mix the compost to ensure a C:N ratio of approximately 15:1 – 20:1 (this means adding about 1 to 2 parts sawdust to 1 part caged layer manure by mass – or about 2 to 3 parts sawdust to 1 part manure by volume).
- ☐ Mix the manure with the bulking material and form into windrows, approximately 1.5m high, depending on machinery size.
- ☐ Add water if necessary during windrow formation to make up moisture to between 50–60% (approx. 1000L per tonne of compost mix given above).
- ☐ Monitor windrows to ensure that heating is taking place – record temperature if required by vendors to ensure complete composting of product.
- ☐ Turn piles weekly or bi-weekly (usually when a temperature decline is observed), adding water as required to maintain 50–60% moisture.
- ☐ The composting process is complete when turning the pile will not result in heating (provided all other conditions for composting are met).

Carcass composting Check List

- ☐ Construct bin or bay for composting operations ensuring the base is impermeable to control drainage, and ensure that runoff is contained.
- ☐ Compost birds daily or store birds in a fridge/ freezer prior to composting to avoid a build-up of pathogens.
- ☐ Put down a 300mm layer of bulking material (sawdust, straw or other carbon source – not manure) on the bottom of the compost pile.
- ☐ Add mortalities (1.5 birds deep per layer).
- ☐ Wet down the feathers of the birds (if necessary*) and add water if required to ensure adequate moisture levels to maintain microbial activity.
- ☐ Add further bulking material (sawdust, straw or manure mix) at approximately 2:1 ratio of bulking material to carcass mass.
- ☐ Ensure that carcasses are covered with 300mm of bulking material to protect from rodents/pests – use additional bulking material if required.
- ☐ Ensure the pile is peaked so that rainfall will shed from the pile.
- ☐ Ensure carcass compost is not accessible to livestock and that material is not spread on grazing land unless livestock are vaccinated. This will reduce the risk of botulism.
- ☐ Ensure aerobic conditions are maintained throughout the whole process to minimise risk of botulism.

For adding additional carcasses

- Remove the top layer of bulking material, ensuring 100 to 150mm of bulking material remains to cover the previous carcasses.
- Add new carcasses and follow steps 3–7 above.
- Ensure that the overall pile height is no greater than 3 meters.

* Water is not essential for carcass composting.

Troubleshooting

1. "My windrow does not heat up!"

Possible problems

- **Incorrect moisture levels (too much or too little)**
  Aim for 40 – 65% – enough to feel wet without it dripping in your hand when gently squeezed.
- **Insufficient mixing / oxygen**
  Turn windrow and observe again after 6 -12hrs.
- **Incorrect C:N ratio**
  Is there enough nitrogen for biological activity? This should not be a problem unless too much bulking material is added – aim for a C:N ratio of between 15:1 and 40:1. To increase nitrogen, add manure.
- **Unavailable carbon**
  The carbon may be in a form that is not accessible for breakdown. If woodchips or other course material is used, the low surface area and low degradability can inhibit composting. Try using straw or sawdust to provide adequate carbon.
- **The composting process is finished**
  If all other conditions are met and the windrow has been composting for some time, failure to heat after turning is a good indication of completion of the active phase of the composting process.

2. "My windrow is creating excessive odour!"

Possible problems

- **Moisture levels are too high**
  This may be caused by rainfall if piles absorb this water. If this is the case turn the pile and form it to shed water – add more bulking material if required.
- **The C:N ratio too low (too much nitrogen)**
  This can cause ammonia loss and odour production – solve by adding more bulking material.

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Composting Equipment

Composting significant amounts of material will require machinery for turning and handling the composting material. Composting can be done using different types of machinery from frontend loaders to self propelled windrow turners. These machines differ in cost, ease of operation and quality of compost produced. Using specialist equipment greatly improves efficiency when composting large volumes of material.

Front end loaders

Front end loaders are often the first choice for smaller composting operations because they may be available on-farm already and have many other uses. A front end loader can be used to turn windrows and piles, and this may be a good option for carcass composting or small volumes of manure composting. However, front end loaders are slow to operate and may not adequately mix the compost piles.

Windrow compost turners

A range of windrow turners are available in Australia, both from local manufacturers and importers. These include:

- Three point linkage units
- PTO driven trail behind units
- Self powered units (turner is driven off a separate engine but mounted to a tractor)
- Self propelled units.

The scale of the operation will usually determine the required size of the compost turner.

Three point linkage models are available for small to medium scale composting, while trailing units are better for larger windrows and can turn larger amounts of compost rapidly. Self-propelled turners are suitable for large scale operations where a significant amount of material is to be composted.

Windrow dimensions

Tractor drawn models can generally turn a windrow less than 3m high, whereas some self-propelled turners may turn windrows up to 4m high by 4m wide. This affects the size and layout of the composting area and the total amount of compost that can be turned. For example, smaller windrows require more space because of the need for traffic alleys between the rows.

Turning rates

Turning rates will vary with the size and type of turner. Three point linkage turners are limited to a turning rate of between 200–400m3/hr, while tractor drawn turners may have a turning rate of 400–800m3/hr. Self-propelled turners can turn at rates of 1200–6500m3/hr.

Power requirements

For tractor drawn turners, the size of the turner determines the power requirements of the tractor. Three point linkage models will require about 50–60 horsepower while a PTO driven trailing turner may require 80–140 horsepower. Tractors will require a creeper gear to travel at a slow speed. Hydraulic assist features are available for turners to remove the need for a creeper gear.

Water application

Some windrow turners can add water to windrows using a trailing hose system. This is ideal for medium to large scale operations and improves operational efficiency. Alternatively, some windrow turners can tow a water tanker that will supply water during turning, and this may be more appropriate for small operations without water infrastructure.

Straddle and auger turners

Straddle turners (as shown above) straddle over the top of the windrow, and turn the windrow in one pass. As such, the windrow width must match the drum length. Auger turners use paddles to lift and move the compost. As they move down the windrow, the compost is moved to one side, reducing the space between windrows. These are good for composting in small areas since less tractor space is needed beside the windrows.

Model	Indicative Cost ($)	Windrow size (m)	Turning capacity (m3/h)
Sittler 507	23,666*	2.1m	458
PSU 36-18-16	22,000	3.6 x 1.8	700
PSU 36-18-20	24,500	3.6 x 1.8	900
EZ 1800	43,989	1.8 x 1	450
EZ 2700	52,789	2.7 x 1.4	950
EZ 3600	59,950	3.6 x 1.8	1400
CT360	51,500	3.6 x 1.8	1300

**(requires shipping)*

Purchasing a windrow turner

Cost is a major consideration when buying a compost turner. The size and type of turner (three point linkage, tractor drawn or self propelled) have the largest affect on price, with the largest self propelled machines costing in excess of $500,000.

The prices above were collected from a range of manufacturers and suppliers in Australia to provide a general price range in 2018 (prices are shown excluding GST). Each supplier may offer alternative products.

The following list of suppliers is provided as a service to farmers. It is not intended to be a comprehensive list of suppliers or their products. No supplier or product mentioned here is endorsed above any other. Buyers are encouraged to carry out their own market research.

Supplier details

For the CT360 and related products contact **JPH Equipment**
www.jphequipment.com.au

For the EZ1800 and related models, contact **EZ Machinery**
www.ezmachinery.com.au

For the PSU models, contact **Cutcon**
windrowcompostturner.com.au

For the Sittler 507 contact **URC recycle**
www.urcrecycle.com

Alternatively, search online for used machinery sales.

ENVIRO FACT SHEET

Free Range Production: Management of range areas

Managing range areas for good environmental outcomes is an important aspect of managing a free range farm.

Managing range areas for good environmental outcomes is an important aspect of managing a free range farm.

Improperly managed range areas result in increased environmental risks from nutrient losses. Nutrients lost in surface water runoff from free range areas may cause eutrophication in water bodies (e.g. creeks, rivers, dams, lakes), promoting the growth of algae. High nitrate levels in water are also toxic to fish, birds, wildlife, stock and humans. Elevated organic matter levels in water reduce oxygenation, affecting fish and other aquatic life. Hence, practices that elevate the nutrient content of runoff should be avoided or the runoff to waterways avoided.

Nutrients can also leach through the soil and contaminate groundwater. Contamination of groundwater can lead to health problems for humans, animals and ecosystems. Once groundwater contamination has occurred, remediation is difficult and expensive. The risk to groundwater is influenced by a range of features of the site, including the depth to groundwater, soil type and the existing quality of the ground water.

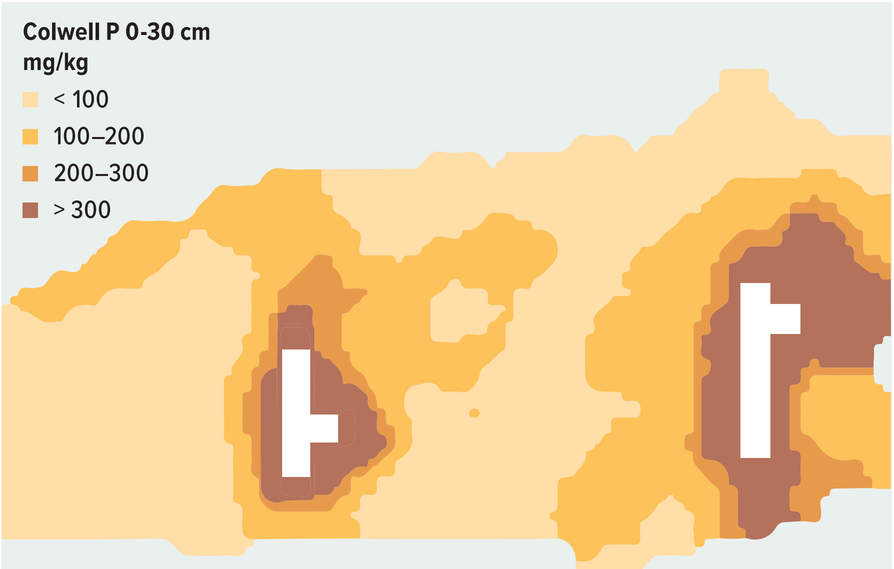

Figure 1. Phosphorus concentration in range areas associated with fixed sheds (Wiedemann and Zadow, 2010)

Nutrients in ground water can also influence surface water, where shallow aquifers are linked to the surface water system.

Other impacts to range areas include the denuding of groundcover, resulting in potential erosion and loss of soil structure, however the high organic content of manure can help to maintain and even improve soil structure.

Nutrient sources such as range areas should be assessed for environmental risk, then designed and managed to control these risks.

Nutrient deposition for fixed sheds

Most free range farms have fixed sheds and a range area around the shed. In these systems, nutrients are deposited in a predictable pattern.

Figure 1 shows that the soil available phosphorus concentration in free range areas is much higher in the areas closest to the shed and this pattern is the same for other nutrients. *Figure 2* shows that soil nitrate levels decrease significantly with distance from sheds, while *Figure 3*

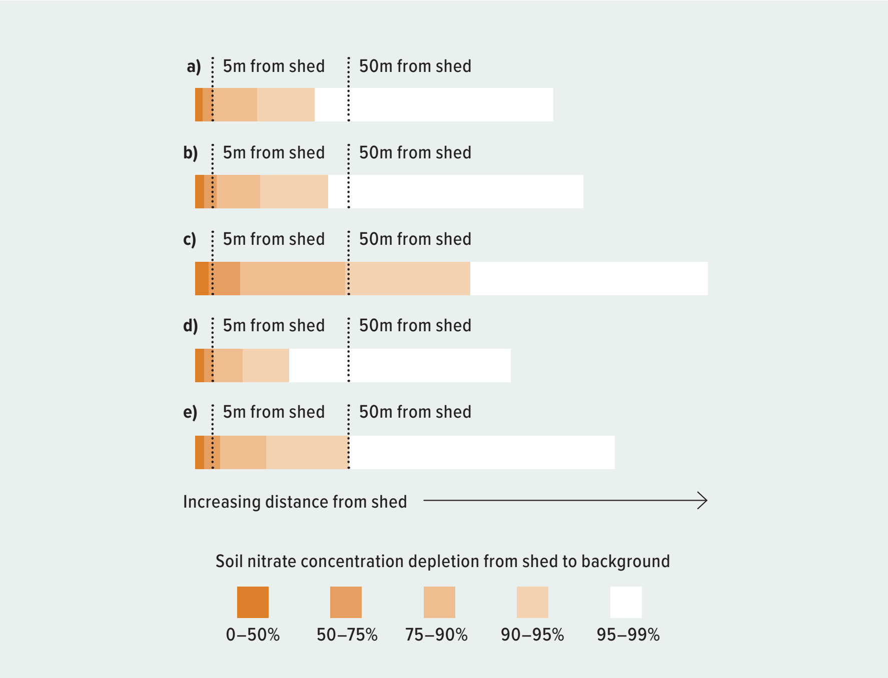

Figure 2. Soil Nitrate concentration and distance from sheds (Wiedemann et. al., 2018)

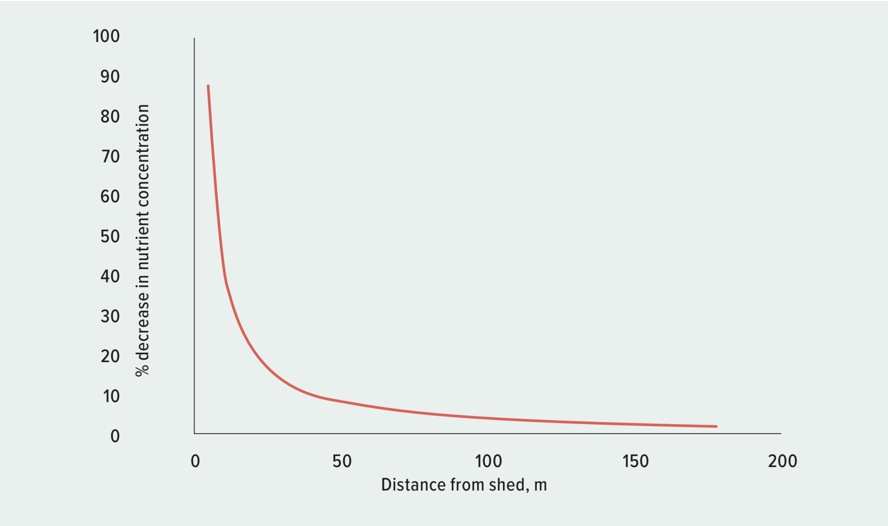

Figure 3. Combined soil nutrient (nitrate-N and available-P) levels and distance from shed (Wiedemann et. al., 2018

shows the trend for both nitrate and phosphorus, indicating that nutrient concentrations at 25m are less than 20% of the levels closest to the shed.

Based on recent research (Wiedemann et. al., 2018, Larsen et al., 2017) it is estimated that around 86% of manure deposition occurs within the shed and the remainder in the range area, with decreasing amounts deposited as you move away from the shed. This reduction in nutrient deposition can be divided into zones as described in *Table 1*. It is important to note that due to the size of Zone 3 (the remainder of the range), the nutrient concentration in this zone is much lower than in other zones and represents a lower environmental risk.

Table 1. Estimated manure deposition in each zone.

Area of Range	Distance From Shed	Estimated Manure Deposition
Zone 1	0–10m	10.5%
Zone 2	10–25m	1.5%
Zone 3	> 25m	2.0%

Effect of Fenced Areas

Fenced areas within the inner range are likely to restrict bird movement and result in higher nutrient deposition rates in the zone closest to the shed.

Management measures for fixed sheds

The Egg Industry Environmental Guidelines (Edition II – McGahan et al., 2018) provide a risk tool for evaluating nutrient loss potential from range areas. Please refer to the guidelines for a more thorough discussion of the risks associated with range areas, how these risks are calculated and subsequent management recommendations.

For 'high risk' sites the following management strategies are recommended in each zone.

Zone 1

The installation of roofed verandas with impermeable flooring and bunding to control manure nutrient loss immediately outside the exit point of each shed (i.e. 2–3m) is recommended to restrict nutrient loss.

Verandas of 2–3m are expected to restrict 50% of nutrient losses. Diversion of rainwater from these verandas and the shed roof is also recommended, to reduce water movement and subsequent nutrient loss. Verandas will require cleaning (as manure builds up in these areas), and removal of this manure/litter. Manure should only be spread in the outer range area (zone 3) after assessing the nutrient status via soil testing.

In the area between the veranda edge and 10m, drainage may be controlled by constructing an impermeable pad, or by using coarse rock or aggregate underlain with an impermeable base, to avoid problems with birds scratching through the pad.

Bunding should be provided to exclude stormwater from running onto these areas. Runoff from these areas may be managed using vegetative filter strips (VFS). More detail on VFSs can be found below.

Zone 2

Monitoring of soil nutrient levels is warranted to ensure unacceptable levels of nutrient accumulation do not occur. Where nutrient accumulation is observed, management strategies applied in other intensive livestock systems such as long-cycle rotations of range areas and nutrient removal via crop production could be used where site conditions allow. Rotation can also be achieved by using movable shelters. Alternatively, compacted pads, bunding and runoff control could be employed as in Zone 1.

Zone 3

The lower nutrient concentration, and higher groundcover in this area poses a reduced environmental risk, even on high risk sites. Wiedemann et al. (2018) showed nutrient levels in this zone, considering differences in background soil fertility, were typically within acceptable agronomic ranges for crop and pasture production and management.

Nutrient levels in this zone should be periodically monitored to check that levels do not increase substantially beyond pasture or crop requirements. If nutrient levels increase substantially, practices adopted in other intensive livestock systems would be suitable in these zones. These include: paddock rotation or periodic crop removal; together with ongoing monitoring to ensure soil nutrient levels do not pose unacceptable risk.

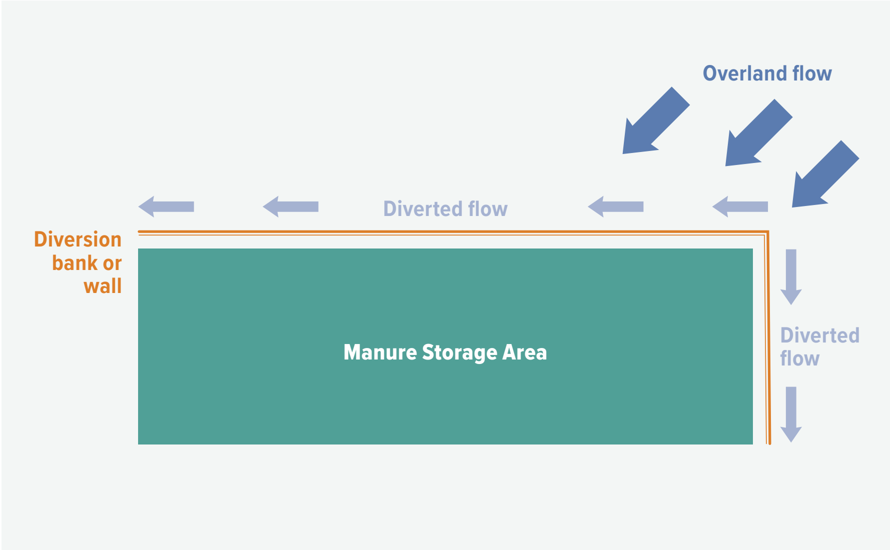

Figure 4. Diversion of overland flow

Refer to the *Egg Industry Environmental Guidelines* (Edition II – McGahan et al., 2018) for more information on monitoring testing and sampling information and suggestions. More detail on VFSs can be found below.

For 'low risk' sites, the following management strategies are recommended:

- Place compacted gravel from 0 to 6m from sheds.
- Divert water from roofs away from range areas.

Excluding overland flow

On high risk sites it is recommended to divert stormwater away from zones which contain the highest nutrient deposition. This prevents the overland flow of stormwater from being able to transport the nutrients (dissolved and in sediment). As shown in *Figure 4*, it is important to consider the site topography and direction of runoff, as any protective measures must redirect water away from the range area.

The measures used to redirect flow could include bunding, diversion banks, or appropriately sized and maintained drainage ditches. Any such measures are likely to cause diverted flows to become concentrated, increasing flow rate and erosive potential. This can be managed by maintaining groundcover along drainage lines, or installing measures which slow flow rates.

Maintaining Groundcover

Maintaining groundcover in free range areas can be difficult, particularly in high traffic areas near the sheds. Similar strategies to those used for nutrient management are appropriate:

- Rotate range areas to allow denuded areas to recover.
- If moveable shade structures are used, ensure they are regularly shifted to allow pasture to recover.
- Spread straw/hay in denuded areas to increase groundcover.

Where groundcover is particularly difficult to maintain, erosion controls are recommended. These include:

- Installing contour banks and associated drainage works.

- Constructing drains that minimise flow convergence and slow/spread flow where possible.
- Repairing rills before gullies form.
- Maintaining groundcover in drain areas, and fencing these areas off where necessary.
- Reducing the flow rate of runoff with control measures (e.g. swales, contour banks, VFSs).
- Using rock/gravel groundcover in high traffic areas such as Zone 1 and 2.
- Directing runoff to a VFS. More detail on VFSs can be found below

Effect of bird numbers

The number of birds present on the range will have a significant impact on the total amount of nutrient deposited in each zone.

Where the number of birds is doubled this is expected to result in double the total nutrient being applied to the range area. As a result, this will increase the total amount of nutrient available for loss, and the potential impacts.

Effect of Shed shape

Nutrient deposition is expected to occur within the same distance of the shed, regardless of shed size or shape. As such, the total area of Zone 1 is dependent on the length of the shed, as shown in *Figure 5*.

For any given number of birds, a smaller Zone 1 area results in higher nutrient deposition rates per m^2. This is associated with higher soil nutrient concentrations, and a higher risk of nutrient loss to the environment.

The manure removal frequency from Zone 1 areas should be determined from both the risk of nutrient loss from the site and the deposition rate of manure per m^2.

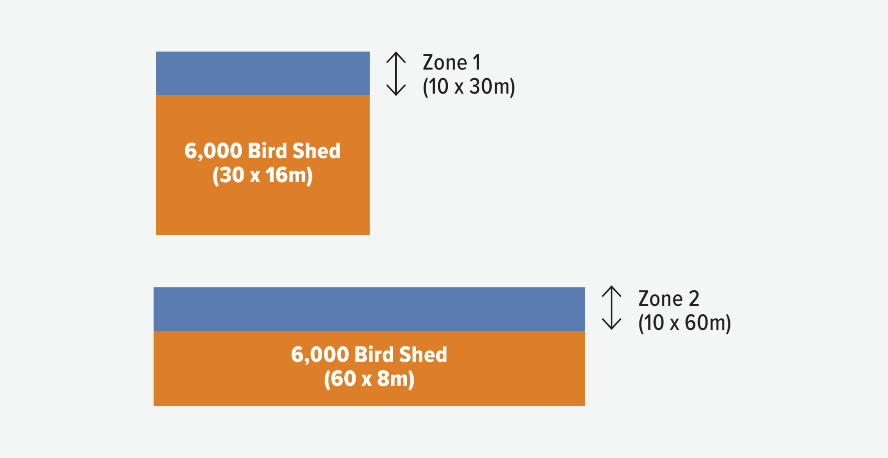

Figure 5. Effect of shed geometry on zone size

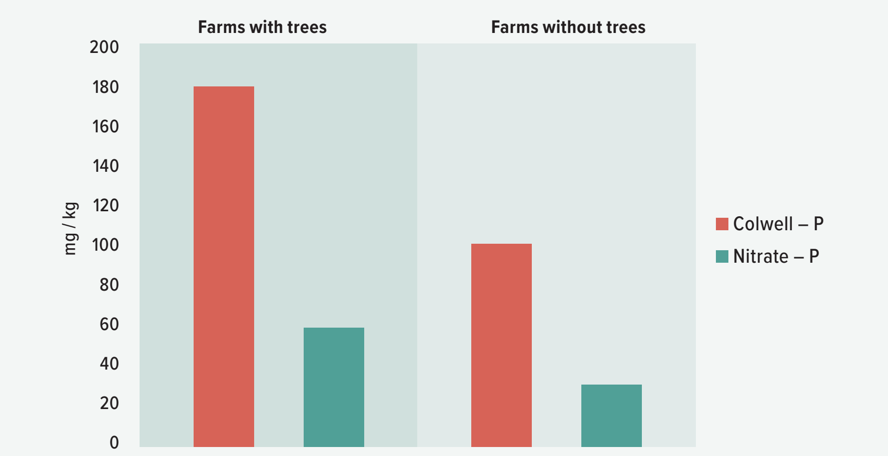

Figure 6. Average soil nutrient concentration on treed and non-treed range areas (Wiedemann et al. 2018).

Impact of Range Enrichment

The presence of trees on the range area has been shown to encourage ranging behaviour, and subsequently increase nutrient distribution further into the range, as shown in *Figure 6*.

Managing Impacts of Range Enrichment

Due to the high nutrient deposition associated with treed areas, a suitable management strategy needs to be developed for treed areas which allows for the regular collection and removal of manure from beneath trees and avenues.

Other forms of range enrichment using artificial structures have been shown to have a similar effect on the ranging behaviour of birds and subsequent nutrient deposition. Artificially enriched areas are also expected to be associated with reduced levels of ground cover.

Due to the difficulty of collecting manure from treed and other artifically enriched areas, artificial shade structures could be used. These structures could be placed on compacted pads to make manure collection easier. Arificial shade structures should also use impermeable roofing materials to exclude rainfall from the high nutrient areas under the shade structure.

An alternative approach is to regularly move shade and enrichment structures, allowing less manure to accumulate in each location and helping to maintain ground cover.

Where fixed structures are used, these areas could be fenced and access to birds allowed only on a rotational basis.

Impacts of Open Floored Housing

In open floored or slatted housing (such as some mobile bird housing) manure deposited within the shed is deposited directly onto the ground. If this manure is not collected, the total nutrient deposition on the range may be 7 times higher than an equivalent sized fixed shed (where only around 14% of nutrients may be deposited on the range area).

Managing Impacts of Open Floored Housing

Regularly moving open floored housing results in less manure deposition in each location. Housing movements should aim to provide fresh ranging areas for birds, ensuring that the majority of nutrient deposition (associated with the housing and immediate area) does not occur in recently used areas.

Regular rotation of range areas also allows for re-establishment of groundcover. Increased groundcover will also utilise nutrients in the manure, lowering the risk of nutrient loss. Groundcover also decreases the risk of erosion, and contributes to healthy soil structure.

Collecting manure from beneath bird housing significantly reduces the total amount of nutrients deposited onto the range. This can be achieved by laying plastic sheeting or similar under the housing unit and collecting the deposited manure for use off-site or spreading in areas of low nutrient deposition. This could be done when housing is moved. Alternatively, hard compacted areas could be provided for shed locations, allowing manure to be easily collected when the shed is moved.

Vegetative Filter Strips (VFS)

VFS are small areas of well maintained groundcover, which are used to reduce the nutrient levels in overland flow/surface runoff. They are designed and located so that runoff must flow across the VFS at a minimum water depth. This reduces runoff volume (though increased infiltration) and allows greater deposition of eroded soil and nutrients, as well as providing opportunity for nutrients to be adsorbed to soils.

The appropriate width of the VFS depends on the slope of the land, the type of vegetative cover within the buffer area and whether there are other stormwater control devices, such as diversion banks. Ideal grasses for a VFS are runner-developing, non-clump forming grasses that can effectively reduce nutrient and sediment concentrations in the runoff.

Generally, wider VFSs reduce the soil loss rate from erosion. However, for the same soil loss rate, areas with higher slopes need a wider VFS than areas with lower slope due to the higher speed of runoff. To be most effective a VFS needs to be located as close as possible to the nutrient source to minimise additional runoff. It is also critical to locate the VFS before any convergence of runoff (i.e. drainage lines).

More detail on how VFSs operate, their effectiveness and how they should be designed can be found in *Egg Industry Environmental Guidelines* (Edition II – McGahan et al., 2018).

Managing Vegetative Filter Strips
To maintain effective operation of a VFS:

- Remove sediment build up at the higher end of the drain or VFS to avoid any ponding.
- If the VFS becomes denuded, consider treatments to maintain high rates of groundcover, or reseed the VFS with runner type grasses. Seek guidance on appropriate species.
- Water during dry periods to maintain effective grass coverage over the VFS. Where appropriate (depending on environmental regulations), alternative water sources should be used to avoid use of potable water.
- Maintain sediment and erosion control measures upslope of the drain or VFS to reduce the sediment load.
- Ensure livestock do not damage the VFS.
- Avoid using VFSs for traffic.
- Avoid leaving tyre or tillage marks in VFSs when maintenance is required.
- Remove any woody stem plants before they exceed 50 mm in diameter from VFSs.
- Avoid damaging VFSs with herbicides and use mowing and slashing to control weeds.
- Consider a cut and cart operation from the VFS to remove mature plant material and promote new growth.

Summary of Recommendations

Range areas should be designed and managed based on the risk rating of the site and the likely nutrient deposition rates in the various zones (associated with distances from the sheds).

Additional management options to minimise environmental impacts from range areas include:

- Use of rotation and spelling to allow denuded areas to recover, which ideally includes hay production or cropping during the rotation phase, as this allows nutrients to be removed from the site. Grazing livestock on the area is significantly less effective than a cropping/pasture production for hay, as most of the nutrients are recycled back onto the site.
- If moveable shade structures are used, ensure they are regularly shifted to allow pasture to recover or use permanent structures that control nutrient loss by having an impermeable roof and a pad.
- If moveable sheds/caravans are used, ensure they are regularly shifted to allow pasture to recover and to reduce nutrient build-up. These operations can also consider a cropping/ pasture harvest rotation or manure capture and removal if conducted on a high risk site.
- Monitor soil nutrients to ensure nutrient application and removal rates are sustainable.

References and Further Reading

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ENVIRO FACT SHEET

Manure Sampling Procedure

Manure sampling is the only way to accurately determine the nutrient and contaminant content of your manure. However, a manure analysis is only an accurate representative if the sample has been collected, handled and analysed correctly

This procedure will outline the correct process for sampling to ensure this is done correctly.

For more details on testing and sampling, refer to the *Egg Industry Environmental Guidelines* (Edition II, McGahan et al., 2018)

Collection and handling

The aim of the collection procedure is to get a representative sample of the manure or litter. You will need gloves, a shovel or hand trowel, a clean bucket, a zip-lock bag and a cooler with ice (for storing and transporting the sample). The sampling procedure is as follows:

1. Label a zip-lock bag with permanent marker, including property name, date, sample type and a description of where the sample was taken from, i.e. 'layer shed no. 1'.
2. Fill eskies with ice.
3. Put on disposable gloves and dust mask (if sampling dusty products). When sampling, do not eat, drink or smoke. Carry out standard hygiene practices.
4. Sample manure after it is removed from the shed if possible*. Shed cleanout will help mix the manure / litter making it easier to get a representative sample.
5. Collect approximately 25 sub-samples from throughout the pile with the shovel and mix these in the bucket.
6. After the sub-samples are mixed together, collect the final sample (about 1kg) and place in the labelled, zip-lock bag. It is recommended to place a second bag over this for protection.
7. Immediately place the sample in an esky, pack crushed ice completely around it and replace the esky lid. Store the esky in the shade.
8. If the sample is to be stored for more than 48hrs, it should be refrigerated or frozen.
9. When all samples have been added to the esky, seal it with the waterproof tape.
10. Thoroughly wash your hands.
11. Complete the analysis request forms and photocopy for your own records (if you have access to a photocopier or fax machine). Place the original forms in an envelope. Clearly address the envelope to the laboratory and add their phone number. In smaller writing, put your own address and phone number on the envelope as "sender". Firmly tape the envelope to the top of the esky.
12. Deliver the samples or arrange for courier delivery.
13. Contact the laboratory to confirm that the samples were received within 48 hours of sampling.

*If sampling must be done within a shed (i.e. in a barn laid system prior to clean out) it is necessary to collect a large number of sub-samples (40–50) throughout the shed, covering areas with high and low amounts of manure coverage to get a representative sample. These samples should include surface and sub-surface litter. Sampling should be done as close as possible to the end of the cycle to be representative of the spent litter that will be available for reuse.

Manure analysis

It is recommended that a NATA accredited laboratory is used for manure analysis. Laboratories are available in most states of Australia, and manure analyses generally cost between $130–$310 (the average is approximately $180) for a basic analysis. Once a laboratory is selected, the next step is to document the type of analysis you require and send this with the sample. The analysis will depend on the reason for testing the manure. As a starting point, the following analysis can be used to cover most agriculturally relevant elements and properties of manure.

Table 1. Typical Manure Analysis Parameters

Parameters		
Moisture (%)	pH	Sodium (%)
Phosphorus (%)	Electrical Conductivity (dS/m)	Sulphur (%)
Nitrogen (%)	Calcium (%)	Zinc (mg/kg)
Nitrate Nitrogen (mg/kg)	Copper (mg/kg)	Molybdenum (mg/kg)
Ammonium Nitrogen (mg/kg)	Iron (mg/kg)	Manganese (mg/kg)
Organic Matter (%)	Boron (mg/kg)	
Potassium (%)	Magnesium (%)	

If there is concern about metals, these can also be analysed. The following metals and contaminants may be requested: Cadmium; Chromium; Arsenic; and Lead. Laboratories can also assess the level of weed seed contamination, pathogens and the degree of 'maturity' for composts. For further details contact your laboratory of choice.

Records

Records of the time, location, sampling procedure and analysis request information sent to the laboratory should all be kept with the manure analysis. Analyses collected over time will show if there are trends in the manure nutrient levels of interest.

References and Further Reading

McGahan, E., Wiedemann, S. G., & Gould, N. (2018) *Egg Industry Environmental Guidelines*, Edition II. Australia, Australian Eggs Limited.

ENVIRO FACT SHEET

Setting Application Rates for Layer Manure

Poultry layer manure (caged layer manure and barn litter) can be a valuable nutrient resource for pasture and crop production systems. However, it must be managed carefully to realise the most value and to prevent losses of nutrients to the environment where they can cause harm.

Nutrient budgeting is a way to account for nutrient movements at the paddock scale to maximise the efficiency of use. It is a tool to help to keep farming operations sustainable. By understanding the nutrient demands of a crop or pasture, an appropriate manure rate can be determined. This saves money and can improve long term performance. Nutrient budgeting can also reduce the risk of losing nutrients to the atmosphere, surface water and groundwater by matching application rates with plant demand.

Nutrient budgets firstly require the calculation of the total inputs of nutrients for the year, including estimates of nutrients added by manure or fertiliser. Secondly, the mass of nutrients likely to be used by the crop or pasture is determined. Nutrients that are not taken up by the crop are either held in the soil or removed from the system through leaching or gaseous losses.

Setting up a nutrient budget

Nutrient budgets require knowledge of:

- Nutrient levels in the soil
- Nutrient requirements (i.e. outputs – removal through plant harvest, export of livestock and losses to the environment).
- Nutrient inputs (i.e. manure, fertiliser)
- Maximum recommended soil nutrient levels

These items can be calculated on a per hectare basis for any area where the same basic management is occurring. A nutrient budget can be calculated using information from previous years to help make predictions for the coming season. The first step is to assess the level of nutrients in the soil.

What nutrients are in the soil?

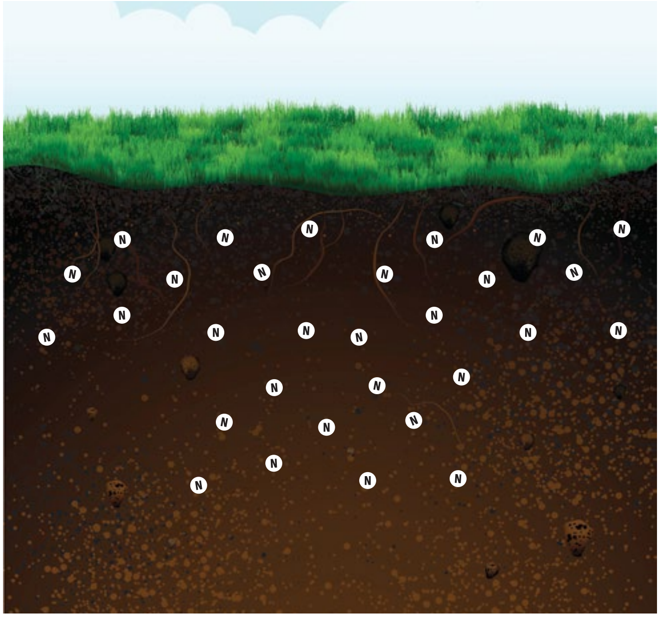
The nutrient status of the soil can be discovered by soil testing, and this is particularly important in paddocks with a history of fertiliser or manure application. Refer to the *Egg Industry Environmental Guidelines* (Edition II, McGahan et al., 2018) for information on soil sampling and testing recommendations.

Once a soil analysis has been done, there are two approaches to assessing soil nutrient levels: i) calculating the total quantity of nutrient per hectare of land, or ii) using 'standard' nutrient targets for different crops or pastures. Calculating nutrient quantities may require agronomic advice. However, standard nutrient targets are available from reference books for most crops and regions. It is important to realise that standard nutrient target levels are influenced by the specific soil properties on your farm such as the ability of the soil to bind phosphorus (P sorption). Some example phosphorus (P) levels for soils in manure use areas are given in *Table 1*. It shows low medium and high soil P levels relative to crop P demand. Examples of low, moderate and high crop P demand are pastures, grain crops, and vegetables respectively.

Table 1. Soil P levels relative to crop demand and sorption

Soil P status	Soil P sorption	Crop P demand		
		Low	Moderate	High
Low	Low	< 10	< 15	< 20
	Moderate to high	< 20	< 30	< 50
Medium	Low	10-30	15-45	20-60
	Moderate to high	20-60	30-90	50-150
High	Low	> 30	> 45	> 60
	Moderate to high	> 60	> 90	> 150

Adapted from Moody and Bolland 1999



Soil nitrogen levels are generally measured as nitrate (N). Ideal soil nitrate-N levels will depend on season, crop and soil interactions and are best determined by an agronomist. However, rough estimates can be made using standard target levels from a reference book such as *Interpreting Soil Test Results* (Hazelton and Murphy, 2007) from CSIRO. Nitrate is highly mobile and easily lost from the soil, reducing plant availability and potentially causing impacts to groundwater. Recommended soil Nitrate-N concentrations at the bottom of the root zone are shown in *Table 2*.

Table 2. Recommended maximum nitrate concentrations

Soil Texture	Moisture Content*	Nitrate concentration**
Sand	0.12	1.2
Sandy-loam	0.15	1.5
Loam	0.17	1.7
Clay-loam	0.20	2.0
Light Clay	0.25	2.5
Medium Clay	0.35	3.5
Self-Mulching Clay	0.45	4.5

Adapted from Skerman 2000

* Soil gravimetric moisture content at field capacity (g water/g soil)

** Limiting soil nitrate-nitrogen concentration (mg NO3N/kg soil)

Measuring total nitrogen can also be helpful on paddocks that have received manure, because this will give an idea of the total reserves of nitrogen that can mineralise from the soil, providing nitrogen for crop or pasture growth.

Outputs

Nutrient outputs can be used to estimate required annual fertiliser or manure application rates.

Once the major system inputs have been determined, similar calculations are needed for the main outputs. Main outputs may include hay, grain or livestock products (liveweight, milk or wool). For livestock, the nutrient content of live beef is approximately 2.4kg N, 0.7kg P and 0.18kg K / 100kg live weight. For milk production, 1000L of milk will remove about 5kg N, 1kg of P and 1.5kg of K. Grazing properties export relatively small amounts of nutrients in the livestock. For example, selling 100 beef steers weighing 500 kg/head in liveweight gain, exports about 1,200kg N, 350kg P and 90kg K per year. Crops generally remove much larger amounts of nutrient per hectare than livestock as shown in *Table 3*.

Table 3. Yield and nutrient off-take with some crops

Crop	Yield (t/ha)	N (kg/ha/yr)	P (kg/ha/yr)
Dryland pasture hay	1-4	20–80	3–12
Irrigated pasture hay	8-20	160–400	24–60
Lucerne hay	5-15	150–450	15–45
Dry land winter cereal (grain only)	2-4	40–80	6–20
Dry land winter cereal (grain + straw)	2-4 grain (+2-5 t straw)	59–239	9–20
Grain sorghum	2-8	40–160	6–24
Forage sorghum	10-20	200–400	30–60

Adapted from Reuter and Robinson 1997

Inputs – fertiliser and manure

Once nutrient availability in the soil, and the nutrient requirement of the crop are known, the required fertiliser or manure inputs can be calculated.

Fertiliser nutrient inputs are calculated by multiplying the application rate (kg/ha) by the nutrient content to give a mass of nutrient applied per hectare. For example, the amount of phosphorus applied with single superphosphate (9% P) applied at 125kg/ha to grazing land is calculated as follows:

125 x 0.09 = 11kg/ha of P.

The standard analysis for fertiliser is printed on the bag or is readily available from the manufacturer.

For manure inputs, a similar calculation is needed to estimate the amount of nutrient per tonne of manure 'as spread', but the key difference is that moisture content must be taken into account. The first step is to obtain an analysis for the manure from a laboratory or to use standard analysis data (refer to the fact sheet; "Composition of Layer Manure.").

Manure analysis results are generally provided on a 'dry basis (db)', however all manure contains moisture at the time of spreading. This moisture acts to dilute the nutrient concentration in each tonne of manure. To calculate the amount of phosphorus in a tonne of layer manure with a dry matter content of 70% (or a moisture content of 30%) and a total phosphorus content of 2.3%, use the following process:

1,000 kg x 0.7 (70% dry matter)
= 700 kg dry matter.
700 kg x 2.3% db
(average phosphorus content in layer manure)
= 16.1 kg P/tonne.

This same process can be applied to other nutrients in layer manure.

Nutrient availability

When using manure, not all of the nutrient contained is immediately available to the plant an this must be taken into account when setting application rates. Plant nutrient uptake occurs when nutrients are present in an inorganic form. Some nutrients need to be converted from the organic to the inorganic form by microorganism decomposition before they become available for plant uptake. Of the macro nutrients available in layer manure, nitrogen and phosphorus can vary widely in nutrient availability, while potassium is stable and highly available from the time of application.

Generally, about 10–25% of the nitrogen in fresh layer manure is present in the ammonium form, while the remainder is in a slower release, organic form. This nitrogen rapidly becomes available to the plant after application, but it is also easily lost to the atmosphere. Losses are highest where manure is applied to the surface and allowed to dry out.

The remaining nitrogen is contained in an organic form and will mineralise over time, releasing nitrogen for plant growth. Between 30–80% of the total nitrogen is likely to become available in the first year. However, the mineralisation rate depends upon a number of factors including soil health, temperature and moisture. See the fact sheet in this series called 'Spreading Layer Manure', for more information.

Immediately available phosphorus may be around 20% in layer manure, and up to 60% may be available in the first year. The availability of phosphorus depends on soil characteristics such as (buffering capacity) and the mineralisation and demineralisation of P by soil microbes. Phosphorus will be more easily accessed by plants where manure is incorporated, but this is not essential.

The nutrient balance

Once soil nutrient levels, outputs and inputs have been calculated, the overall nutrient budget is:

Final soil nutrients = initial soil nutrients + inputs - outputs.

The result will show if more or less nutrient inputs are required to balance the equation. Where the final soil nutrient level is higher than the initial level, nutrients will be stored in the soil or lost to the environment. Losses should be avoided wherever possible, as these are both a financial cost and a risk to the environment. In particular, nitrogen and phosphorus are harmful to water and in some cases air quality, and need to be minimised by balancing the nutrient budget as much as possible without compromising yields. Nutrient budgets are a useful tool for managing fertiliser and manure applications, providing greater efficiency within the system, saving money and helping to protect the environment, giving a win-win situation.

References and Further Reading

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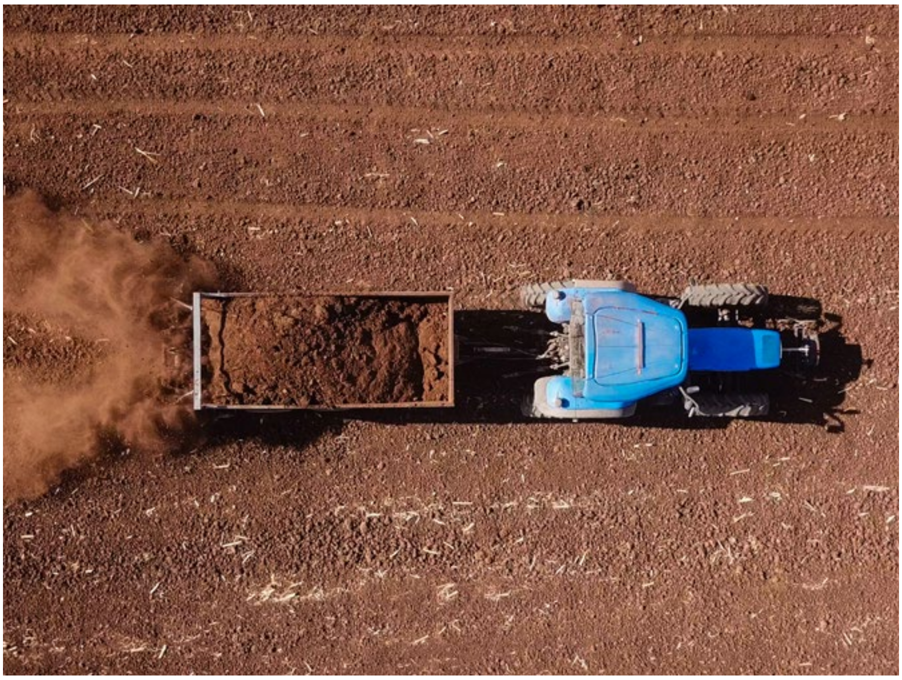
ENVIRO FACT SHEET

Spreading Layer Manure

Layer manure (caged layer manure and barn litter) is a highly valuable nutrient source and soil conditioner when spread at suitable rates. However, good spreading techniques are needed to realise the potential value of this resource. Spreading needs to occur at the optimal time to maximise nutrient availability and minimise potential adverse soil impacts like compaction. Using the right equipment and information, simplifies management and improves production.



Spreading Rates

A nutrient budgeting process is the best way to find the optimal long-term manure spreading rate (see the 'Layer manure – setting application rates' fact sheet in this series). Once the target spreading rate is known, the spreader needs to be calibrated to ensure the manure is applied at the correct rate evenly across the paddock. One way to check spreader calibration is provided in the following example.

Example: Measuring Your Spreading Rate

1. Take a strip of builder's plastic or tarpaulin (ideally 10m x 2m) and lay it down in path of the spreader.
2. Run the spreader over the drop sheet at the correct operating speed.
3. Weigh manure from 1 x 1m squares at several points across the width of the spreading pattern.
4. Take the mass of manure weighed (kg/m^2 and multiply by 10,000 to convert to kg/ha).
5. Divide the result by 1000 to get tonnes (t) per ha.

This process can be repeated for several passes to check the average spreading distribution and width.

Distribution

Poor distribution of manure by spreaders can cause uneven application and irregular plant growth. Distribution can be affected by manure consistency, the type of spreader and the operator. Generally, manure with a moisture content of 25–30% will spread best. Dust can be a problem from dry manure (<15%). However, if the moisture content exceeds about 35%, bridging will be a problem in many spreader designs. For most spreaders, an application rate of at least 2t/ha is needed to achieve an even spread. For some spreaders, higher application rates may be needed to achieve good performance. Operator efficiency may also strongly influence manure distribution.

Some spreaders alter the application rate with the forward speed of travel, which can also cause variability in application where operators are not adequately trained.

Compaction

Compaction is caused by the movement of large implements/vehicles/machinery across paddocks. Compaction is most likely to occur when soils with a moisture content close to field capacity are subjected to heavy loads (via machinery etc.). Ideally, spreading would occur when the soil is quite dry. Compaction of crop land can be reduced by setting up the spreader to run on controlled traffic lines. Spreading manure on a three to five year rotation and supplementing with inorganic fertiliser as required also reduces the compaction risk and saves money by reducing the application frequency.

Timing

The optimal timing of manure applications depends upon multiple factors. These include:

- crop or pasture nutrient requirements,
- field conditions (soil moisture),
- wind conditions, and
- timing of other management events (i.e. cultivation and sowing).

The application of layer manure 2–6 weeks before sowing (or peak pasture demand) is recommended to allow time for nutrients to mineralise from the organic matter in the manure. If the manure has been correctly composted, the timing of application is less critical, and the risk of nutrient drawdown is minimal. Ideally, manure spreading should occur when the risk of compaction is minimised.

Social and Environmental Considerations

Manure spreading can disperse dust and odour over considerable distances. If manure is spread close to neighbours or other sensitive areas, this should occur when the wind speed is low and ideally on weekdays. Consulting with neighbours about the best time to spread manure may reduce nuisance and help avoid complaints. Odour releases can be reduced by incorporating manure soon after spreading or by irrigating after spreading.

The risk of environmental harm must be considered before spreading manure. Manure should only be spread on the intended area.

Do not spread manure and spent litter near watercourses and drainage lines, or on steep slopes where erosion losses may occur. The planting of appropriate vegetative filter strips and trees can also be useful in intercepting nutrients, dusts and other particles. While a small amount of rain following application can be useful, spreading when heavy rain is forecast is not recommended.

Refer to the *Egg Industry Environmental Guidelines* (Edition II, McGahan et al., 2018) for more information on risk factors associated with nutrient loss to surface and groundwater.

Food Safety and Biosecurity

Allow a minimum of three weeks between application of manure and spent litter before grazing. Relevant state biosecurity regulations may specify longer times.

Where applying manure to horticultural crops greater controls are required. Only apply properly composted manure or treated proprietary organic products that contain less than 100 E. coli per gram, as side dressing.

Refer to *The Freshcare Code of Practice –Food Safety and Quality* (Freshcare, 2016) and the *Australian Guidelines for On-farm Food Safety and Fresh Produce* (DAFF, 2004) for information regarding the application of organic manures to vegetable crops.

Maximise the time between application and crop harvest. Do not apply untreated animal manure where direct or indirect contact may occur with the edible part of the crop. Do not apply manure and spent litter to the foliage of crops to be consumed by humans. Refer to state biosecurity and biosolids application guidelines to determine appropriate by-product utilisation practices. Visit www.biosolids.com.au/guidelines for links to relevant state guidelines.

Options for Spreading Manure

There are many options for getting manure spread, including: engaging a contractor, purchasing a spreader with others in a farmer group or purchasing a spreader for your own use. Contractors may operate on an hourly rate or a 'tonnes spread' basis. Rates quoted by contractors range from $12t to $20/t (2018), depending on the distance of transport from stockpile to spreading area and other conditions. As spreaders are used infrequently, they are a good item for a farmer group to purchase and share, reducing the capital cost for each owner. There are several factors to consider when selecting a spreader to buy. Most important are the type, moisture level, and amount of manure which will be spread. Some design features to be considered include:

- **Spreading pattern and width:** To ensure an even spreading pattern and application rate are achieved.
- **Vertically vs horizontally mounted beaters:** Vertically mounted beaters generally spread over a larger area with each pass, throwing manure beyond the width of the spreader. Whereas horizontal beaters usually only spread about the width of the spreader.

- **Spinners:** Generally provide a wider and more accurate spreading pattern than beaters alone.
- **Floor width:** The maximum moisture content of manure that can be spread without bridging depends upon the floor width and the width of the rear door of the spreader. Generally, the belt driven machines cannot spread manure with a moisture content exceeding 40%.
- **Conveyor belt vs moving floor chains:** These can be either hydraulic or PTO driven. Conveyor belts may need to be replaced more often as the belt wears more easily than chains.
- **Rotation speed:** The rotation speed of the beaters affects the width of spread and application rate.
- **Size:** Spreaders vary greatly in size, from 1t capacity to over 20t capacity. The smaller capacity spreaders (1–2t) are unsuitable for spreading large amounts of manure because of the time spent loading and travelling. Larger capacity trailing units are probably the best option for on-farm use. Trailing units vary in size from less than 5t to over 20t capacity. Dual purpose units can be used for spreading other products such as lime and fertilisers, which may offset the cost, however these require a more consistent manure with lower moisture levels.
- **Price:** The size of a spreader generally determines the price. As a guide, prices for some trailing (tow behind) spreaders in 2018 are:
    - 1–4m^3 – $10,000–$15,000
    - 10–16m^3 – $50,000–$65,000

Spreaders can also be truck mounted, pricing varies depending on the truck type and fitting costs.

References and Further Reading

DAFF (2004) *Guidelines for On-Farm Food Safety for Fresh Produce*. Canberra: Commonwealth of Australia.

Freshcare (2004) *Freshcare Code of Practice - On-farm Food Safety Program for Fresh Produce*, 2nd Edition edition. Sydney: Freshcare Ltd.

McGahan, E., Wiedemann, S. G., & Gould, N. (2018) *Egg Industry Environmental Guidelines*, Edition II. Australia, Australian Eggs Limited.

ENVIRO FACT SHEET

Storing Layer Manure On-Farm

Providing a storage area for manure improves management flexibility and allows manure supply to be matched to demand. Shed cleaning operations are generally timed to fit in with other operations. This can produce large quantities of manure at times when demand for reuse is low. This may contribute to low prices for manure sold off site, or the need for some form of on-site storage. Having a properly designed and constructed storage facility can improve manure handling and sale prices by holding the product until demand is higher.

Manure Management & Storage

Storing manure can cause odour nuisance and water contamination by nutrients unless the appropriate storage design and management is put in place, taking into account site constraints. Appropriate control measures and design principles should be based on the level of risk at each site. Refer to the Egg Industry Environmental Guidelines (Edition II – McGahan et al., 2018) for more information on determining risk factors for nutrient loss to surface and groundwater.

High moisture manure is often associated with increased odour emissions because it promotes anaerobic breakdown. Storing manure in windrows and turning at least once is likely to reduce the moisture level of the manure and promote low odour aerobic decomposition and partial composting. For covered storages, ventilation may be required to manage odour production.

Storage Systems

Different types of manure storage areas suit different production systems and locations. If the facility is located in a rural area, windrow or stockpile storage may be an option. However, if the farm is in a more densely populated area, a covered storage is likely to be more appropriate, in order to reduce potential odour impacts.

Stockpile or windrow storage

Manure can be safely stored in a stockpile or windrow for an extended period if the site has been carefully selected and constructed. On sites with a high risk of impacts to groundwater, stockpiling manure should be undertaken on a formed pad. A well prepared pad surface provides two advantages. Firstly, it ensures the pad is trafficable in all weather conditions and secondly, it minimises leaching of water from the manure to groundwater. Materials that can be used to form an impermeable pad, include:

- concrete/paving,
- cement stabilised earth, and
- compacted earth.

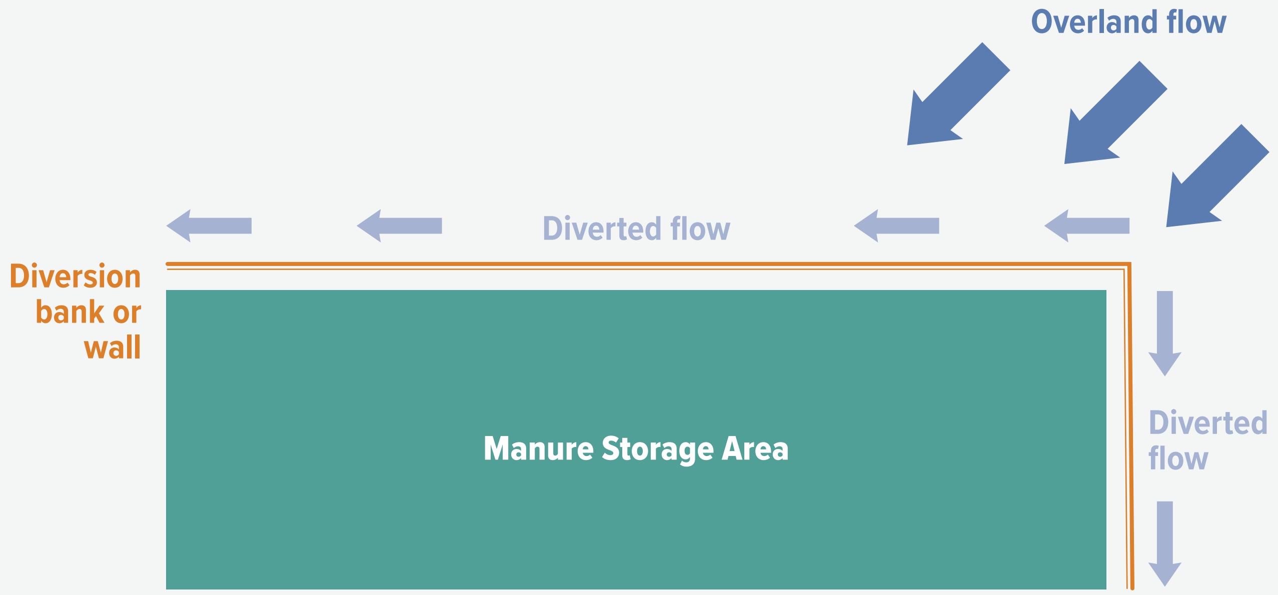


Figure 1. Bunding of storage areas

Runoff control

Site design and layout measures should be responsive to the level of risk for the site. For instance, where there is only a small amount of runoff from the storage area, a Vegetative Filter Strip (VFS) may be adequate. However, local council and state environmental regulations will need to be observed where applicable.

Ponds and dams should be avoided on layer farms where possible due to biosecurity concerns associated with attracting waterfowl. However, If the storage area is not roofed, installation of a dam may be required to catch runoff from outdoor manure and spent litter compost or stockpile sites and this can be managed by locating it at a distance from the sheds.

Design the dam to hold a 1 in 10 year, 24-hour storm event. Dams should not be located near sheds to minimise biosecurity risk. For localities with winter dominant rain, a monthly water balance calculation should be undertaken to ensure overflows are infrequent.

Sediment trap

A heavy storm may carry sediment from the stockpile to the holding pond. A simple sediment trap can collect the solids before they enter the holding pond, reducing the solids and nutrient loading of the pond.

Disposal of retained runoff

The contaminated runoff collected in holding ponds can either be evaporated or irrigated onto pasture / suitable crop. Careful analysis should be undertaken to ensure that evaporation ponds are able to store sufficient runoff to cope with prolonged wet periods. Where effluent is irrigated, both long-term water and nutrient balances should be undertaken for the reuse areas.

Storage Sheds

Storage sheds are useful where there is no option for an outside stockpile. While construction of storage shed is more expensive, the improved flexibility in manure handling may offset this cost. Sheds offer greater certainty regarding control and management of potential odour impacts and ensure that manure is separated from causes of runoff and leaching to groundwater. Covered storages also reduce the problems of unsightly manure stockpiles, and the potential for fly breeding nuisance. The storage needs to be sized to contain the required amount of manure storage and to provide adequate room for machinery to operate inside.

Sizing

The required size of a manure storage area is a major determinant of the construction costs. It depends primarily on manure production and the period of storage required. For example, if manure needs to be stored for six months to coincide with cropping cycles, the storage facility needs to be large enough to hold the manure production for this six-month period before space will become limiting again. For caged layer systems, fresh manure production is approximately 80 m^3 / 1000 birds / yr based on a moisture content of 55% and a density of 450 kg/m^3.

For litter based systems this figure is closer to 50 m^3 / 1000 birds / yr, due to decomposition in the shed. This assumes one third litter floor and two thirds slatted floor, with manure and litter removed at 40% moisture and a density of 400kg m^3. These numbers may vary with different systems but can be used as a guide to calculate the required manure storage size.

As a rough guide, a small windrow with 45° slide slope, 1.8m wide, 0.9m in height, and 100m long would contain approximately 80m^3 of manure. A large windrow with 45° slide slope, 3.6m wide, 1.8m high, and 100m long would contain approximately 320m^3 of manure. A large flat-topped stockpile of 10m radius and 5m in height, with 45° slide slope may contain around 900m^3 of manure.

Buffer Distances

Adequate buffer distances should be provided between the operations of the enterprise (including manure/spent litter utilisation areas and free-range areas) and any nearby groundwater and surface waters. Buffer distances aim to reduce the risk of nutrient impacts on surface and ground water, as well as biosecurity impacts to water storages. These distances allow greater opportunity for potential contaminants to be deposited or adsorbed.

Regulations

Manure storage may require a licence approval depending on the amount of manure that is being stored, and this will vary from state to state. Approval may need to be gained from both the local council and state environmental regulators. Storage may provide a way to improve manure management and boost sale prices and can be done in a variety of ways to suit each enterprise while maintaining the surrounding environment.

References and Further Reading

McGahan, E., Wiedemann, S. G., & Gould, N. (2018) *Egg Industry Environmental Guidelines*, Edition II. Australia, Australian Eggs Limited

ENVIRO FACT SHEET

Subjective On-Farm Monitoring

Subjective monitoring is one way of measuring the impact of your farm on neighbours and other nearby sensitive land uses. This can help to avoid complaints and demonstrate social responsibility within the local community.

Attempt to resolve disputes by participating and cooperating in any dispute resolution mechanisms available. Gather relevant evidence and identify and implement strategies to remedy the problem, then contact the complainants to inform them of the outcome of any investigations and any actions taken to avoid future associated problems.

The main method for measuring the community amenity impact is the number of complaints received. While this is an imperfect measure (i.e. some people won't complain when there is a problem and others will complain when there is no problem) it does aid in identifying when neighbours perceive that a farm is having an unreasonable impact on their enjoyment of life.

Record full details of any known complaints received, along with the results of investigations and corrective actions taken in a "Community Feedback/ Complaint Register" (included in this factsheet). For more details see the *Egg Industry Environmental Guidelines* (Edition II – McGahan et al., 2018). Also consider examining complaint data to identify trends in complaints received such as the time, date, weather and on-farm activities.

Monitoring should focus on the main causes of off-farm amenity impacts such as odour, dust, noise and light. These should be performed at potential high impact times (manure and spent litter clean-out, shed cleaning or manure/spent litter application) at the most sensitive land uses (e.g. near neighbours). Regular subjective monitoring can also help to identify the effects of changes in management practices on amenity impacts. Examples of blank monitoring forms are included in this fact sheet.

Odour Intensity Assessments

Odour intensity is best assessed at a series of designated assessment points around the property boundaries. A designated staff member responsible for monitoring environmental impacts should regularly undertake odour assessments (i.e. every three months). The assessments need to occur when odour is most likely to create a nuisance. The assessments can be undertaken using the German Standard VDI 3940: Determination of Odorants in Ambient Air by Field Inspection as a guide. The VDI scale and procedure are provided in the odour monitoring record included in this fact sheet.

To ensure accuracy in assessments it is important that the assessor is not desensitised to odours. Hence, the assessments can only occur if the assessor has not been in or around the sheds for at least three hours. During the assessment, record the following in the odour monitoring record:

- The number of fans operating (if mechanically ventilated).
- The number of hens on farm.
- Prevailing weather conditions, including wind direction, estimated wind speed and shade temperature.

This data forms the basis of the monitoring program to be maintained over time.

Dust Assessments

Dust intensity should also be measured at designated assessment points, following a regular monitoring program (i.e. every three months). Dust levels are assessed by visual criteria. A designated person should always undertake dust intensity evaluations to ensure a consistent approach. Dust assessments need to occur at the most likely time of peak dust emissions, such as when traffic volumes are high. During the assessment, the following data need to be recorded in the dust monitoring record (included with this fact sheet):

- The number of fans operating (if mechanically ventilated).
- Prevailing weather conditions, including wind direction, estimated wind speed and shade temperature.
- Vehicle movements (i.e. number/hr).

Similar but more frequent assessments and recordings should be made during prolonged dry periods or after a complaint, when the wind speed is moderate to strong and the wind is blowing from the poultry sheds towards the dust monitoring point. The results of the visual assessments should be kept in the dust monitoring record.

Noise Level Assessments

Noise levels should also be measured at designated assessment points following a regular monitoring program (i.e. every three months). These assessments should be carried out by a designated staff member. The assessments are to occur:

- After 6:30pm.
- When the wind is light to moderate.
- During a period of high activity, such as the loading of eggs, manure or spent hens.

The assessment characteristics must be recorded in the noise assessment record (included in this factsheet). The designated monitoring staff member should also monitor the level of rattling noises from storage silos, augers, fans and feeder lines at a set interval (i.e. every three months).

Light Intensity Assessments

Light intensity is less likely to change over time than odour and dust. However it is suggested that a designated staff member should undertake periodic field assessments of light impacts at designated light monitoring points. This is to confirm that farm external lighting levels remain acceptably low and that vehicle lights do not cause light related nuisance. The assessment can be recorded in the light monitoring record included in this fact sheet. Increased monitoring will be needed if there is a significant change in the potential light impact (e.g. loss of vegetative screens, modification to lighting at the facility).

Summary

Regularly monitoring potential sources of nuisance and recording the findings of these assessments provides information to assess changes in the level of impact over time. If increases in impacts can be linked to particular management practices then ways of minimising impacts on receptors can be investigated and implemented before problems arise.

References and Further Reading

McGahan, E., Wiedemann, S. G. & Gould, N. (2018) *Egg Industry Environmental Guidelines*, Edition II. Australia, Australian Eggs Limited.

Queensland Government (2008) *Environmental Protection (Noise) Policy 1997.* Brisbane, Australia: Queensland Government.

VDI-RICHTLINIEN (1993) *Determination of Odourants in Ambient Air by Field Inspections*. Dusseldorf: Kommission Reinhaltung der Luft im VDI and DIN.

Community Feedback/ Complaint Register

Community Feedback/Complaint Register	
Date	
Time	
Details	
Distance and direction to complainant	
Name of person advising of complaint	
Method of delivery of complaint	
Name of complainant	
Complainant contact details	

Investigation Details						
Temperature at time of complaint (select)	Cold	Cool	Mild	Warm	Hot	Very hot
Wind strength at time of complaint (select)	Calm	Light	Moderate	Fresh	Strong	Gale
Wind direction at time of complaint						
Person responsible for investigating complaint						
Investigation method						
Findings of investigation						

Action Taken	
Corrective actions	
Communications with complainant	

Noise Assessment Record

Name	Date & Time	Noise Monitoring Points (Level of Noise Nuisance)		
		MP1	MP2	MP3

Noise Monitoring Points (Level of Noise Nuisance)

0 Not audible

1 No annoyance

2 Very little annoyance

3 Some annoyance

4 Annoying

5 Quite annoying

6 Very annoying

7 Extremely annoying

A Sound pressure level

B Its duration

C The rate at which it happens

D It audibility

E Whether it is continuous at a stead level or whether it has a fluctuating, intermittent, tonal or pulsing nature.

F Whether it has vibration components

NOTE: Characteristics as described in Part 1 of the Environmental Protection (Noise) Policy (Queensland Government, 2008)

Odour Monitoring Record

STEP 1: Using the German VDI 3882 (VDI-RICHTLINIEN, 1993) odour intensity scale (shown in the Table to the right), record odour intensity every 30 seconds over a 10 minute period.

STEP 2: Enter the highest intensity level experienced during the 10-minute period into the record below.

STEP 3: When an odour intensity of A-D is experienced, corrective action is required.

Odour intensity	Intensity level
Extremely strong	**A**
Very strong	**B**
Strong	**C**
Distinct	**D**
Weak	**E**
Very weak	**F**
Not perceptive	**G**

Name				
Date				
Time				
Wind direction				
Wind strength				
Any farm details (No. hens, No. fans operating)				
Ambient Temperature				
Odour Monitoring Point (Intensity Scale)	**MP1**			
	MP2			
	MP3			

Dust Monitoring Record

Name				
Date & Time				
Wind direction				
Wind strength				
Any farm details (No. fans operating, Vehicle movements/hr)				
Ambient Temperature				
Dust Monitoring Point (Dust levels)	MP1			
	MP2			
	MP3			

Light Monitoring Record

Monitoring point		MP1	MP2	MP3			
Name							
Date & Time							
Light source visible (yes/no)							
Strength of visible light and details	Weak						
	Moderate						
	Strong						