FACTSHEET
AGRICULTURAL ENGINEERING

ORDER NO. 04-033

MAY 2004

AGDEX 743

Ontario Ministry of Agriculture, Food and Rural Affairs

AERATION OF LIQUID MANURE

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(Replaces OMAFRA Factsheet, *Aeration of Liquid Manure,* Order No. 86-042)
(Printed April 2006)

Over the years, farmers have looked for ways to eliminate or reduce odours associated with manure storages. One of the more successful methods is the mechanical aeration of manure, though it is not without its drawbacks. Aerators reduce the manure's nitrogen content, require fairly high capital investment and are expensive to operate and maintain.

Generally, only consider aeration as a short-term technique for reducing odour problems. In the long term, producers are better off choosing other odour control solutions that preserve nutrients and do not use as much energy.

An understanding of aeration begins at the microbial level.

ANAEROBIC AND AEROBIC BACTERIA

As soon as the animal excretes manure, bacteria are at work breaking down the organic compounds. The two most common situations involve either anaerobic bacteria or aerobic bacteria. The amount of oxygen present determines which type of bacteria will be found.

Anaerobic bacteria populations grow in conditions where no oxygen is present. In a typical liquid manure system, oxygen is used up quickly and anaerobic bacteria multiply, breaking down the organic compounds.

Some of the byproducts of this process are gases such as carbon dioxide, ammonia, sulphur-based compounds, volatile organic compounds (VOCs) and methane. These gases and others are the reason for the objectionable odours usually associated with anaerobic manure storages.

Aerobic bacteria require oxygen to grow. If oxygen is supplied continuously, this type of bacteria will convert the organic matter to carbon dioxide, water, and microbial cells. Little or no odour is found with aerobic breakdown of manure.

Aeration is the process of mixing air (containing oxygen) into the manure to promote the growth of aerobic bacteria. Oxygen must be supplied either naturally or mechanically.

Natural Aeration

When manure is kept in large, shallow storages, enough oxygen can be introduced naturally to keep the air/liquid interface aerobic. This results from wave action on the surface and the subsequent introduction of oxygen. The maximum depth of these "lagoons" is 1.5 m (5 ft). While the entire profile of liquid may not be aerobic, the aerobic conditions near the surface effectively reduce odour emissions.

This system, however, is not practical for Ontario farms because of the large surface area and shallow depth required, as well as the fact that microbial activity slows down in cold weather.

Mechanical Aeration

Many types of aerators exist that mix air into the manure. Higher volumes of air can be added with systems that bubble, blow or splash air into a tank or storage. Commercial wastewater treatment plants and sewage treatment plants have used this equipment for years.

A variety of these systems have been used on farms in Ontario to control odour emissions. But there are several disadvantages for on-farm use.

- The initial cost is high.
- The ongoing energy cost is high.
- Maintenance costs can be high.
- Effectiveness is reduced in cold weather.

- The introduction of antibiotics and sanitizers can upset or destroy the aerobic bacteria that must be present.

- Nitrogen loss to the atmosphere is increased with mechanical aeration.

There are different approaches to operate these systems. Lower volumes of air can be added by using a pump that takes liquid from the bottom of the tank and spreads it over the surface. Since the action is continuous there is always an exchange of liquid from top to bottom and an addition of air to the liquid on top. However, when improperly designed these systems actually contribute more odour than is reduced through the mixing of air into the liquid. This especially occurs in systems with high solids content.

Despite the disadvantages, some farmers feel that the advantages – especially odour control – warrant the use of properly designed mechanical aerators.

Design Considerations for Full Aeration

Mechanical aerators are usually assessed by their ability to dissolve oxygen in water. Floating aerators typically achieve oxygen (O_2) transfer rates in manure of 1.2–2.1 kg of oxygen per kilowatt-hour (kg O_2/kWh) of energy used.

Aerators are sized based on the biochemical oxygen demand or "BOD content" of the manure in which they are working. The BOD or BOD_5 (or the 5-day BOD) refers to the amount of oxygen required by bacteria to stabilize decomposable organic matter under aerobic conditions. BOD levels for different manure types are listed in Table 1.

Additional design considerations include the ability to mix or move liquids throughout the storage. A complex design of an aerator can be undertaken using factors including the clean water transfer rate, saturation temperatures and other factors not readily available in the field. When implementing an aerator for odour control, these factors can be omitted in favour of a generalized approach outlined below.

Consider the following two examples. All of the data is from Table 1.

Example 1: Total aeration for a beef herd of 300 animals weighing an average 454 kg

Step 1 The BOD production for the manure from one beef animal is 0.72 kg/day.

Step 2 For complete aeration of this manure, oxygen must be supplied in an amount equal to twice the BOD in the manure (i.e. 2 kg O_2/kg BOD).

$2 \times 0.72 = 1.44$ kg O_2/day for each animal

Step 3 Convert to hourly rate of O_2 addition:
1.44 kg/day ÷ 24 h/day = 0.06 kg O_2/h

Step 4 For a 300-animal manure load, the total is:
$300 \times 0.06 = 18$ kg O_2/h

Step 5 Assume a transfer rate (from the manufacturer's specifications) for the aerator at 2.0 kg O_2/kWh

Step 6 The required size of the aerator is:
18 kg 0_2/h ÷ 2 kg O_2/kWh = 9 kW (12 hp)

Example 2: Total aeration of manure from a 100-sow farrow-to-finish operation

Step 1 From Table 1, the daily BOD for each sow (farrow-finish) is 2.4 kg/day-head

Step 2 For complete aeration of this manure, oxygen must be supplied in an amount equal to twice the BOD in the manure:
$2 \times 2.4 = 4.8$ kg O_2/day for each animal

Step 3 Convert to hourly rate:
4.8 kg/day ÷ 24 h/day = 0.2 kg O_2/h

Step 4 For a 100-sow (farrow-finish) manure load, the total is:
$100 \times 0.2 = 20$ kg O_2/h

Step 5 Assume a transfer rate of the aerator at
2.0 kg O_2/kWh

Step 6 The required size of the aerator is:
20/2 = 10 kW (13.4 hp)

Partial Aeration

Aeration at a full aeration level ensures that the manure storage is maintained in an aerobic state and that all of the solids are held in suspension. However, experience has shown that odour control can be achieved through aeration at lower levels.

When operating at a lower rate of aeration, the result is complete mixing and aeration of the surface layer only. The lower part of the storage will likely remain in an anaerobic state. The solids in the surface layer will settle out and be decomposed by anaerobic bacteria. However, as the gases produced in the anaerobic zone at the bottom of the storage pass through the aerated zone near the top of the storage, some odorous compounds are broken down by aerobic bacteria.

The rate of aeration needed to achieve this partial aeration is about half of the BOD production. Therefore, a range of values can be used to size an aerator – from half the BOD to twice the BOD production. The higher the level, the more complete the mixing, and the higher the percentage of aerobic decomposition. Table 1 shows partial and complete aeration rates for the major livestock species.

Note that the values in this table are for a well-mixed manure. By separating solids from liquids, the aeration rates can be decreased by as much as a factor of four. This can be achieved, in part, by minimizing vertical mixing in the storage and only aerating the upper layer. In addition, the BOD production can vary greatly, depending on feed, storage type and other conditions. Use this table as a rough guideline.

TABLE 1. Design of Aeration System — Oxygen Requirement

		Oxygen Capacity Needed (kg/day-head)		
Animal	**Weight (kg)**	**Daily BOD_5 Production (kg)**	**Complete Aeration (kg)**	**Partial Aeration (kg)**
Dairy	454	0.77	1.54	0.38
Beef	454	0.72	1.45	0.36
Swine	16	0.032	0.064	0.016
	29	0.059	0.122	0.029
	68	0.14	0.27	0.07
	91	0.18	0.36	0.09
Sow and Litter	170	0.45	0.90	0.23
Farrow to Finish (per sow)	n/a	2.4	4.8	1.23
Sheep	45	0.04	0.08	0.02
Poultry	21	0.006	0.012	0.003
		0.001	0.002	0.0005

* Adapted from Midwest Plan Service, 1983

Equipment

The **floating aerator** is the most common type of aerator found on Ontario farms. Most of these pump liquid laterally and into the air, creating surface turbulence and a large water-to-air surface area for oxygen transfer (*Figure 1* and *2*). The downside of such a system is that in creating turbulence and spray there is potential for some odorous compounds to be released to the atmosphere.

Another design is the **downdraft, induced-aspiration aerator.** It pumps liquid laterally about 1.5 m (5 ft.) below the liquid surface and forces air through an aspiration tube at the point of pump discharge. This results in a good mixing of the top layer of storage with little surface turbulence (*Figure 3*).

A **surface-type aeration system** is used with windmills and low-power (less than 1 hp) pumps. These are lower cost systems. However, the oxygen transfer rates are not yet published and, with the windmill system, depends on the wind. The impeller is located approximately 50 cm (20 in.) below the water. The action of the impeller, under a 24 km/h wind velocity, draws liquid in the storage upwards with a 9 m^3/s (2,000 gpm) flow rate. The liquid then flows out onto the surface – there is no "breakage" of the surface – and a thin surface layer travels radially outward from the pump. The surface velocity remains quite high even at large distances from the pump (Bugg, 1996).

An aeration system referred to as an **oxidation ditch** can be found on some farms. It consists of a continuous open channel, or raceway, under a slatted floor. Manure is kept moving down one side of the channel and back the other. Air is mixed into the manure by an aeration rotor. This system is not common in Ontario mainly because of high costs to install and the more serious consequences of potential foaming.

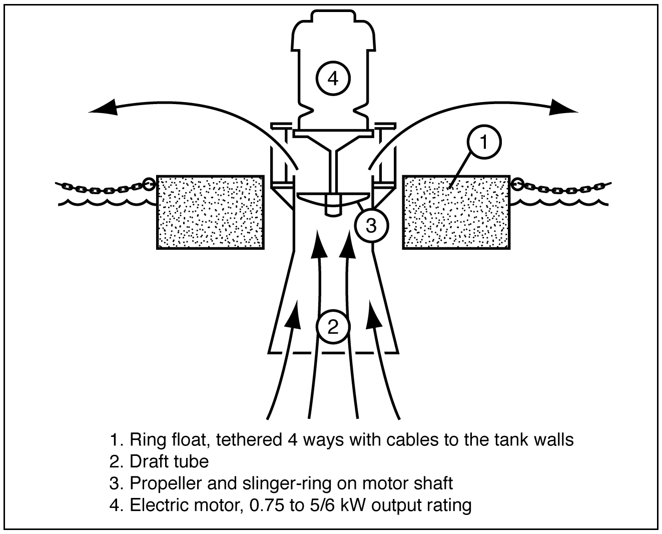

Figure 1. Floating propeller-type surface aerator

Figure 2. An operating floating propeller-type surface aerator system. (*Photo courtesy Jacques Whitford Consulting.*)

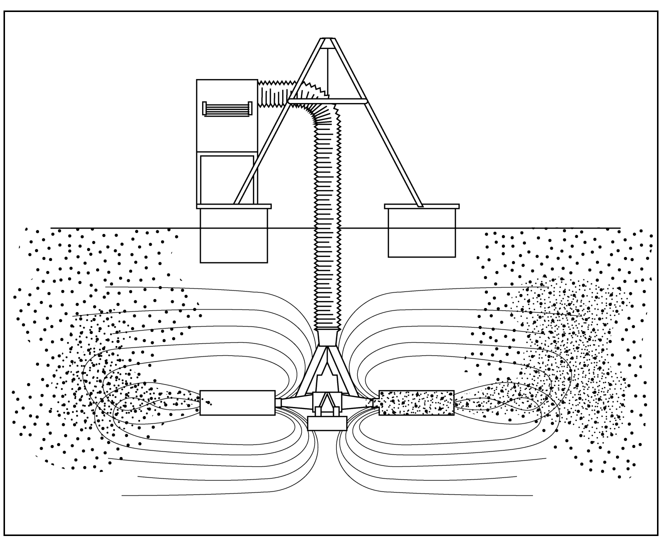

Figure 3. Down-draft, induced-aspiration aerator.

COSTS: PURCHASE, OPERATION AND MAINTENANCE

If you are considering installing an aerator, the bottom line is very likely to be a question of cost. Costs of the floating aerators vary greatly and depend on such things as capacity and quality of construction.

Aerators vary in price depending on the power and how effective the system is at adding the oxygen. As noted earlier, rates typically vary from 1.2–2.1 kg of oxygen per kilowatt-hour (kg O_2/kWh).

A 5–10 hp aerator will cost about $8,000–$10,000, while larger units of 25–30 hp will be $25,000–$30,000. Three-phase power or single-phase power converted to 3-phase is recommended for the smaller motors and a requirement for larger ones.

Windmill and low flow-rate surface-type systems are in the $4,000–$5,000 range, with a small premium for stainless steel (strongly recommended). Also be sure to verify oxygen transfer rates with the supplier.

On-farm energy prices in Ontario are currently at $0.10/kWh; and demand charges of $12/kW. (Only farms with a 400 amp service or larger will be subject to kW demand charges.)

The following examples illustrate the financial considerations of purchasing an aerator.

Example 3: Complete aeration analysis at a beef facility for a 300-head beef herd weighing an average of 454 kg

Steps 1–5 (from previous Example 1)

Step 6 A 9 kW aerator would be required

Step 7 Energy operating costs calculated at $0.10/kWh; running the system 24 h/day, 365 day/yr, and demand charges of $12/kW

- 9 kW × $0.10/kWh × 24 h/day × 365 day/yr = $8,212/yr for energy consumption

Demand Charges:

- 9 kW × $12/kW/month × 12 months per year = $1,296 (required only for large energy users)
- Annual total energy and demand charges would be $9,508

Step 8 Purchase price = $10,000

Step 9 Maintenance costs of 10% annually of purchase price = $1,000/yr

Example 4: Partial aeration at a medium-sized hog facility. Feeder pig operation houses 800 pigs, average weight of the pigs is 68 kg (for a finishing pig marketed at 120 kg)

Step 1 From Table 1, the daily BOD requirement for "Partial Aeration" would be 0.07 kg/day-head

Step 2 For partial aeration of this manure for all 800 animals: 800 × 0.07 = 56 kg/day

Step 3 Convert to hourly rate:
56 kg/day ÷ 24 h/day = 2.3 kg O_2/h

Step 4 Assume a transfer rate of the aerator at
1.6 kg O_2/kWh

Step 6 2.3 kg O_2/h ÷ 1.6 kg O_2/kWh
= 1.5 kW (2.0 hp) aerator would be required

Step 7 Energy operating costs calculated at $0.10/kWh; running the system 24 h/day, 365 day/yr, and demand charges of $12/kW

- 1.5 kW × $0.10/kWh × 24 h/d × 365 d/yr = $1314/yr for energy consumption

Demand Charges:
- 1.5 kW × $12/kW/month × 12 months per year = $216
- Annual total energy and demand charges would be $1,530

Step 8 Purchase price = $2,500

Step 9 Maintenance costs of 10% annually of purchase price = $250/yr

For the above example, if the farmer wanted complete aeration, all of the costs would be multiplied by a factor of four.

Use of Aerators in Flush Systems

There are two typical installations for the floating aerators. One consists of the aerator(s) being located in the long-term manure storage structure. Sometimes a barn-floor flushing system is used with this configuration. Flushing with poorly aerated water could result in significant odour in the barn. Another disadvantage of using a flush system from an exterior storage is that the introduction of flush water lowers the air temperature in the gutter area in the winter. In the case of dairy this may be acceptable. However, for swine, it can create intolerable drafts and chill the animals. In addition, many swine biosecurity standards would not allow this type of system.

TABLE 2. Typical Aeration Pump Power Capacities for Various-Sized Liquid Manure Tanks

Sizes hp	Manure storage capacity (ft^3)	Pit Depth 16 ft diameter (ft)
7.5	38000 (1076 $m^{3)}$	up to 55 (16 m)
10	55000 (1557 $m^{3)}$	up to 65 (20 m)
15	70000 (1982 $m^{3)}$	up to 75 (23 m)
20	113000 (3200 $m^{3)}$	up to 95 (29 m)
25	180000 (5097 $m^{3)}$	up to 120 (36 m)
30	246000 (6966 $m^{3)}$	up to 140 (42 m)

NB: Oxygen transfer rates and desired operation will vary these numbers.

The other typical installation involves an aerator set up in a holding tank adjoining the barn. The barn gutters empty into the holding tank where the manure is aerated. This installation is tailor-made for flushing systems and helps lower odour levels in the barn. The manure is kept at a higher temperature in the winter, which helps the aeration process. It also does not create the cold areas in the barn that are found with the previous system when flushing. As the holding tank is filled, manure is pumped out to the long-term storage where it then reverts to anaerobic breakdown. This means there is no odour control around the long-term storage structure.

OTHER CONSIDERATIONS

It may be preferable to install multiple small aerators instead of a few large aerators. This results in increased mixing throughout the storage and avoids localized zones of high or low aeration.

Most farmers try to optimize the use of nitrogen in manure for crop production. In Ontario, nutrient management regulations assist in properly assessing available nitrogen in the manure and balancing nitrogen with cropping needs. Phosphorus limits will also prevent over-application of manure, even in circumstances where the nitrogen content of manure has been reduced.

Operators using an aeration system will need to test the material being spread on the land if a Nutrient Management Plan is required for that farm unit. Please note that the nutrient content values available in the nutrient management documents available from OMAFRA do not account for the changes that result in the volatilization of nitrogen through aeration.

Aerators designed to polish low-BOD wastewaters prior to discharge may require maintenance when used with manure. Manure contains more corrosive elements compared to municipal wastewater, and often has higher solids contents. Aerators designed for industrial wastewater use may be more appropriate.

If you want to install aeration equipment, carefully review all the advantages and disadvantages. Also consider other methods of odour control, such as floating or permanent covers, as alternatives. Although aeration works when the system is designed properly, many farmers will likely come to the conclusion that the high costs are very hard to justify.

This Factsheet was written by **Don Hilborn**, By-Products Engineer, and **Jake DeBruyn**, New Technology Integration Engineer, OMAFRA, London.

FOR YOUR NOTES

Do you know about Ontario's new Nutrient Management Act?

The provincial Nutrient Management Act (NMA) and the Regulation 267/03, as amended, regulates the storage, handling and application of nutrients that could be applied to agricultural crop land. The objective is to protect Ontario's surface and groundwater resources.

Please consult the regulation and protocols for the specific legal details. This Factsheet is not meant to provide legal advice. Consult your lawyer if you have questions about your legal obligations.

For more information on the NMA call the Nutrient Management Information Line at 1-866-242-4460, e-mail nman@omafra.gov.on.ca or visit www.omafra.gov.on.ca.

Factsheets are continually being updated so please ensure that you have the most recent version.

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ISSN 1198-712X
Également disponible en français
(commande n° 04-034)

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