New Zealand PORK

GOOD PRACTICE GUIDE

Nutrient Management in Pork Production

Funding support for this project gratefully received from

Ministry for Primary Industries
Manatū Ahu Matua

3rd Edition revised November 2017

Table of Contents

Foreword

A key role of NZPork is to provide farmers with the information and tools that address the long-term environmental sustainability of pigs and pig farming in New Zealand. This is a continuing focus of the industry to meet consumer and stakeholder expectations. Nutrient management has become a key focus for many Regional Councils as they work to address water quality issues in their region.

Many thanks to the Ministry of Primary Industries (MPI) Sustainable Farming Fund for their support and funding of the project titled 'Good Practice Nutrient Management for Pig farms' which resulted in the first edition of this guide. This included valued contribution from farmers, Massey University, Regional Council staff and NZPork.

This updated edition of the guide includes the topics of:

- Nutrient make up and volumes of manure
- The highly variable make up of manure
- On farm handling practices
- Land application of nutrients
- Accurately measuring land application of nutrients
- Tools available to develop nutrient budgets

This guide provides an excellent introduction to the issues associated with manure handling and nutrient management and I recommend it to all farmers.

Sonya Matthews
General Manager
New Zealand Pork
November 2017

Background

This booklet is designed to provide pork producers guidelines for good management practice for handling nutrients produced in their operations. Knowledge about the amount of manure and plant nutrients is the first step in the proper operation and handling and management of nutrients produced from a pig farm. The nutrient and volatile solids content of piggery manure will vary depending on the make-up and digestibility of feed, age of pigs, amount of feed wastage and the amount of water used to flush and wash the manure from the pig facilities. Pork producers need to be aware of their responsibilities when applying nutrients to land and ensure the manure from their farms does not pose an environmental risk to ground or surface water quality.

This document was updated in 2017 to be consistent with the guidance given in the NZPork: Pork Industry Guide to Environmental Management (formerly called EnviroPork) and the and the Industry agreed- Good Management Practices for outdoor pigs. NZPork has developed an effluent management plan template for both liquid effluent and solid manure management. These publications are available on the Environmental Management pages at the NZPork Corporate website (www.nzpork.co.nz).

Edition 1: March 2014
Edition 2: February 2017
Edition 3: November 2017

Introduction

Pork production is a process utilising a number of resources to produce a valuable protein food. During this process by-products are produced - primarily dung and urine, which once removed from the pig is called effluent. Pig effluent can include faeces, urine, cleaning water, rainwater, soil, bedding, waste feed and spilt drinking water. It typically contains concentrations of organic matter and macro- nutrients such as nitrogen (N), potassium (K), phosphorus (P), salts, microorganisms and various trace elements. The production of these by-products can have both positive and negative environmental consequences; the actual effect is dependent on the choices the farmer makes.

The impact of an individual farm on the environment depends on pig numbers and concentration, weather, soil type, and waste management strategies. Pig effluent is a valuable source of nutrients, and when managed well can improve pasture and crop production at the same time reducing fertiliser costs.

The production of these nutrients can lead to land and water quality management issues for piggeries. The main issues affecting water quality are nitrogen, sediment, phosphorus and pathogens.

Good practice guidelines developed for pig farms must help preserve and enhance productive soils, while maintaining water quality and preventing other negative impacts on the environment.

Nutrient volumes added to the pig farm in the form of feed and bedding are not matched by the removal of nutrients in the form of pig meat and gaseous losses via volatilisation. The balance of the nutrients remains as manure, mortalities and spent bedding, and need to be applied to land to meet grass or crop demand. Nutrient applied excess to plant requirements has the potential to move through the soil as leaching, or across the soil as runoff or via windblown dust.

Negative environmental impacts can occur from:

- Nitrogen – mainly by leaching to ground water
- Phosphorus and sediment by surface runoff to water ways
- Pathogens by surface runoff to water ways

Regulatory requirements

The Resource Management Act (RMA) is New Zealand's principal legislation for environmental management. This Act of Parliament promotes the sustainable management of natural and physical resources such as land air and water.

The summary points below highlight the sections of the RMA that can affect pig farmers.

Section 9 of the RMA- Restrictions of the use of land

This section states that no person may use land in a way that contravenes a national environmental standard (NES), regional rule or district rule unless it is expressly allowed by resource consent. If there are no NES, regional rules or district rules relating to a particular use of land, that activity can be carried out as of right.

Uses of land that District and Regional Councils may have rules that include:

- Use of land for an indoor/ outdoor piggery

- Use of land for storing or stockpiling liquid, slurry or solid effluent
- Use of land for spreading liquid, slurry or solid effluent
- Use of land for farming

Section 14 of the RMA -Restrictions relating to water

This section states that groundwater and surface water cannot be taken or used unless it is expressly authorised by a rule in a regional plan (i.e. permitted activity), or a resource consent or the water is for the reasonable needs of an individual's animals for drinking water and that take does not have or is unlikely to have an adverse effect on the environment.

- If you are not on a reticulated council water supply and are taking water for stockwater, piggery washdown or irrigation you need to check whether your take will comply with the relevant Regional Rule or whether consent is needed.

Section 15 of the RMA- Discharge of contaminants into environment

Section 15 (1b) requires that any discharge of a contaminant onto or into land that may result in that contaminant entering water cannot occur, unless it is expressly allowed by a NES or a proposed or operative regional rule or resource consent. Discharges to land that Regional Councils may have rules include:

- Discharges to land of liquid, slurry of solid effluent and spent bedding
- Discharges of fertiliser to land

Section 15(2A) states that no person may discharge a contaminant into the air, or into or onto land in a manner that contravenes a regional rule unless the discharge is expressly allowed by a NES or other regulations, resource consent or is allowed as an existing lawful activity under s20A. Discharges to air that Regional Councils may have rules for include:

- Discharges to air from the piggery buildings/ sheds
- Discharges to air from the spreading of liquid/ slurry/ solid effluent/ spent bedding
- Discharges to air from outdoor pigs

Pig effluent make-up

How do we manage the nutrients on farm? There is an old adage that states 'before we can manage anything, we must be able to measure it'.

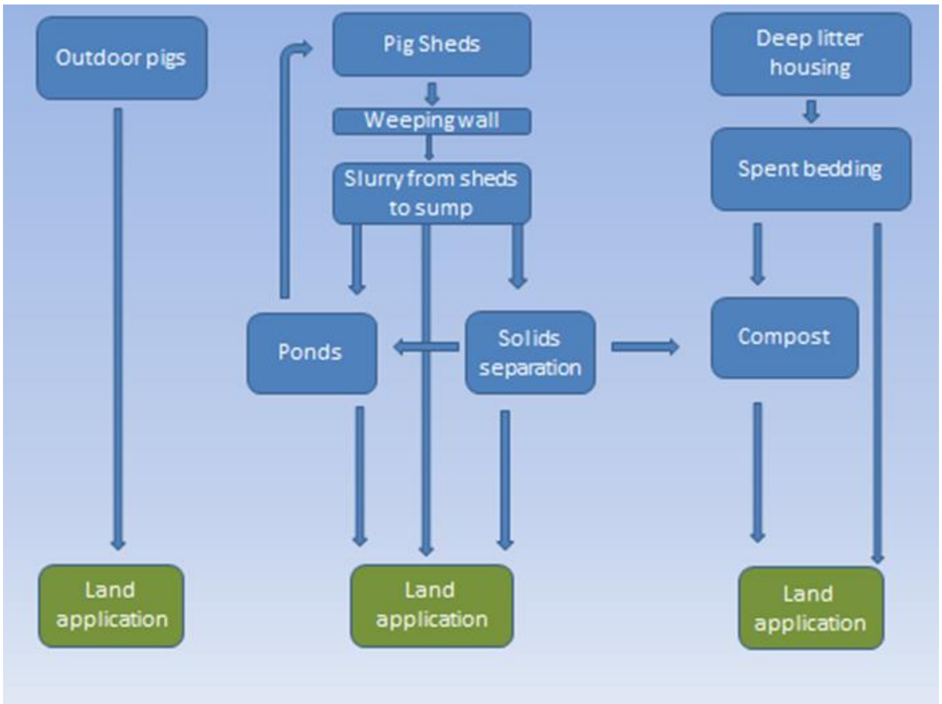
The maximum and average volumes of raw effluent produced per farm each day, as well as the composition (nutrient content) of the raw effluent prior to further treatment; can be determined using published data. However, the composition and volume will vary from farm to farm and from day to day on any particular farm. The volumes produced are dependent on age and structure of the herd, diets, and production practices. Nutrient losses also occur with handling and a number of other processes that the material undergoes before final discharge, usually to land.

Processes can include:

- Storage in pits under shed in 'pull plug' system and flushed to sumps, then irrigated direct to land or discharged to anaerobic/aerobic ponds, sometimes via a solids separation unit.
- Flushing direct to sumps and irrigation to land
- Flushing direct to anaerobic/aerobic ponds
- Flushing through a solids separation unit and discharge to ponds or irrigation to land
- Material scraped 'dry' and slurry spread to land

- Deep litter systems where 'spent' bedding is spread direct to land or composted in piles and then spread to land or on sold
- Separated solids may be spread direct to land, or stored and composted and then spread to land or on sold
- Outdoor pigs direct discharge to land

Figure 1: Schematic of effluent management processes



Whatever system or combination of systems are used, they should be designed to collect all the effluent with sufficient storage capacity and at the same time minimise the volume of effluent by reducing spillage and leakage from drinkers, diverting storm water, minimising cleaning and flushing volumes and recycling flush down water. Check with your Regional and District Council as to rules and setbacks for sumps and manure storage areas.

The table below will provide pig producers with published information on nutrients produced on farm.

Table 1: Predicted solids and nutrient output for each class of pig (kg/hd/yr)

Pig Class	Total solids	Volatile solids	Ash	Nitrogen	Phosphorus	Potassium
Gilts	197	162	35	12.0	4.6	4.0
Boars	186	151	35	15.0	5.3	3.8
Gestating Sows	186	151	35	13.9	5.2	3.7
Lactating Sows	310	215	95	27.1	8.8	9.8
Suckers	11.2	11.0	0.2	2.3	0.4	0.1
Sow and Litter	422	325	97	50.0	13.0	11.0
Weaner pigs	54	47	7	3.9	1.1	1.1
Grower pigs	108	90	18	9.2	3.0	2.4
Finisher pigs	181	149	32	15.8	5.1	4.1

Source:(Tucker et al.,2010)

Remember:

- The manure is a variable product.
- The nutrient content of the product that is applied to land is affected by the solids content, handling processes and the length of time the product is stored.
- It is important to regularly analyse the product at the point it is being applied to land.
- Check with your Regional Council about the nitrogen loading rate.

Nutrient budgets

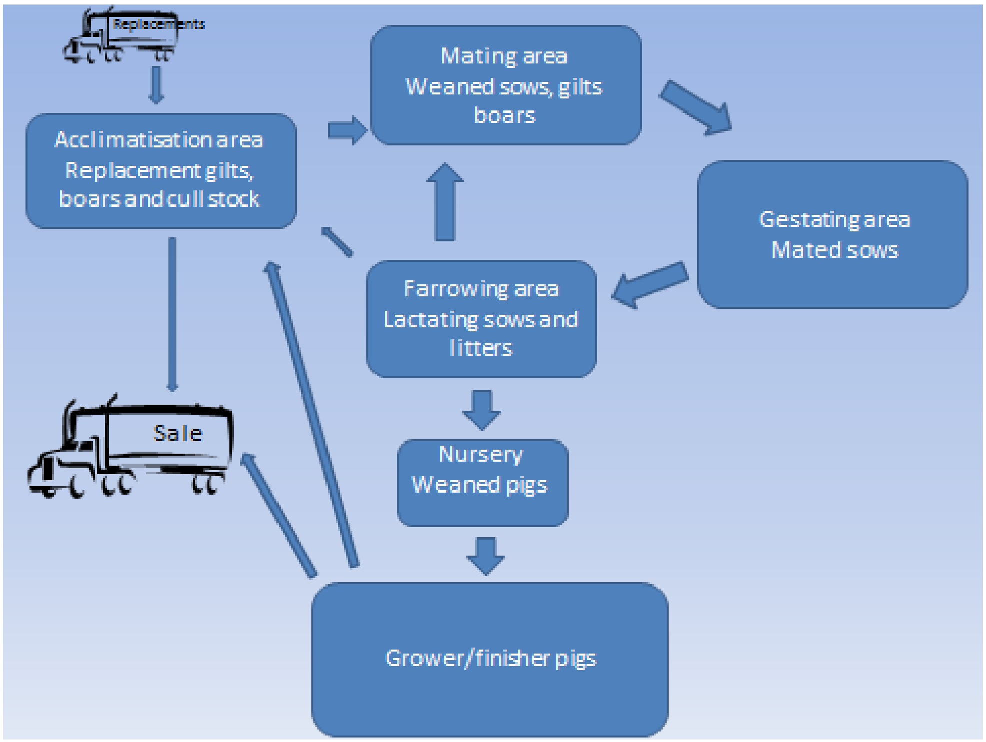
With most manure or the end products of various processes and treatments being applied to land, it is important that the nutrients are applied in a sustainable manner. Nutrient budgets are a tool to assist in balancing and matching nutrients applied to the soil to meet plant and soil requirements. A commonly used nutrient budget is OVERSEER which is a software application (see www.overseer.org.nz). OVERSEER is a farm management nutrient budgeting model, able to assist with fertiliser and lime recommendations for a number of farming systems. OVERSEER is a model that provides estimates of the rates of the nutrients Nitrogen (N), Phosphorus (P), Potassium (K), Sulphur (S), Calcium (Ca), Magnesium (Mg), Sodium (Na) as well as acidity for pastoral blocks. OVERSEER provides estimates of nutrient inputs and outputs on a per hectare basis. At present there has been a separate module for outdoor pigs developed and will be integrated with the main

OVERSEER tool in late 2017. Indoor piggeries can use the main OVERSEER tool for application of nutrients to land.

Types of pig farming systems

A wide range of farming and housing systems are used to raise pigs. Breeding units carry breeding sows, their replacements and boars. The management of the breeding unit is on a regular weekly flow or batch system where at any time there will be gestating sows, sows about to be mated, boars, replacement gilts, and lactating sows and litters on hand. Pigs weaned (known as weaners) from the breeder unit can move to a weaner/nursery facility on the same site or be sold or transferred to another farm. They remain in the nursery for up to 6 weeks and are then transferred to a grower/finisher facility where they are grown until point of sale at about 20 weeks of age. At each stage the housing, feed, environmental and husbandry needs are different, and this will determine the type of accommodation.

Figure 2: Schematic layout of a pig farm structure and pig flow



Types of housing systems

There are different housing systems, with different systems used for manure collection, storage and treatment, and they all should be designed to minimise environmental impacts.

Indoor housing can consist of different styles of buildings, constructed from timber or steel framing with varying amounts of insulation. Walls can be constructed of concrete panels, concrete blocks, plywood and 'freezer panel' walls with corrugated iron or 'freezer panel' roof construction. Ventilation systems include fully enclosed controlled environments to more reliance on natural ventilation using curtains and roof vents. Pole barns, utility implement sheds or hooped framed shelters covered with a water proof fabric are often used in conjunction with straw or sawdust bedding as a deep litter system.

Outdoor pig farming operates in fenced paddocks with a weather proof hut or shelter available to protect the pigs and access to shade from direct sunlight. This system is mainly used in areas of the South Island where rainfall is lower and where free draining soil lends itself to outdoor pig farming. Manure is deposited directly on to ground by pigs. Farmers can incorporate pigs into an arable rotation where nutrients can be utilised by subsequent crops or grass, with 'cut and carry' silage as a method of exporting accumulated nutrients.

These housing systems will incorporate different handling, processing and use of nutrients produced in manure. These systems range from solid floored pens which are hosed out, to varying proportions of slats where manure, urine, waste feed and water, falls or is washed into a channel which can be hosed or flushed on a regular basis. Other fully slatted systems operate a 'pull plug' system where the manure, urine, waste feed and water falls into a pit under the slats and is stored and is flushed out when the pigs are moved from the pen. Dry scraper systems can also be used to limit the amount of liquid that has to be handled and transported. Scrapers remove manure and wastewater from channels under slats.

Most pig manure is handled as a liquid (slurry). The consistency of manure is usually classified as solid, semisolid, slurry or liquid, depending on its fluidity.

Classes of manure:

- Liquid effluent is defined as material containing less than 10% solids.
- Slurry has between 10 and 20% total solids and will flow.
- Sludge has more than 20% total solids will not flow.
- Solid manure is deep litter and usually includes other bedding materials.

The hydraulic load is the amount of water in the effluent. Obviously the amount of water used to remove manure from the building has a large effect on its moisture content.

With slatted or partially slatted floors, the manure and spilt water can drop through the slats either into a manure tank or concrete storage pit or into drains where it can be scraped and washed away.

The slurry can be flushed from the drains into a sump or tank for storage or into a pond. The water used for flushing is either clean water or treated effluent recycled from the pond.

Photo 1: Pigs on slatted floors where manure drops through the slats into under pen pits

With solid floors the manure can be scraped or hosed into drains and washed away. The effectiveness of this system depends on pen and floor design and how often floors are cleaned, flushed out and de-clogged.

Liquid manure is stored in many different types of facilities. Storage under the shed in a ‘pull plug’ system is of concrete construction and follows the pen dimensions, and can flush to the exterior directly or in to a central collection pipe leading to a sump. The manure is typically stored under the pens for one throughput cycle of pigs. Storage sumps and pits outside the sheds can be rectangular, square or round and constructed of earth, concrete, steel or a combination of these materials. They can be above, below or partly below ground with a varying storage depth and may incorporate anaerobic and aerobic ponds. Without agitation it can be difficult to get the manure to circulate properly and some hosing may be required. Correctly designed pits and sumps will assist in flushing out all the solid material. Stirrers may be required to agitate and thoroughly mix the material prior to pumping to ensure a more consistent product as well as lessening the likelihood of blockages from solids.

Manure Gases

Be aware of gas build-up, which can reach hazardous levels. The manure gas hazard is highest during agitation as bubbles contained in the manure are released.

What toxic gases are present around such storage facilities? The four main gases produced from decomposing manure are Hydrogen Sulphide (H_2S), Methane (CH_4), Ammonia (NH_3), and Carbon Dioxide (CO_2). In high concentrations, each of these gases may pose a health threat to humans and pigs.

Hazards caused by these gases are:

- Toxic or poisonous reactions in people or pigs
- Oxygen depletion resulting in asphyxiation
- Explosions, which can occur when oxygen mixes with gases such as methane.

Characteristics of these gases

H_2S is considered the most dangerous of the by-products of manure decomposition. It has a distinct rotten egg smell and is heavier than air. After breathing this gas for a short time, your sense of smell becomes fatigued and you can no longer detect an odour. At low concentrations H_2S irritates the eyes and respiratory tract while at moderate levels exposure causes headache, nausea, and dizziness. At high concentrations, H_2S paralyzes the nerve cells of the nose to the point where the person can no longer smell the gas.

Both H_2S and CO_2 are heavier than air and will tend to settle to the lower areas of the manure storage pit or sump and remain in high concentrations even after ventilation. NH_3 has a distinct, sharp, penetrating odour detectable at very low concentrations. It is heavier than air and at moderate levels of concentration it can irritate the eyes and respiratory tract. Carbon dioxide is heavier than air and difficult to detect. It replaces oxygen in air and can asphyxiate. At moderate concentrations it causes shortness of breath and dizziness.

It is a major contributing factor to animal deaths by asphyxiation in confinement buildings with faulty ventilation. In addition to manure decomposition, carbon dioxide is also a by-product of respiration.

Methane is odourless and lighter than air, so it tends to accumulate at the top of manure pits. It can asphyxiate at extremely high concentrations. The main hazard is its flammable, explosive nature. Methane is extremely difficult to detect without gas detection instruments because it is odourless but it should be anticipated as being present in all manure storage areas.

Below ground storage facilities, pits and sumps are more hazardous than above ground structures and those with enclosed or are covered by lids are more hazardous than uncovered systems. Design the sumps and pits in a way that allows pumping equipment to be quickly and easily removed, without having to enter the sump or pit.

Manure removal

With all hydraulic systems the removed material will go to some form of sump prior to being pumped over a screen, into a tanker, to ponds, or direct to land. Early in the process a ‘weeping wall’ is often incorporated to ‘capture’ large solid particles and sandy material prior to it entering a pump. The sump should have capacity to handle the largest flushing volume. This will depend on flushing frequency, volumes and routines pump capacity and frequency of use, as well as extra capacity for breakdowns. Some form of mechanical stirrer may be required in the sump to prevent solids settling out and to ensure a consistent product is being pumped out. Sumps may also be used as temporary storage prior to filling a vacuum tanker for direct land application.

Photo 2: Example of a 'weeping' wall to collect heavy materials

A different housing system called deep litter incorporates a 'bed' of straw or sawdust on which pigs live. The bedding material absorbs the manure and is usually cleaned out between batches of pigs, when the spent bedding is spread to land or accumulated for composting. Bedding can be removed if soiled and/or more added to keep the pens clean. These systems operate on a larger space allowance per pig.

Deep litter housing with pigs

Housing with deep litter has concrete floors that use straw, sawdust or a combination as bedding. A solid floor makes cleaning easier and prevents nutrient leaching. Fresh litter should be used for each batch of pigs and sufficient bedding is needed for the absorption of manure and spilt water. The principal requirement is a restriction on water wastage and minimal spillage into the bedding. Regular addition of fresh bedding, particularly towards the end of the batch cycle, may be needed to maintain dry conditions within the sheds. This will also alleviate potential odour problems. Forty per cent of the shed floor area should be maintained as dry lying area for pigs until the end of the batch. Open deep litter yards without concrete floors should be avoided.

Photo 3: Showing pigs housed on sawdust bedding

Shed litter quality can be gauged by the level of visible moisture. There should be no free moisture visible in the litter and no puddles, pools or wallows. The use of bowl-type drinkers and/or siting of the drinker through the pen wall can minimise water wastage and spillage into the bedding.

Spent bedding can be applied to the paddock directly or after it has been composted. Solid manure, such as deep litter bedding and compost, supplies valuable organic matter to soils. This can improve soil structure, increase the water-holding capacity of coarse-textured sandy soils, improve drainage in fine-textured clay soils, provide a source of slow release nutrients, reduce wind and water erosion, and promote growth of earthworms and other beneficial soil organisms.

Direct land application of spent bedding

Spent bedding is normally cleaned out of the shed using a front-end loader or bobcat and can be spread directly to the paddock with a tractor-drawn or truck-mounted spreader.

Photo 4: Composted spent bedding being applied to pasture

For longer transport distances use bigger units with larger capacity to minimise the number of trips required, but keep in mind that the bigger units are heavier and can cause compaction of the soil. Compaction can be minimised by using heavy equipment on the land only when soil moisture levels are at an appropriate level. Spread when the wind is blowing away from the neighbours. Be aware of waterways when spreading product to land. Have a grassed or planted riparian buffer strip between cropping areas and waterways. Spread litter as evenly as possible at a calibrated rate suited to the specific crop and expected yield and work within Regional and District Council requirements for buffer distances and application levels.

Keep records of:

- quantity of manure and litter spread each year
- nutrient analyses/ estimates of the litter to be spread
- land area to be spread (location/block name used in OVERSEER)
- date(s) of application

Provide a storage area for the stacking of extra spent litter with sufficient space that can accommodate the material collected over a number of months. The capability to store litter reduces or eliminates the need to collect, remove, and spread litter on the same day, allowing it to be spread to land when weather and cropping or grazing conditions are compatible. Nutrients from litter can be best utilised when spread near or during the growing season of the crop. The frequency of application will need to be determined based on nutrient loading.

The storage area can be contained within a bunded (earth diversion bank) (in low-rainfall areas) or concreted (in higher rainfall areas) area. The storage facility can be either open or enclosed and roofed (to eliminate runoff effects from rainfall). Walls can be useful for stacking and loading, and where connected to the floor can also act as a bund.

Drainage water and leachate from the storage area should not be allowed to run off to land, but instead be collected into effluent treatment or other collection ponds for treatment or reuse.

Storm water run-off from shed roofs should be diverted from storage and treatment facilities.

Photo 5: Truck spreading solid material to pasture

Check with your District and Regional Council for their rules dealing with separated solids and spent bedding.

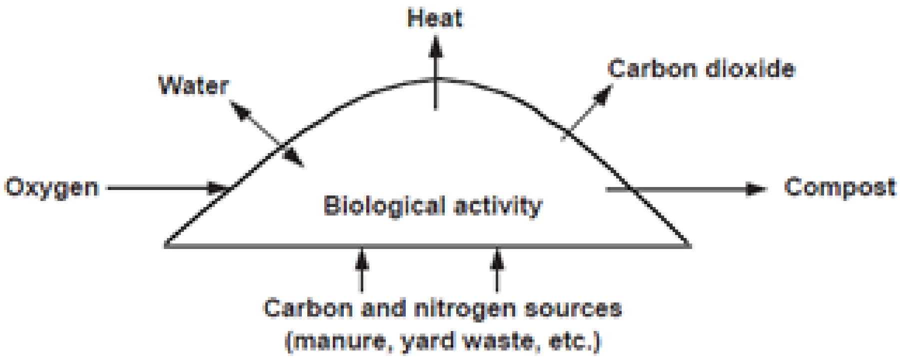
The composting process

Composting is an aerobic, biological process which uses naturally occurring micro-organisms to convert biodegradable organic matter into a humus-like product. The process destroys pathogens, converts N from unstable ammonia to stable organic forms, reduces the volume and improves the nature of the end product. It also makes animal waste easier to handle and transport, and often allows for higher application rates because of the more stable, slow release nature of the N in compost.

The effectiveness and rate of the composting process is influenced by factors such as temperature, oxygen supply (i.e. aeration), moisture content, pH, carbon to nitrogen ratio, particle size and degree of compaction.

A simplified chemical equation for aerobic respiration which takes place during composting is as follows:

$$H_2O + C_6H_{12}O_6 + \text{micro-organisms} + O_2 = CO_2 + H_2O + \text{heat energy} + \text{micro-organisms}$$



Under optimal conditions, a composting cycle is typically twelve weeks. This consists of active composting of around eight weeks, (up to twice as long if management has been less intense). Active composting is completed when the microbes have utilised available nutrients, this can be tested by adding water (wetting the pile) and this does not raise the temperature to 55-65°C. A four-week 'curing' period is then required to further decompose some compounds and large particles in the compost

The microorganisms digest carbon as an energy source and ingest nitrogen for protein and reproduction; microbes need more carbon than nitrogen to remain active. Sawdust, straw or newspaper and cardboard are good sources of carbon.

Carbon (C) in organic matter is the energy source and the basic building block for microbial cells. Nitrogen (N) is also very important and, along with C, is the element most commonly limiting. Preparing feedstock to an optimum C:N ratio results in the fastest rate of decomposition, assuming other factors are not limiting (e.g. oxygen, moisture, nutrients, temperature). The ideal C:N ratio for composting is generally considered to be around 30:1, or 30 parts carbon for each part nitrogen by weight. At lower ratios, nitrogen will be supplied in excess and will be lost as ammonia gas. Higher ratios mean that there is not sufficient nitrogen for optimal growth of the microbial populations, so the compost will remain relatively cool and degradation will proceed at a slow rate.

The optimum pH range for composting is somewhere is between 5.5 and 8.5. A high pH, above 8.5 encourages the conversion of nitrogen compounds into ammonia gas, resulting in nitrogen loss from the compost. To keep the pile aerobic, oxygen can be supplied through the addition of bulky, high carbon agents (e.g. straw or sawdust), or by pile turning.

With turning compost, the material is mixed and agitated in a windrow to increase the porosity and improve oxygen content which enhances passive aeration. With turning the capacity to absorb rainfall is also maintained and the cool and hotter portions get mixed (remember the edges of the windrows are cool). Turning can be accomplished with front-end loaders or specially designed turning machines.

Photo 6: Windrows of composting spent bedding material

For removal of rocks, oversize material and contamination such as plastic bags the rows need to be screened. This can be done with a mobile screener. The choice of mesh size is determined by the intended end use/ market sought for products.

Compost rows and heaps are a point source of pollution when located close to waterbodies and directly onto soil. Check your Regional Council requirements regarding the location of the storage of the compost and the surface on which it is to be stored. Many councils will have at least 50m setback requirement and require resource consent for compost storage areas of a certain size (area).

Composted spent bedding to land

Composting spent litter will minimise odour, eliminate weed seed contamination, reduce pathogen loading and could provide an improved fertiliser product.

All spent bedding can be transferred to separate composting area.

The composting site should have permanent water diversion that keeps surface runoff away from compost storage areas. The placement of manure storage, stacking or composting area should be a safe distance from flood ways, water ways, springs or well.

The composting area can consist of windrows (horizontally extended piles); long rows of spent bedding (solid manure) of 1.5-2.4 m high and 1.5-3 m wide, depending on the size of the composting area. The composting can also be done under cover which will minimise leachate production and potential contamination issues.

Composted separated solids to land

The removed solids can be transported and used for composting. The compost can be applied to land or sold. Good compost management, as previously discussed in regard to spent bedding, should be employed.

Since a carbon to nitrogen ratio of 15-40:1 optimises microbial growth, straw, sawdust or other high carbon materials often need to be added to sludge and separated solids for successful composting.

The heavy equipment used for manure application driven over land can cause soil compaction.

Sludge/slurry

Sand traps and ‘weeping walls’ are placed in the system prior to pumping, and are designed to collect larger objects and heavier material such as stones and sand thereby reducing the inorganic content of the effluent. Slurry can be transported by tank wagons or by pipelines to be irrigated to land.

Tank wagons are available in different sizes (3,500-44,000 Litres). Tank wagons generally have two functions; the transport of manure to land as well as the spreading or injecting into the soil. Direct injection to soil has the benefits of reduced runoff, reduced odour, and greater nutrient uptake by plants.

Pumps are used to pump the slurry into the tank wagon or through the pipelines. Pumps need to be specially designed to handle thick fluids. To minimise blockage they are usually with open-type impellers and cutting or chopping devices at the inlet to the impeller. Filling of tank wagons requires only low-pressure pumps, where the movement of manure through long pipelines and land application require high-pressure pumps.

Solids Separation

Solids separation systems are incorporated in to manure handling facility to separate larger solids from liquid. Removing solids lessens the organic matter content that has to be ‘processed’. Before application to land or entering a pond system, the slurry can be screened so that the solids (usually with a diameter 1 mm or more) are removed which will lessen pump blockages and de-sludging requirements of ponds. The solids removed are handled separately and can be applied to land or composted. There are various types of solids separators including static ‘run down’, vibrating, and rotating screens, and screw type presses.

Photo 7: Screw press type of solids separator

The solids separation facility should be constructed of impervious material and all drainage and leachate drain back into the liquid handling system to enter ponds or be irrigated to land.

Biogas Digester

Slurry can also go through an integrated digester and gas storage unit. The effluent out of the digester can be land applied, and methane will also be produced which can be burnt to produce electricity and heat.

There are advantages of land applying the effluent out of the digester, in comparison to effluent that is only screened:

- Reduced odour
- Reduced pathogens
- Slurry handling costs reduced because the liquid fertiliser is easier to spread than slurry (it can be pumped through existing irrigation equipment pipes, instead of tankered on to the land)
- Nutrients in the waste converted to mineral form, making them readily available to growing plants

Disadvantages could be size, siting and high cost to set up.

Liquid manure application to land

Plan your irrigation area in advance. Some parts of the farm may not be suitable for liquid manure application. Look at a farm map and identify such factors as waterways, soil types, natural drainage patterns and swamps, contour, wind direction, sensitive activities, neighbours and dwellings that you can avoid in your irrigation set up or application plan. Liquid manure can be applied straight to land without treatment. Liquid manure is applied to land using liquid manure tankers or irrigation equipment. Tanks, which range in size, are pulled behind a tractor or mounted on a truck (which make over the road travel quicker and safer). Liquid manure tankers discharge manure from the rear of the tank on the soil surface by sprinkler. Various types sprayers or soil incorporation tools can be used (drag-hose system, dribble bar, direct injection) and are generally mounted directly to the tanker. Manure distributes through hoses and discharges through a soil incorporation tool. These fittings reduce the risk of spray drift and potential odour issues as well as ensuring the nutrients in manure are place where plants can use them.

The main aim is to apply an appropriate depth of liquid manure uniformly to the paddock, at a rate that allows all of the liquid to soak into the soil and not flow away from the point of application. The irrigation system needs to be designed appropriate to the soil type, the topography of the area to be sprayed, and the condition of the paddock at the time of irrigation (crop, cover, water content, weather, expected weather conditions). Soils have differing infiltration rates and abilities to absorb and drain water. Coarse textured soils have a greater infiltration rate than fine textured soils.

Flushing the pipelines at the completion of each irrigation session with fresh water will lessen the risk of solids settling in a low point and causing a block in the irrigation equipment and avoids discharge of manure if the system is disassembled.

Proper land application is dependent on three performance characteristics:

Performance characteristics	**Determined by**
Sprinkler application rate	Soil infiltration rate or soil permeability
Depth of application per irrigation event	Soil water-holding capacity (depends on soil type and moisture content at time or irrigation)
Total depth of effluent applied annually	Amount of nitrogen or other limiting nutrient allowed annually (under nutrient management plan)

Each time effluent or solid by-products are spread on land, record:

- the type of material and spreading method
- the date and time of spreading
- what land area was spread
- the irrigation/spreading rate (kL/ha or tonnes/ha)
- weather conditions (including wind direction)

A chart like the example below will allow a record of land applications to be documented.

Date	Time	Type of manure spread	Location/pad dock	Weather/wind direction	Application rate/time

Most pig manure is applied to broad-scale cropping or pasture. The photos below illustrate visible benefits of applying pig manure.

Photo 8: Manure applied to cropping paddock; foreground no manure applied

Photo 9: Manure applied to pasture; foreground no manure applied

Aerobic and Anaerobic Ponds

The organic, nutrient and pathogen loadings in effluent can be reduced to produce a more usable product. Irrigation from aerobic ponds will produce less odour but will contain lower levels of N. Ponds are different from liquid manure storage because they are operated to encourage anaerobic digestion of organic material while it is being stored. Material from the aerobic ponds might also recycle effluent/water for flushing. A typical setup has a two-stage pond system (an anaerobic pond followed by an aerobic pond or series of ponds).

Anaerobic Ponds

The anaerobic pond is the first pond in the treatment system. This pond is without oxygen to encourage the growth of anaerobic bacteria, which breaks down the solid content of the effluent. To operate well, the pond needs to be deep (at least 4 metres) with a relatively small surface area for maintaining a low oxygen content to help the survival of the anaerobic bacteria. The pond should be as deep as possible while maintaining separation from groundwater.

Manure must be added slowly and uniformly to the pond system, to avoid an upset to the biological treatment system.

The manure gets drained/ flushed from the (farm) pits/ gutters straight into the pond on a frequent basis.

Sludge accumulates on the bottom of the pond. There is always need for a minimum volume to maintain microbial organisms in the system to treat the new manure entering the pond. Pond design should account for vehicle access to enable de-sludging. This may involve a longer narrow layout to enable a digger arm to reach the bottom of the pond.

Biochemical oxygen demand (BOD) gives an estimation of the quantity of organic matter in the effluent, in terms of the amount of oxygen required by bacteria to break it down. Effluent should be transferred from the anaerobic to the aerobic pond through a baffled pipe. The baffle should stop the floating solids from blocking the pipe and transferring to the aerobic pond. To avoid short-circuiting i.e. material not spending sufficient time in the pond, there should be separation between inlet and outlet pipes. The inlet should be at one end/corner of the pond and the outlet should be at the opposite end/corner. Baffles across the pond can also be added to increase retention time and reduce short circuiting. Make sure there is access and a method of opening the pipe between the ponds for inspection or to deal with blockages.

Aerobic Ponds

The aerobic pond is the last pond in the system. It contains oxygen to allow the growth of aerobic bacteria which utilise the remaining nutrients. This pond also allows for some further settling of suspended solids. Surface area is the most important consideration as sun and wind are essential for the efficient operation of the pond. The ultraviolet light from the sun reduces disease-causing organisms. Algae populations within the aerobic pond use the ultraviolet light to develop and produce oxygen, which is used by bacteria to further break down the organic matter in the effluent. Aerobic ponds should not be deeper than 1.2 metres. Aeration can be further increased mechanically with stirrers.

Photo 10: Aerobic pond with reserve storage capacity for winter or high rainfall events

Contents of the aerobic ponds are normally applied to land by spray irrigation systems. Manure with less than 4% solids is pumped as easily as water through normal irrigation systems. It is impractical to transport highly dilute manure by tank wagon or truck and pipeline transport is most common. These ponds are not typically agitated or completely emptied. A pump is used to pump the effluent out of the pond. Pumps can be mounted on a pontoon and float freely on the pond surface. Pumps and other irrigation equipment will need to be checked regularly for struvite, a scale that builds up on pumps, pipes and pipe bends and will reduce irrigation efficiency and can cause blockages. Struvite is a compound made up of magnesium, ammonium and phosphate and can contribute to the build-up of solids in ponds.

Irrigation to land

Application to land is the final stage in the process. Soil has the ability to utilise irrigated manure by filtering out the suspended solids and micro-organisms, the nutrients such as nitrogen are chemically processed (denitrification) and released or used by the soil, and organic matter is broken down by soil micro-organisms which along with plants utilise the nutrients released. In addition, sunlight and drying have the effect of killing harmful microorganisms in the manure. Apply effluent to short pasture to allow better infiltration into soil and pasture to recover more quickly, maintaining clean, palatable regrowth.

To effectively irrigate, knowledge of soil and landscape features is necessary to calculate appropriate depth, intensity and area of land for application of liquid manure. Soils maps will help determine soil type and other considerations include artificial drainage, slopes and the water holding capacity of the soil.

An understanding of some soil water terminology will assist in planning of manure applications.

Saturation: a soil is said to be saturated when all the pores are full of water. This occurs after heavy rainfall where water going into the soil is faster that that being lost by drainage and evapotranspiration from plants. Any irrigation will cause ponding or overland flow.

Field capacity: Is the water content of the soil after excess water has drained away and water is stored in the soil micro pores where plants can access it.

Soil water deficit: is the amount of water required to bring soil to field capacity. This occurs when the plants remove water faster that it is coming in. Irrigate when there is a soil water deficit and the amount will depend on soil types. If ponding occurs when there is a soil water deficit the application rate is too high.

Measure soil water deficits

To provide actual soil moisture data, a number of different tools can be used including:

- An on-farm soil moisture tape, which only relates directly to the paddock that it sits in, it is electronic and trends can be plotted over time.
- A handheld soil moisture meter, which can be carried around the property, providing soil-moisture data on a paddock-by-paddock basis.
- Tensiometers, measure soil water potential and ask the soil dries water is sucked from the soil causing a suction gradient which is detected by a gauge, data is manually collected.
- Time Delay Transition technology, allows for continuous monitoring so that data can be captured overtime and transmitted to a computer
- Soil moisture sensors, which can monitor moisture in many areas and provide real time data and analysis.
- Use regional soil moisture data (e.g. NIWA), which is not farm-specific.
- Use visual assessment of the soil and time since the last rainfall event

The level of irrigation undertaken will depend on soil moisture content, temperature and time since last rainfall event. Obviously higher application rates can occur in summer compared to winter.

Infiltration rate

This is the rate at which water enters the soil and it is necessary to determine the speed at which the soil absorbs water to prevent ponding and overland flow. Surface runoff occurs when application intensity exceeds the soil's maximum infiltration rate. This may be further affected by other soil or landscape features such as pans, drains, soil compaction, or ground slope. Infiltration rates can vary between properties and even for similar soil types and should be determined for each soil type encountered. For example, the infiltration rate of well-structured irrigated soils maybe higher than on previously un-irrigated soils.

With the use of low application rates and allowing a spell between applications, nutrient leaching and groundwater contamination will be avoided and the risk of surface runoff is minimised. Low application rate methods allow for greater control of application depth as well as better matching of the soil's ability to infiltrate and absorb applied effluent, thereby maintaining nutrients within the plant root zone.

The best application conditions are those causing odours to be diluted quickly, typically sunny windy days, followed by cloudy, windy nights.

- Soils with low infiltration rates and sloping land: low rate irrigation is preferred over high application rate travelling irrigators
- Soils with impeded drainage or low infiltration rate: low rate irrigation and the use of deferred irrigation is recommended
- Well drained soils: travelling irrigators should be adequate

> Do not irrigate liquid manure if the soil is water logged, flooded or snow covered

Deferred irrigation

Effluent from the pond can be spread to land using deferred irrigation. Deferred irrigation is the process where effluent is retained (in a pond) during the cold and wet periods of the year until the soil is warmer, when plants can use the nutrients. Effluent is then applied during the dryer and warmer days, in amounts that keep it in the topsoil and root zone. The aim is to use all the water and nutrients for grass/crop growth so that there is none left over to leach to ground water or run off to surface water. There needs to be enough space in the pond for two to three months' worth of storage. When the 'main' pond is full, the effluent will run into a holding pond, until there is a dry spell and a deficit in soil moisture and you can lower the pond level again.

A diversion channel, bund or cut-away ditch around the pond embankments needs to be installed to prevent water runoff from the land entering the pond system (to divert surface runoff). Divert storm water to prevent it entering the pond system.

Regular inspections focused on the maintenance of the ponds are necessary, a checklist can be helpful and inspection records need to be kept.

Most ponds' construction consists of soil or clay banks or they can be artificially lined with a plastic liner. Liners are necessary if clay material for compaction is not available or if it is required by your Regional Council.

All ponds should have a fence around them with warning signs for the protection of people and stock and to avoid stock damaging pipelines and embankments. Ready access for machinery for cleaning is another consideration.

Covered ponds/ Biogas collection

In anaerobic ponds in the absence of oxygen, anaerobic microorganisms break down manure to biogas, which consist mainly of methane and carbon dioxide. The biogas that is produced in the pond as a result of the digestion of the effluent can be collected underneath an airtight, heavy duty, plastic pond cover. The cover also acts as buffer storage. A network of pipes extracts the biogas from underneath the cover. Before the biogas is ready for use, it needs to be pumped through a filter for the removal of traces of corrosive hydrogen sulphide gas and through a gas cooler for moisture reduction.

The combustion of recovered methane in a generator can be used to produce on-site heat and electricity if pond usage is high enough. Otherwise gas can be collected and flared off with a low pressure gas flare. New Zealand has not yet a working carbon trading scheme. Covered anaerobic ponds also eliminate odour emissions.

For the typical New Zealand piggery, the benefits of covered anaerobic treatment ponds could outweigh the disadvantages. Potential benefits are: reductions in operational costs for energy, security of energy supply, proactive control of odour emissions from effluent systems, simplification and greater flexibility of effluent management and effluent nutrient application.

The production of biogas depends on the volume and depth of the pond and seasonal temperature variation, which is influenced by the local climate.

The pond location is important and should be located close to the manure exit from the building or solids separator. It should also be close to where you want to use the biogas, like an existing boiler or electricity generator. Ideally the effluent should flow by gravity from the building, through the solids separator and into the covered anaerobic pond without the use of a pump.

To minimise the cost and effort of installing the cover, the ponds are generally deep (4-6 m), and rectangular shaped.

The installation needs to be done properly, non-leaking seams are vital for all pond covers that collect biogas for combustion.

The cover should be strong, 0.8-1.5 mm thick and UV resistance, like polypropylene or low density polyethylene, with a 10-20 year guarantee.

Water from rainfall should be collected from the cover. This collection of rainwater can be done with the use of lateral depression by using weighted pipes on top of the cover. NIWA designed and describe this system in their reports for the different piggeries where they covered anaerobic ponds for biogas (Heubeck & Craggs, 2010). The lateral depressions channel the rainwater to a larger longitudinal depression in the middle of the pond, from which rainwater can be drawn-off using a suitable pump.

The pond can be soil-lined/sealed on land with clay soils or artificial lined if the soil is not suitable e.g. with land that has permeable rocky soils. A range of artificial liners can be used such as polyethylene, polypropylene or concrete.

The inlet pipe should be 1 m below the pond surface and 3m in from the berm. To reduce short circuiting of the inflow to the outflow, the inlet pipe should be fitted with a 45^{o} elbow facing towards the bottom.

The outlet pipe should be 0.5-1m below the pond surface to allow for any floating organic material to stay in the pond for further decomposition.

The amount of build-up of sludge is variable and will depend on design criteria and loading. Total removal of accumulated sludge should not be needed over the lifetime of the cover (10-20 years). Sludge can be partially removed with vacuum tankers so the addition of a designed built in 'proboscis' tube will allow removal of solids from beneath an operating cover.

Nutrients and their loss

Nutrients are lost from effluent during storage. Nitrogen, in particular, will be lost through volatilisation into the air as ammonia (NH3). The longer the effluent is stored the less nutrients are available for land application.

The availability to plants of nutrients, particularly N, from applied manure can be influenced by the forms of the nutrients contained in the manure, and methods and times of application.

Laurenson *et al*. (2006) gives an overview of the nutrient dynamics of piggery effluent when applied to land, in particular the transformation and loss of nitrogen (N) and phosphorus (P) from land treatment systems, and how the specific characteristics of effluent affect the various physical and biochemical factors influencing this.

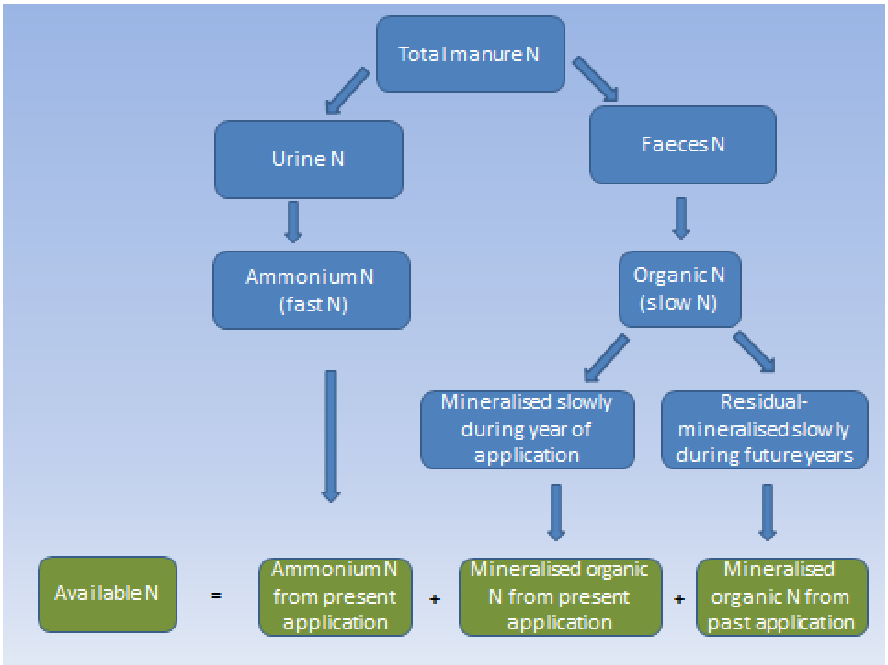
Most of the nitrogen in manure is in an organic form and must be mineralised (converted into ammonium or nitrate forms) before it is available to plants. The greatest nitrogen contribution in pig effluent comes from the urine and mineralisation happens straight after excretion.

Of the N contained in the organic form about 20-30% is estimated to be mineralised and becomes plant available inorganic form of N in the year of application to land.

Transformations of Nitrogen in the soil

There are different processes that determine the availability of Nitrogen in the soil for environmental loss or plant uptake

Figure 4: Transformation of nitrogen in the soil



Organic Nitrogen must first undergo mineralisation to become plant available. Microorganisms convert Organic Nitrogen to ammonium. Mineralisation occurs during manure storage and following application to soil.

Immobilisation is the reverse process where inorganic N is converted into organic N. This conversion is only temporary as Nitrogen is released back to the soil (and plant available pool) once the microorganisms die.

Ammonium N in manure can be lost to the atmosphere as ammonia gas via a process called volatilisation. This can be minimised by using covers on manure storage and incorporating the manure into the soil directly after surface application (ammonium will be nitrified by soil bacteria) to minimise manure exposure to the air. Practices that minimise volatilisation will also reduce odour.

Once applied to land, ammonium will rapidly undergo nitrification, where ammonium (NH_3 or NH_4^+) is oxidised by nitrifying bacteria to nitrite (NO_2^-) and then to nitrate (NO_3^-).

De-nitrification - the completion of the nitrogen cycle by returning N to the atmosphere as N_2 gas.

Transformations of Phosphorus in the soil

Phosphorus is an essential nutrient for both plants and animals. Plants need it for flowering and reproduction, as well as energy exchange. Phosphorous concentration is greatest in faeces and varies in relation to dry matter and the amount given in the diet. In manure Phosphorus is present in organic matter and as dissolved reactive phosphorous. It does not easily form gases and stays in the manure through storage and treatment. In treatments that reduce the mass of manure, like composting, the concentration of Phosphorus increases because the amount is not reduced.

Phosphorus can combine with magnesium and ammonium to form struvite (magnesium ammonium phosphate hexahydrate). After land application, some Phosphorus is transported in runoff, some moves into the soil profile, and some is bound by metal ions (calcium, aluminium, and iron). Phosphorus concentration is also likely to vary with soil depth.

The soils capacity for binding Phosphorus depends on pH, cation exchange capacity, rainfall, type of soil, and presence of metals (aluminium and iron oxides).

Nutrient loss and variation

Pig manure compositions can vary according to onsite management techniques such as stocking rates, retention time in treatment systems, storage characteristics and environmental conditions. One of the main factors affecting the composition of manure is the addition of water to solid manures. Both solid and liquid manures have their advantages and disadvantages. Irrigation of pasture using liquid manures (e.g. slurry or discharge from anaerobic/aerobic lagoons) can provide available nitrogen (N) directly to plants, as well as providing a moisture source in dry conditions. Liquid manure application to land may also result in N leaching and the release of odour. Solid manure, such as deep litter bedding and composts, supplies valuable organic matter to soils. This can improve soil structure, increase the water-holding capacity of coarse-textured sandy soils, improve drainage in fine-textured clay soils, provide a source of slow release nutrients, reduce wind and water erosion, and promote growth of earthworms and other beneficial soil organisms.

The main influence manures have on plant growth relates to the form that the N is in within the manure, which itself depends on the type of manure treatment system.

The two main forms of N within manure are:

1. Plant available N (inorganic N such as NH_4^+ and NO_3^-)
2. Organic N (Requires mineralization within the soil by microbes before it is available)

Both liquid and solid systems contain both N types. However, liquid systems generally have a higher concentration of plant-available N, while solid systems have a higher concentration of organic N. This generally means that when applied through best management practices, liquid manure will have a more direct effect on plant growth providing available N to the crop directly after the time of application. However, the N will move through the soils at a faster rate than organic N so there is a higher risk of leaching. By contrast, nitrogen from solid manure is likely to have a slower release, providing plant-available N to the crop over a longer period of time (several seasons).

N can also be lost during the storage and treatment of manure through a number of different mechanisms (e.g. volatilisation, de-nitrification) reducing the total N load applied to soils. The following table outlines average N losses from various effluent treatment systems.

Table 3: The range in loss of N from various treatment processes

Treatment system	Percent N Loss (%)
Anaerobic Lagoons	55-99%
Pit storage	15-30%
Deep Bedding	10-60%
Liquid slurry	15-60%
Solid Storage	20-70%

Source: (Intergovernmental Panel on Climate Change,2006)

An indication of the variation in values from various manure treatments are shown below for the analysis of a number of different farm samples.

Table 4: Summary average values in kg/m^3 (Various sources)

Pig Manure Av. Values	N	P	K	Ca	Mg	Na	S
Slurry	2.1						
Screened slurry	1.5	0.2	0.5	0.4	<0.1	0.2	**<0.1**
Screen + pond	0.5	0.1	0.4	0.1	<0.1	0.1	<**0.1**
Ponds	**0.2**	**0.1**	**0.2**	**0.1**	**<0.1**	**0.1**	**<0.1**

Source: NZ Piggeries surveyed by Ian Barugh, Massey University (unpublished)

The best method to improve the utilisation of N will be to reduce the storage time for effluent or deep litter and losses during application can be minimised by incorporating the effluent or litter directly into the soil.

Remember:
• The manure is a highly variable product.
• The nutrient content of the product that is applied to land is affected by the solids content, handling processes and the length of time the product is stored.
• Therefore it is important to regularly analyse the product at the point it is being applied to land.

Table 5: Brief summary: pros and cons of liquid and solid manure treatment systems

	Pros	**Cons**
Liquid slurries	• Low N loss in storage • High in plant available N • Provides irrigation in dry environments • Doesn't require expensive storage facilities	• Prone to leaching N if application rates are high or occurs during unfavourable environmental conditions • High in pathogens • High potential for odour emissions, particularly if surface-applied
Anaerobic/ aerobic lagoons	• Remaining N is available to plants • Provides irrigation in dry environments • Contains a lower level of pathogen than slurries	• High N loss during storage (approximately 60-80% loss) • Prone to leaching N if application rates are high or occurs during unfavourable environmental conditions • High potential for odour emissions, particularly if surface-applied from the anaerobic
Separated solids	• N in separated solids is generally organic nitrogen useful to build up soil organic material • Organic N requires mineralization within the soils prior to being available to plants resulting in slower release of nitrogen over a longer time frame • Application to soils improves soil structure water retention, drainage, aeration and cation exchange capacity (CEC)	• Low N content as in pig manure slurries. Most nitrogen is dissolved and therefore does not separate with screening • Less N leaching (however, leaching can occur in a high rainfall high groundwater table) • particularly in sandy soils, increases organic material, of the soils • Contains pathogens

Spent bedding from litter systems	• Contains a combination of available N and organic N (slow releasing N). • Application to soils improves soil structure in sandy soils, increases organic material, water retention, drainage, aeration and CEC of the soils • Long term release of organic N to soils • Lower risk of odour	• Available N can be lost depending on storage conditions • Some N loss occurs inside the animal housing (mostly in the available N form) • Contains pathogens
Composted material	• Stable material i.e. low in pathogens and low weeds due to heat generated • Significant odour reduction • Application to soils improves soil structure in sandy soils, increases organic material, water retention, drainage, aeration and CEC of the soils	• N loss occurs during composting (lower N content than fresh deep litter)

Both solid and liquid manures have their advantages and disadvantages.

The main influence manures have on plant growth relates to the form that the N is in within the manure which itself depends on the type of manure treatment system.

Liquid manure sampling

Nutrient concentration is usually the critical factor in determining the amount of manure to be spread per hectare of land (application depth and rates). Laboratory analyses of the manure need to be done to establish a trend or baseline of manure nutrient concentration. Manure samples are taken for nutrient and dry matter analyses. Information from lab analyses can take several days. Analyses results from previous sampling/ storage emptying times can be used to anticipate the present analyses, estimate proper application rate and calculate the nutrients actually applied to land. The results from the current analyses can be used for the adjustment of any planned future commercial fertiliser rates and subsequent manure applications. A manure sampling history can be developed and used over time. This history can show how consistent nutrient concentrations are from year to year. Use the same laboratory each year for consistency.

Measure the quantity and composition of effluent irrigated

While pump and irrigation manufacturers provide performance specifications as to the application rates and flows, it is recommended to determine actual paddock application rates.

A method to:

- Obtain a sample for analysis of the nutrient content of manure.
- Determine the application rate to the paddock.

To determine the application rate:

1. Set a number of small containers in a line across where the irrigator will travel at normal speed
2. Take the time when the irrigator starts spraying into the containers
3. Note when it has passed.
4. Calculate the time difference and convert it to hours.
5. Measure and record the depth in each container
6. To obtain the sample for nutrient analysis, combine all the samples into a bucket.
7. From this pooled sample take a sample for analysis following the protocol required by the laboratory that will undertake the analysis.
8. Chill the sample and send to the laboratory with your details and tests required such as dry matter, total nitrogen, phosphorus and potassium.

Application depth, rate and nutrient loading

1. Determine the average and maximum application depth

Container	1	2	3	4	5
Depth (mm)	12	14	9	13	12

Add together the depth in each container to get a total = 60 mm. Then divide the 60 by 5 (number of containers) = 12 to obtain the average application depth in mm.

2. Rate of application

This is determined by dividing the average application depth by the time taken in hours. The time was determined in step 4 above and if that was 30 minutes which is 0.5 of an hour, the application rate is 12 mm divided by 0.5 = 24 mm/hour.

3. Nutrient loading per pass

Using the laboratory result calculate the amount of nutrient per m^3. Laboratory results may be in other units such as mg/kg e.g. N 500 mg/kg. This converts to 0.5 kg N / m^3.

Each mm application is 10,000 litres or 10 m^3 /ha. If the application depth is 12 mm then the total application is 120 m^3, therefore the amount of nutrient applied per pass with the irrigator is 120 m^3/ha multiplied by the nutrient concentration of 0.5 kg N / m^3 equals 60 kg N /ha.

Solid manure sampling

In solid manure handling systems, the spent bedding may vary from one location to another within sites and often from season to season. To obtain a representative sample, manure sampling is undertaken before manure is applied to the land.

Place a sheet of plastic or tarp on the field. Fill the spreader with a load of manure and drive the tractor and manure spreader over the top of the plastic to spread manure over the sheet. Collect subsamples. Like in storage facility or bedding pile/row, sample in a grid pattern so that all areas are represented. Combine 10 to 20 samples in a bucket or pile and mix thoroughly.

Note: samples may be taken from anywhere in the process for analysis and may overestimate the nutrients available.

Take a subsample using the hand-in bag method for analyses:

- Place a sample bag inside out over one hand.
- With the covered hand grab a representative handful of manure and turn the sample bag right side out over the sample with the free hand.
- Squeeze excess air out of the bag and seal it.

Freeze the samples immediately to prevent nutrient losses if they can't be sent to the laboratory straight away. The laboratory may provide a sample bottle that looks more suitable to holding liquids. Try and ensure a representative sample of the compost is inserted into the container and sealed.

There are range of compost analysis that the laboratory can offer. The type of analysis or test requested will depend on where the compost will be applied. In determining the optimal application rate any legal requirements will need to be considered which may impact on the type of the test obtained. While it is common to need dry matter, Nitrogen, Phosphorus and Potassium tested there may be other requirements. For example, if the compost is being used for food production such as vegetables then heavy metal tests could be required.

If the user of the compost is expecting to put this data into OVERSEER as part of a nutrient budget then following information is required:

- Tonnes/month wet weight
- Dry Matter (DM) content %
- Nutrients: Nitrogen (N), Phosphorus (P), Potassium (K), Sulphur (S), Calcium (Ca), Magnesium (Mg), Sodium (Na)

Application rate and nutrient loading

The laboratory will provide a report with the test results. The reporting units received from the laboratory are:

- % = g/100g = g analyte / 100g compost
- mg/kg = ppm = mg analyte / kg compost
- (to convert mg/kg (ppm) to %, multiply x 0.0001)

Using the laboratory results calculate the nutrient per kilogram. In an example where the laboratory results have come back with 0.7% N, this is equivalent to 0.7g/100g or 7g per kg (1000g). Some resource consents will state that the input should not exceed 150kg Nitrogen per hectare per annum.

Next you need to find out the weight of the compost you plan to spread. If you have access to a weighbridge in your community then this is ideal. Weigh the truck with the compost loaded and then subtract the tare weight of the truck. For example, if the weight of the compost to be applied is 18,000kg then the amount of N applied to land will be 0.7% of this or 126,000g or 126kgN.

If there is no access to actual weights and the spreader is getting filled from the bucket on the tractor, work out how many cubic metres the bucket holds and the approximate weight of the compost per cubic metre. This could range from 400 kg/m^3 dry to 800 kg/m^3 damp. For, example the compost is very dry and approximately 400 kg/m^3. The bucket on the tractor is $0.9m^3$ capacity so every bucket will contain approximately 400kg x $0.9m^3$ = 360 kg of compost. The N content of the compost will be 360 kg x 0.7%=2.52 kg N. An application of 59 bucket loads per hectare would be required to reach the 150kgN per hectare per year input level (150kgN/2.52kgN per bucket= 59.5 buckets) if no other fertiliser/nutrient sources where added.

The NZ Pork Effluent Management Plan template can be used to document the plan for solid manure management as well as record applications.

Note: The spread rates need to factor in nutrient requirements of any cropping system that it is applied to. This would be calculated by a fertiliser representative or other specialist.

Soil sampling

The farm needs to be soil tested to determine the nutrient levels in the soil before manure application. The sampling location needs to be representative of the land that is used for application. Collect soil samples in a grid or zigzag pattern. Mark location of sample on an aerial map or drawing. Take samples from several different sites, around the same time each year. Don't take samples when the soil is water logged. Sample when nutrients are most vulnerable to leaching, which could be after the cropping cycle.

Samples can be taken with a standard soil sampling probe or screw auger, but a spade also works. Take at least 10 samples. Take soil surface samples and also sample soils that are ploughed to the depth of ploughing. Mix the different samples thoroughly in a bucket and take a subsample for analyses.

The nutrient requirement of the pasture or crop could also be used to match the nutrient input to plant uptake.

Note: Avoid taking samples from paddocks 6-8 weeks after sows have been removed from paddocks as the soil will be unstable (hot) and the sample will be inaccurate.

Table 6: Estimates of some common plant yields and their nutrient accumulation status

Container	Nutrient removal kg/tonne		
	N	P	K
Wheat (grain)	19	4	5
Barley (grain)	19	3	4
Oats (grain)	15	3	4
Maize (grain)	20	3	4
Maize silage	22	5	20
Irrigated pasture	20	3	15
Lucerne	31	3	25
Beetroot	42	3	40
Potato	25	2	22

Source: modified from (McGahan and Tucker, 2003)

Table 7: Estimates of nutrient removal (Horne personal communication 2014)

Crop	Normal yield (DM tonne/ha)	Nutrient removal range (kg/ha)		
		N	P	K
Pasture baleage	2-4	70-140	6-12	44-88
Pasture silage	2-4	70-140	6-12	44-88
Turnips crop	8	210	37	372
Pasture	10	350	37	270

Source: Horne D, personal communication 2014.

Most manure management plans use nutrient retention values that consider the impact of application method on plant availability. More nitrogen is volatilised when applied on the surface than when injected. Effluent that is land applied via an irrigation system may have only 10-20% of the nitrogen in the effluent available to the plant when the plant needs it. The nitrogen value of the manure therefore is not the nitrogen content in the manure but the amount of nitrogen that is actually available to the plant.

The effluent can be applied to land repeatedly but a minimum interval between applications is required to allow for infiltration and for the solids to be taken up by the soil. The minimum application interval (days) depends on the water and solids content of the effluent and soil type as well as stock rotation, pasture length, prevailing weather, and Regional Council regulations.

Looking at the effect of faecal contamination on pasture, Roach *et al.* (2001) suggest for farmers to withhold grazing cattle from effluent-treated pasture for a minimum of 15 days, and preferably 20 days if possible, allowing time for further bacterial inactivation. Rest periods between applications are also needed to give pasture time to regain palatability for stock.

Photo 11: Irrigation of piggery manure to pasture

Key points with land application of pig manure

1. Prepare a nutrient budget to plan the fertiliser applications and fit in manure applications as part of a whole farm approach
2. Know what you are putting on- this involves knowing how much is applied in each application and the number of applications to give the total amount of nutrients applied annually. The volume going on per application will be measured in mm, the application rate is how fast it is going on and is measured as the number of mm/hour, and the amount of nutrient applied at each application as per a laboratory test of the nutrient concentration.
3. Keep the volume of irrigation in the plant root zone where it will be used. The amount will vary with soil type.
4. Know your irrigators' spray pattern.

Examples of good practice recommendations are:

- Screen out larger particles for example, by the use of stone traps or solid screens. Aerobic/anaerobic pond systems will remove solids.
- Apply manure to short pasture.
- **Do not** graze stock on any land or vegetation visibly contaminated with manure.
- Incorporate solids into soil or spread thinly.
- Apply solids to fit in with re-grassing or cropping programmes.
- Keep stock away from stockpiled litter, manure and composting areas.
- If you provide manure direct to other properties, ensure that persons receiving the product understand the requirement to withhold stock from grazing on visibly contaminated pasture, and to keep animals away from stockpiled material.

When effluent is applied to cropping land it is advisable to work the effluent into the topsoil before sowing and planting. Effluent can also be applied to a tree plantation.

References

Heubeck, S., & Craggs, R. J. (2010). *Biogas recovery from a temperate climate covered anaerobic pond*. Water Science and Technology, *61*(4), 1019-1026.

Intergovernmental Panel on Climate Change. (2006). *2006 IPCC Guidelines for National Greenhouse Gas Inventories. Chapter 10: Emissions from Livestock and Manure Management.* Intergovernmental Panel on Climate Change.

Tucker, RW, McGahan, EJ, Galloway, JL and O'Keefe, MF, 2010. *'National Environmental Guidelines for Piggeries - Second Edition'*, APL Project 2231, Australian Pork Ltd, Deakin, ACT, Australia.

Laurenson, J. N. S., Bolan, N. S., Cartwright, G., Wheeler, D. M., & Redding, M. R. (2006). The Transformation and Loss of Major Nutrients following the Application of Piggery Effluent to Land. *Report prepared for the New Zealand Sustainable Farming Fund*.

McGahan, E., and Tucker, R. (2003). "*Resource Manual of Development of Indicators of Sustainability for Effluent Reuse in the Intensive Livestock Industries: Piggeries and Cattle Feedlots. Project No. 1816.*" Australian Pork Limited, Canberra, Australia.

Roach, C. G., Longhurst, R. D., & Ledgard, S. F. (2001). Land application of farm dairy effluent for sustainable dairy farming. In PROCEEDINGS OF THE CONFERENCE-NEW ZEALAND GRASSLAND ASSOCIATION (pp. 53-58).

Useful resources

- NZPork: pork industry guide to environmental management (formerly called EnviroPork) (www.nzpork.co.nz)
- NZPork: Effluent Management Plan template (www.nzpork.co.nz)
- The Industry Agreed- Good Management Practices (www.canterburywater.farm/gmp/)
- Irrigation Installation Code of Practice and Technical Glossary (www.irrigationnz.co.nz)
- Irrigation Design Code of Practice and Standards (www.irrigationnz.co.nz)
- Australian Pork Limited- Piggery Manure and Effluent Management and Reuse Guidelines (www.apl.com.au)
- Water New Zealand Good Practice Guide- Beneficial Use of Organic Materials on Land (www.waternz.org.nz)