Factsheet: Impact of Land Application of Swine Manure on Soil, Water and Human Health

Executive Summary

Swine manure can be used as a fertilizer on many fields. It contains essential nutrients and organic matter that will help improve crop yield and soil quality.

Application of manure can be accomplished by surface spreading, deep injection or incorporation, or by mixing surface applied manure with the soil.

Impact of manure on the soil: The application of manure improves the soil’s ability to support crop growth. Potential risks include soil compaction, nutrient buildup and sodicity problems, however these are minimized by proper management. Any fertilizer, commercial or manure, has the potential to buildup nutrients in the soil.

Impact on water: Proper manure management, and correct timing of application will control any runoff from fields. Problems such as nutrient buildup and eutrophication occur in nature as well.

Most nutrients found in manure are held by the soil particles. As such, they cannot be moved to groundwater aquifers.

Impact on human health: Only some of the microorganisms found in manure have the potential to harm humans or animals. The normal methods of managing manure reduces the survival of these organisms.

Proper manure management and storage will eliminate the threat to soil, water and human health. The pork industry prides itself on proper management and ensuring the protection of the environment for the future.

Introduction

What is swine manure?
Liquid manure consists of undigested/wasted feed, and the by-products of animal digestion. The majority of manure from pig barns is in a liquid form called slurry. Slurry consists of 94 to 98% water from the excretion of animals, the cleaning of barns, spilled drinking water and from staff showers.

A typical hog operation on the Canadian Prairies
Source: Quadra Management Services

Why do we add manure to soils?
Manure is a dilute multi-nutrient fertilizer containing macro and micronutrients needed to meet crop requirements. Applying manure at proper rates will increase yields and improve soil productivity and structure while minimizing the risk of water contamination.

Manure application completes the nutrient cycle beginning with the crop uptake of nutrients from the soil. The pigs digest the nutrients from the crop and return the undigested portion to the soil as manure.

What does manure contain?
The composition of manure varies depending on the type and age of animal, food, water content, storage and handling procedures, and climate. Nutrients often found in swine manure are listed in Table 1.
Nutrient Liquid Swine Manure kg/1000 L Commercial Fertilizer * kg/1000 L

**Macronutrients**
- Total Nitrogen: 3.0 180
- Total Phosphorus: 0.9 20
- Total Potassium: 1.0 20
- Total Sulfur: 0.4 20

Reference: SAF, 1999

**Micronutrients**
- Total Copper: 0.005-0.05
- Total Manganese: 0.005-0.05
- Total Zinc: 0.005-0.1
- Total Iron: 0.02-0.1
- Boron: 0.001

Reference: Schoenau et al 1998

* this is a typical formulation for a liquid fertilizer.
(Schoenau et al., 1998)
( multiply by 10 to convert to lb/1000 gal)

### How is manure applied to the soil?

A common method used in the prairies is deep injection. This method directly applies the manure into the soil at a 10 to 20 cm (4 to 8 inch) depth. Injecting manure places nutrients where the crop roots can best use it, prevents runoff and reduces odour.

Surface application or broadcasting applies the manure to the surface of the soil. Examples of this include application with dribble bars and irrigation. Dribble bars have pipes leading to the soil surface which dribble manure to the surface and can be used to apply manure to standing crops.

Incorporation mixes the soil with the surface applied manure. Reducing the interval between application and incorporation means that more nutrients are retained for crop growth, and decreases both odour emissions and the chance of rain causing runoff because the manure is attached to and protected by the soil particles.

### How does manure differ from commercial fertilizers?

<table>
<thead>
<tr>
<th>Manure</th>
<th>Commercial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diluted so large quantities are required</td>
<td>Concentrated so less quantity is required</td>
</tr>
<tr>
<td>Organic matter must be decomposed for plant availability</td>
<td>Comes in forms the plants can immediately use</td>
</tr>
<tr>
<td>Availability of N from manure in year of application is 60-70% that of urea (a commercial fertilizer), and 50% for P</td>
<td>Majority of nutrients are available immediately after application</td>
</tr>
<tr>
<td>The slow release of nutrients provides extended availability throughout the year</td>
<td></td>
</tr>
<tr>
<td>Has a variable composition</td>
<td>Balanced, is easily blended</td>
</tr>
</tbody>
</table>

Source: Prairie Agricultural Machinery Institute

### What are alternative methods of handling manure:

Composting involves the natural breakdown of carbon, making the manure more stable for use as a fertilizer or a soil conditioner. This requires large additions of straw or other organic material. If it is done correctly, it eliminates all weed seeds, and pathogens.

Solid liquid separation may be beneficial to decrease the amount of water and volumes to apply. The solid manure can then be spread on the field with a spreader. This process is costly and not very effective at higher moisture contents.
How is manure application rate determined?
Application rate is based on crop requirements, current nutrient supply of the soil, moisture conditions, growing season conditions and the nutrient value of the manure. In Saskatchewan, requirements are based on the amount of N needed for crop production.

Because of the high P content of manure, it may be necessary to apply manure based on the crop P requirement, and add commercial fertilizer to meet the N requirement.

Further information on proper management practices can be obtained from the SAF Manual for: Developing a Manure and Dead Animal Management Plan (1997).

What are the nitrogen losses associated with manure application?
Application to the soil should maximize the retention of nutrients for future crop production. However, losses can occur. Nitrogen can be given off to the atmosphere in the form of ammonia gas or nitrous oxide. Nitrate or ammonium can migrate beyond the root zone and remain tied to the soil or be transported to the groundwater systems.

Ammonium in the soil can be taken up by plants, immobilized by microorganisms, converted to ammonia (NH$_3$) and lost as a gas, attached to the clay particles, or converted to nitrate where it may be moved out of the system.

The exact losses depend on the application system and are shown in Table 2. Injection or broadcast with incorporation within 24 hours retains the most nitrogen. This is beneficial for both crops and the environment.

<table>
<thead>
<tr>
<th>Application Method</th>
<th>Total N loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injection into forage</td>
<td>Less than 2.5%</td>
</tr>
<tr>
<td>Broadcast on forage</td>
<td>14 — 16%</td>
</tr>
<tr>
<td>Incorporation within 24 hours</td>
<td>1 — 5%</td>
</tr>
<tr>
<td>Incorporation within 2 days</td>
<td>15 — 25%</td>
</tr>
<tr>
<td>Incorporation after 2 days</td>
<td>25 — 35%</td>
</tr>
<tr>
<td>Incorporation after 3 days</td>
<td>40 — 60%</td>
</tr>
</tbody>
</table>

Impact on Soil

What are the benefits of applying manure to the soil?
Manure:
- Increases crop productivity and yield
- Increases the ability of the soil to retain valuable nutrients
- Increases organic matter content which in turn provides the following benefits:
  - Improves cation exchange capacity which increases the soils ability to hold nutrients
  - Improves soil structure
  - Increases water infiltration resulting in reduced runoff
  - Protects soil from erosion
  - Decreases bulk density
  - Improves soil tilth making the soil easier to work
  - Moderates soil temperature by increasing the water content
- Supplies macronutrients and micronutrients required for crops
- Provides nitrogen later in the season, which may result in higher protein content in the crop
- Increases microbial activity which can increase the availability of nutrients
- Increases water holding capacity of soils and water available to the growing crop

How long does manure last in the soil?
Manure is a long-term supply of nutrients. It can take 3 or more years for microorganisms to break down and release all the nutrients in manure.
What happens if fertilizer is over applied?
When more nutrients are supplied than required by the crop, environmental risk increases. This can occur for both manure and commercial fertilizer. After excessive surface application, nitrogen can be moved by surface runoff or be transported beyond the root zone.

Ammonium, the major form of nitrogen in liquid manure, is not very mobile in the environment. Microorganisms are required to convert ammonium to nitrate. Nitrate is a form of nitrogen that is easily dissolved in water and therefore is easier to move.

Phosphorus, P, is tightly bound to the soil particles. Therefore, to get P moving to the rivers, the soil must be saturated with P or the soil particles must move through the system.

Too much fertilizer can cause harm to the crop; therefore, it is important that soil tests and manure nutrient tests are done regularly to ensure proper application.

What are Possible Risks Associated with Application:

With proper manure handling practices as outlined in the manure management plan for each farm, the risk of nutrients or microorganisms migrating to sensitive surface or groundwater locations can be minimized. No human activity is 100% risk free.

For example, heavy metals may be made available to plant and animal uptake if the soil is made more acidic. However, there is a low risk of this occurring with swine manure.

The over application of any fertilizer can cause nutrient buildup, crop damage, or increase the potential for nutrient movement. The risk of this occurring is negligible with proper management practices.

If water with a high sodium content is used in hog barns, then there is a potential for salt buildup with repeated applications. Research is currently looking into this.

Heavy machinery used in incorporating or spreading may cause compaction if used on soils that are too wet.

Impact on Water

What conditions must be met for water contamination to occur?

Water contamination, surface or groundwater cannot occur unless all of these conditions are met:

- There must be excess fertilizer, manure nutrient or other contaminant, which is not tied up by soil or plants, and is available to move with the water and soil.
- Rainfall must occur before the contaminants are bound to the soil, taken up by plants or naturally decomposed.
- There must be sufficient rainfall to carry the contaminant off site.
- There must be a receptor (surface water body or ground water aquifer).

Ground Water

How can the nutrients from manure enter the groundwater?

Contamination of ground water by manure requires the movement of nutrients and bacteria through the soil. When manure is applied to soil, nutrients are taken up by plants, attached to the soil or are broken down by native soil microorganisms. Therefore, if manure reaches water, it does not have the same characteristics that it had when applied.

The downward movement of nutrients and water is called leaching. Clay particles attract and hold many excess nutrients in place. However, the soil contains interconnecting pores and root channels, which facilitate the movement of nutrients to the ground water.

Ground Water
The rate of movement through the soil depends on the type of soil, amount of water present, and time of year. Water and the dissolved nutrients travel faster through sandy soils due to the coarser texture and larger pore size. This movement is increased if a tile drain is in place.

During the time in the soil, nutrients and bacteria are exposed to oxygen and will be subject to natural decomposition processes. Reclamation of aquifers can be difficult, and care is required to ensure they are not contaminated.

What nutrients can contaminate groundwater?
Only nutrients dissolved in solution can leach through the soil profile. In most Western Canadian soils, elements such as phosphorous, are tightly bound to soil particles making phosphorous difficult to move. The nutrient of most concern is nitrate. Nitrate is soluble and may move through coarse textured soils. If water with a high nitrate content (more than 45 mg/L) is given to newborn babies, oxygen deficiencies may result (Blue Baby Syndrome).

Surface Water
How do contaminants get into the surface water?
Timing of application is important in controlling runoff for surface applied manures and commercial fertilizers. Large rain events that occur before incorporation can move manure and soil particles off the field and into nearby waterways.

Nutrient runoff losses depend on fertilizer concentration, soil type, timing and method of application. Proper management practices, as mentioned earlier, will decrease the potential for contamination.

When soil erosion occurs, phosphorus, ammonium and other nutrients and bacteria can be transported with the soil particles to surface water bodies.

What are the effects of surface water contamination?
Additional nutrients in water, from manure or commercial fertilizers, can enhance a natural process called eutrophication. In eutrophication, additional nutrients allow for rapid growth of algae and other aquatic plants. This can deplete oxygen, restrict light, smother bottom-dwelling organisms, and reduce species diversity.

Eutrophication can occur naturally without the application of manure or fertilizers to land. Nitrogen and phosphorous are naturally present in the environment and will be moved by natural processes.

Water is a valuable resource on the prairies. Manure management operations act to ensure that this resource remains clean.

Source: Saskatchewan Agriculture & Food

Application of manure at proper rates will not contaminate water more than chemical fertilizers (Gangbazo et al., 1997).

What licensing and regulations are applied to manure application?
The Agricultural Operations Act requires that large intensive livestock operations obtain approval for their manure management plans. A manure management plan must outline the method of hauling, storing and using manure, and takes into account several manure and crop factors. The nutrients made available from manure depend on specific type of animals, and crop nutrient use, which is based on type of crop, soil climatic zone and target yields.
Impact on Human Health

Introduction

Manure from animals, including humans and wildlife, contain microorganisms. Only a small number of the microorganisms that are shed in faeces have the potential to cause disease (pathogenic) in humans and animals. The remaining organisms are beneficial or cause no harm. The presence of a microorganism does not mean that humans can contract a disease from contact or ingestion. The young, elderly and immunosuppressed individuals are most susceptible for contracting infections, and the symptoms are often more severe.

Table 1: Frequency of Occurrence Intestinal Pathogens in Humans, Cattle, Pigs, and Poultry

<table>
<thead>
<tr>
<th>Pathogen</th>
<th>Pigs</th>
<th>Human</th>
<th>Cattle</th>
<th>Poultry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Giardia lamblia</td>
<td>1-20%</td>
<td>1-5%</td>
<td>10-100%</td>
<td>0%</td>
</tr>
<tr>
<td>Cryptosporidium spp</td>
<td>0-10%</td>
<td>1%</td>
<td>1-100%</td>
<td>0%</td>
</tr>
<tr>
<td>Salmonella spp</td>
<td>0-38%</td>
<td>1%</td>
<td>0-13%</td>
<td>10-100%</td>
</tr>
<tr>
<td>Campylobacter jejuni</td>
<td>2%</td>
<td>1%</td>
<td>1%</td>
<td>100%</td>
</tr>
<tr>
<td>E. coli 0157:H7</td>
<td>0.4%</td>
<td>1%</td>
<td>16%</td>
<td>1.3%</td>
</tr>
<tr>
<td>Yersinia enterocolitica</td>
<td>18%</td>
<td>0.002%</td>
<td>&lt;1%</td>
<td>0%</td>
</tr>
</tbody>
</table>

Percentage of animals that are shedding the pathogenic microorganisms

Introduction continued

The types and numbers of pathogens found in manure at the time of application are dependent upon storage time. Survival of pathogenic organisms in hog manure is dependent upon species and can vary from 10 days to over a year, shown in Table 2. Once applied to the soil, survival varies depending on the type of soil and species of organisms. Composting or drying manure reduces pathogen survival.

Parasitic Pathogens

These disease producing organisms live and grow within a host animal.

**Giardia**: Commonly known as “Beaver Fever” is a parasite that can infect swine. Giardia is predominantly transmitted through ingestion of faeces or food contaminated by faeces; however, waterborne transmission to humans has been reported. The environmental stage of the parasite (cyst) has been shown to be degraded in liquid hog manure storage and are inactivated by drying. It is unlikely that distribution of liquid manure poses a serious threat for contamination of surface water.

**Cryptosporidium**: This parasite is transmitted through faeces in the same manner as Giardia. Poor hygiene leads to transmission between humans and from cattle to humans. This parasite in hogs is not an environmental concern provided that manure is handled responsibly. There are no reports of humans being infected with Cryptosporidium from pigs. Most likely the strain carried by pigs cannot infect humans.

Bacterial Pathogens

**Salmonella**: Salmonella is usually transmitted to humans by eating foods contaminated with animal faeces. Application of manure to horticultural crops such as lettuce, sprouts and mushrooms, that do not undergo further processing can be a source of infection. Produce should be washed properly before consumption. Salmonella and other bacterial pathogens can be introduced to water by contaminated animals that have direct access to water bodies, leakage from septic systems, or contaminated runoff.
Others:

Ascaris suum (roundworms): Human infection of this roundworm from pigs is rare. Ascaris eggs were identified in only 1% of manure samples. This means that there is a minimal risk of human infection from environmental contamination of water or soil by hog waste. However, if a herd is heavily infected, humans should be cautious and avoid ingesting contaminated manure and soil.

Toxoplasma gondii: Hog manure poses no risk of transmission to humans.

**Table 4: Survival of Animal Pathogens Present in the Environment**

<table>
<thead>
<tr>
<th>Material</th>
<th>Temp</th>
<th>Duration of Survival</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>Frozen</td>
<td>&lt;1 day</td>
</tr>
<tr>
<td></td>
<td>Cold (SC)</td>
<td>&gt;1 year</td>
</tr>
<tr>
<td></td>
<td>Warm (30C)</td>
<td>&gt;1 year</td>
</tr>
<tr>
<td>Soil</td>
<td>Frozen</td>
<td>&lt;1 day</td>
</tr>
<tr>
<td></td>
<td>Cold (SC)</td>
<td>&gt;1 year</td>
</tr>
<tr>
<td></td>
<td>Warm (30C)</td>
<td>&gt;1 year</td>
</tr>
<tr>
<td>Animal Manure</td>
<td>Frozen</td>
<td>&lt;1 day</td>
</tr>
<tr>
<td></td>
<td>Cold (SC)</td>
<td>&gt;1 year</td>
</tr>
<tr>
<td></td>
<td>Warm (30C)</td>
<td>&gt;1 year</td>
</tr>
<tr>
<td>Liquid Hog Manure</td>
<td>1 year</td>
<td>&gt;1 year</td>
</tr>
<tr>
<td>Compost</td>
<td>2 weeks</td>
<td>&gt;12-28 weeks</td>
</tr>
<tr>
<td>Dry Surfaces</td>
<td>1 day</td>
<td>1-7 days</td>
</tr>
</tbody>
</table>

Time required until pathogen can no longer be detected

*Numbered references can be found on the last page

Source: M. Olson, University of Calgary

**Campylobacter:** Small numbers of this organism can lead to infection. Cattle and hog manure are potentially a source of waterborne infection as direct contamination and agricultural runoff can lead to large numbers of organisms in water. This occurs where animals including wildlife have direct access to bodies of water and when runoff from surface applied manure can contaminate surface water. Campylobacter from pigs may or may not be infectious to humans.

**Escherichia coli (E. coli):** Although E. coli may be found in faeces, water and soil, fewer than 1% are potentially harmful strains. E. coli O157:H7 and some other strains produce potent toxins that can cause severe illness in humans. As pigs rarely excrete these toxin-producing E. coli, pig manure is considered a very low risk of human infections.

**Yersinia enterocolitica:** Most strains pose no health risk to humans, however some strains are potentially harmful. One strain, Y. enterocolitica O:3, isolated in the faeces of up to 83% of pigs is infectious to humans. Although there are no documented transmission studies, pigs have been implicated in human infections. These organisms are degraded within a month in faeces and slurry (Table 2).

**Conclusions**

- With proper manure management and storage, the threat to land, water, and human health can be eliminated. This includes deep injection of manure to prevent runoff. Storage in earthen manure storage or composting will help to eliminate microorganisms.
- Plants cannot take up pathogens and because of the dry conditions, they cannot survive for more than a day on plants. As a result, there is no potential for harm in eating grains grown from manured fields.
- Proper manure management including the application of nutrients in amounts required by crops, will effectively control the potential for groundwater or surface water contamination.


