Development of a Farm-Scale System to Compost Liquid Pig Manure

Ron Fleming and Malcolm MacAlpine, Ridgetown College - University of Guelph
Ridgetown, Ontario, Canada, N0P 2C0
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Summary

A liquid manure composting system has been developed and is now operating at Ridgetown College, University of Guelph, located in Ridgetown, Ontario. The composter is an in-vessel system, with forced aeration and mechanical turning. Liquid swine manure has been mixed with a variety of substrates to produce a material that is compostable. Straw, wood fibre, corn stover, corn cobs, tree leaves and combinations of these materials have been tested. We have had excellent success in controlling odours from liquid pig manure. The ratio, by weight, of liquid manure to substrate ranged from 1.9:1 to 8.1:1 for straw, and was lower for wood fibre (average 1.1:1), corn stover (average 3.0:1), leaves (average 1.2:1), and corn cobs (average 2.0:1). The amount of manure processed expressed as a function of time and compost channel area has been as high as 28.5 L/day/m^2.

Background

Liquid manure systems are used on most swine farm operations in Ontario, especially in the new barns. The handling, storage and land-application of liquid swine manure have raised considerable environmental concerns - especially with odour. The potential to contaminate surface water or groundwater is also very real, and various studies have attempted to get a handle on this problem and come up with ways to prevent it (eg. Fleming, 1994; McLellan et al., 1993; Fleming and Bradshaw, 1992).

The odour issue has been a challenge to swine farmers for many years. A great deal of research effort has gone into developing and testing products or systems to reduce or eliminate manure odours. Composting is a proven system for solid manure and is well documented (eg. NRAES, 1992). Very little has been done with liquid manure, however. Patni et al. (1992) reported on a study where liquid poultry manure was composted using peat and chopped straw in a passively aerated pile. While this was encouraging, it had two major drawbacks - the entire process took too long (seven to ten weeks), and peat is not a suitable material for widespread use because of high cost and the fact that its use is non-sustainable. Patni (1997) has completed a study using passive aeration with liquid manure and straw. The preliminary results showed that straw could successfully be used and that the heat produced during composting helped to evaporate a considerable portion of the liquid in the manure.

Composting of liquid manure would have the benefits of controlling storage and spreading odours, two of the biggest problems with swine manure. It also would provide a material that should have less impact on water quality than raw manure since most of the nitrogen is transformed into an organic form rather than the usual ammonium form.

Objective

The objective of the study was to develop and test a composting system for liquid swine manure, capable of becoming an integral part of a typical on-farm manure management system.

Composter Setup

In conjunction with Global Earth Products, an on-farm composting and processing unit has been installed at Ridgetown College (University of Guelph), Ridgetown, Ontario. The unit is covered to exclude all precipitation and consists of three adjacent channels, each 2.2 m wide, 1.8 m deep and 15.2 m long. The overall layout is shown in Figure 1. The walls separating the three channels are of reinforced concrete. The compost turner is a prototype - the MARVEL, designed by Lagace Systech Corporation. It is hydraulically operated, originally powered by a 7.5 kW electric motor driving a hydraulic pump. This powered a 7.3 kW hydraulic motor to operate the apron and the hydraulic cylinders needed to lift the apron. A 2.25 kW electric motor drives a second hydraulic pump that powers four hydraulic motors to operate the drive wheels. The control panel includes a PLC controller to operate the turner. The turner travels down each channel on steel tracks - it can be moved from one channel to the next at one end on a steel transfer cart.

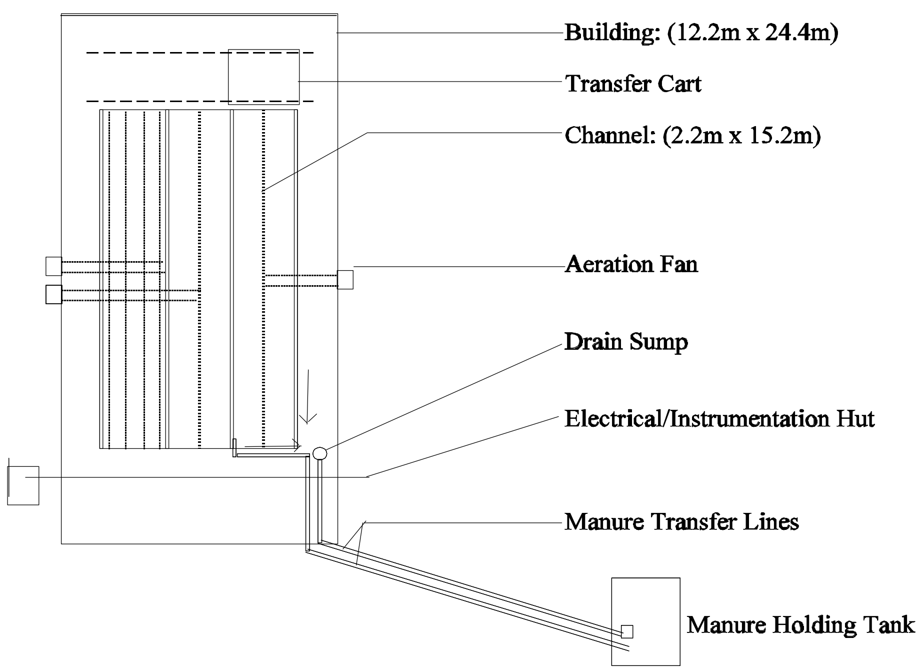

Figure 1 Overall layout of the composting building, showing channels, manure supply and aeration fans

Liquid manure is stored nearby in an underground covered holding tank. It is pumped into the compost building, when needed, using a Goulds sewage pump (Model: WS1012BF, 0.75 kW, 473 L/min at 6.0 m head). The transfer line is 50 mm PVC water pipe. This is all mounted on an overhead wooden beam and is designed to be self-draining. A flexible hose transfers manure to the turner through a 50 mm x 23 m flexible plastic “milk truck” pipe. Incoming manure flow is measured using a Greyline Instruments DFM-III Doppler Flow Meter.

Excess liquid manure is allowed to drain out of the channels and is collected in an underground sump and pumped back to the outside storage using a Myers Sewage Pump (Model: WHR5P-2, 0.38 kW, 150 L/min at 6.0 m head). Running time is recorded by the data logger and related to the volume of liquid pumped.

The initial electrical service for the installation consisted of a 200 amp, 240 volt, single phase service. The main panel is located in an instrument hut located beside the compost building - kept separate to prevent damage due to high humidity levels. Modifications to this setup are discussed later.

One aeration fan is provided for each of the three channels. The fans are Airstream Inline Centrifugal Fans (Model # ILC-318, 2.25 kW electric). They are rated at 1650 L/sec at a static pressure of 100 mm. The fans force outside air through a transition plenum to two 250 mm PVC water pipes and then to the individual aeration floors. In each of these ducts is a pressure transducer (Omega Canada Inc., model PX154-025D1). These three devices are connected to the data-logger and record the static pressures.

Channel 1 contains a spigot floor system, consisting of four lengths of 100 mm PVC pipe buried in the concrete floor. On top of each pipe, at 30 mm intervals, is a plastic spigot (a cone about 75 mm high). The top (small end) is recessed slightly below the finished floor level. In it is a 6 mm diameter hole, through which air enters the compost. Channel 2 contains a concrete floor with a central plenum 200 mm wide having regularly spaced holes to allow air to enter the pile in the centre. The original floor in Channel 3 consisted of a sub-floor of concrete, covered by crushed stone, in which a 150 mm diameter PVC pipe was buried. On the underside of this pipe were two rows of holes to allow air out into the stone before being forced up through the compost.

Temperatures in each channel are measured using six thermocouples, connected to the data-logger (Campbell Scientific CR10 data logger, shielded thermocouple cable type T 24-AWG). There are also thermocouples set up to measure outside air temperatures and the temperature of air inside the building.

The data logger is programmed to read the temperatures and operate the aeration fans. A base level of aeration is maintained (e.g. 3 minutes on in each hour) and when any one of the 6 thermocouples in a channel exceeds a predetermined level (e.g. 66 °C), a second level of aeration is initiated - 3 minutes out of 10 (to prevent excessive heat and subsequent die-off of bacteria).

Composter Operation

Unlike many commercial systems, this is operated as a batch system. This was chosen to allow the flexibility to experiment with turning frequencies, etc. and to develop the best recipe without having to regularly remove small amounts of “finished” compost. We felt that many farmers would prefer to remove an entire batch every few weeks rather than have to deal with relatively small amounts every day or two.

The process operates as follows:

a) Substrate (a material with a high C:N ratio - such as straw) is added to the channels using a tractor and loader. Substrate is only added at the start of each batch.

b) Liquid manure is dropped from a pipe mounted on the turning device. All drainage liquid is intercepted, and pumped back into the holding tank.

c) The mechanical turner moves down the channel, mixing the substrate and manure. The

speed of travel is pre-set at 1.2 m/min. The turner consists of an inclined apron and a series of slats that lift the material up and drop it on the back side, displacing the material about 2.5 m. Since this is a batch system, the machine must move in two directions - it is designed to allow for turning going both ways. Only one turning device is used and it is moved from one channel to the next on a track located at one end of the channels.
d) Aeration from beneath is supplied as needed to maintain aerobic conditions.
e) The material is turned and manure is added about three times during the first two weeks - until the final desirable moisture condition is achieved (i.e. between 60 and 80%).
f) After a period of time ranging from two to six weeks (discussed later), material is removed. A portion is held back an used as "seed" compost for the next batch.
g) The compost that is removed is placed in bulk in a storage area for "curing" - further breakdown of organic matter.

Composter Evaluation - Results

Evaluation of the turning equipment

Since the equipment was initially set up, there have been a number of changes/improvements to the Marvel turner. For certain materials, the machine was underpowered. We changed the drive to a 15 kW 3-phase electric motor and a 15 kW hydraulic motor on the apron. The turner has now operated successfully in leaves, wood fibre, corn stover and straw. This has meant switching to 3-phase power. Power of at least 15 kW for each 2.2 m of apron width is required. Since most farms do not have 3-phase power, they will need to install a phase converter.

Corrosion in the composting building has not been a problem. Metal parts have shown virtually no rust in spite of an environment with liquid hog manure. Their has been little or no rust and limited wear on any moving parts.

Work environment issues are of some concern. Some compost materials can be very dusty and mouldy. Shredded straw was the worst for dust but once manure was applied the dust was controlled. Wearing dust masks was essential when turning straw and corn stover. We have seen no evidence of the presence of any gases that could present a breathing hazard. Manure can be a hazard in the work environment due to the presence of pathogens and offensive odours. Limited contact with manure is possible by wearing proper clothing such as gloves and coveralls, and taking care in handling hoses and fittings. Valves to drain connections have been installed, as have valves that can shut off the flow of manure. Noise during operation of the turner has not been an issue. The hydraulic and electrical motors produce little noise.

The method for applying manure has undergone some improvements. We now use two evenly-spaced manure application nozzles (from Husky Farm Equipment Ltd.). These are set so that the deflector plate faces downward. These nozzles give fairly even coverage and have no problem with plugging.

Evaluation of the aeration system

Aeration is scheduled based on the temperature in the compost. Each channel uses three pairs of temperature probes, spaced near the ends and in the middle. Paired temperature probes are inserted, one near the surface and the other near the bottom of the mass. The probes are removed during the turning operation. Originally, the data-logger/controller was set to switch from the constant level of aeration to an increased level when the average temperature of all six probes exceeded 55 ºC. It soon became obvious that, even though there were high temperatures, there was a range in temperatures. In fact, the average temperature in any of the channels is often below 55 ºC, depending on the materials being composted. The program was re-set to switch the fans onto the high rate when the temperature at one of the probes exceeded 66 ºC. This has worked well and apparently has supplied enough air to the composting material - temperatures have rarely exceeded 70 ºC and there has been no evidence that the process has gone into an anaerobic state. The variation of temperatures within the channel is greatest near the start of the process and evens out as time goes on - it appears to be related to evenness of application of liquid manure.

The plenum static pressure is measured at each fan. Static pressures are typically in the 120 to 165 mm range. Static pressure seems to be unrelated to compost material - i.e. dense materials have not led to an increase in static pressure. Pressure drop in the aeration system has not been measured, but it does not appear that under-sizing of the ducts is leading to the high static pressures. As mentioned earlier, the evidence suggests all parts of the channels are receiving adequate levels of aeration (though the mechanical turning may be helping).

The crushed stone floor used in Channel 3 was replaced with a concrete floor similar to that in Channel 2 between Batches 4 and 5. There were two reasons for this: a) It was difficult to drive on the floor to add materials and remove compost, and b) The temperatures never reached as high levels in Channel 3 as in the other two channels - whether this was related to the aeration system or drainage or something else is unknown. When we removed the crushed stone from Channel 3 to prepare for pouring the concrete floor, we found that the stone was filled with compost in parts of the channel. This would have prevented uniform aeration in the channel.

The performance of the aeration systems in Channels 1 and 2 was similar. The original expectation was that the spigot floor system in Channel 1 would out-perform the centre plenum of Channel 2. It did not increase the speed of the composting process. It did not affect the static pressure at the fan. The temperatures were similar. Observations so far suggest that the added expense of installing the spigot floor system is not justified for this type of system. Unfortunately, we do not have documentation of the difference in costs of the two floors. The spigot floor took approximately twice as long to prepare before placing concrete in the channels. Then the holes were drilled in the spigots. Normally, the supplies would cost more for this system. The floor in Channel 2 was much easier to install. If anything, the spigot floor has had more problems, as the holes tend to plug easily when compost is removed from the channel.

In an attempt to document differences between the aeration floors, temperature profiles were measured in each channel on several occasions during June to August, 1998. Up to 30 temperature readings were taken from each channel, representing two different depths, five positions along the length of the channel and three locations across the channel (i.e. close to each channel sidewall, and in the centre). In general, the temperatures near the surface of the pile were slightly lower than those from deeper in the pile. There was no tendency to have warmer temperatures in the centres of the channels compared to near the walls. The variations of temperatures within the three channels were similar - no floor type appeared to give a more uniform temperature than the others.

With the onset of winter in January 1999, it was obvious that the aeration fans in areas with significant snowfall should be located under cover or inside the compost shelter. It was first feared that gases and moisture produced in the compost building would damage the fans.

Corrosive gases do not appear to be a problem. Placing the fans inside the compost shelter may be practical - alternatively, a shelter should be constructed for the fans in areas of significant snowfall.

Evaluation of the physical setup - general

During the first two batches, we did not have experience at judging moisture levels of composting material. As a result, this material had a higher moisture content than desirable, thus slowing down the process. A microwave oven and balance are currently used to quickly determine moisture levels, with a high degree of accuracy. Generally, dry matters start at about 90% (e.g. dry straw) and eventually drop to about 25 to 35%.

The turner provided the most challenges due to the fact that it had to tear up big round bales, operate in channels full of dry material, operate in much wetter, heavier material, and do all of this with rather limited power. Eventually, modifications were made to allow it to operate efficiently in a variety of consistencies of material.

Removal of composted material was very difficult in Channel 3, with the crushed stone. This floor type lends itself much better to a continuous flow system. The skid steer loader dug into the stones if the driver was not very careful.

Channel width has created some problems. The channels are narrow enough that a tractor with front-end loader has a hard time making the turn into Channels 1 and 3 after coming through the doorway of the building. It still appears to be wise to have a building covering the composter, to prevent precipitation onto the compost. It is not as obvious whether the end walls are needed for this building, however. Wider channels would make channel loading and unloading much easier, whether end walls are used or not.

Evaluation of the compost process - general

a) Odours - Odour assessments were made on a rather subjective basis using college staff working in the building. Since odour concerns were the main driving force for this project, it was important that the project be run in manner that would minimize odours. In fact, it was soon obvious that odours were not an issue with this system. The composting system and the manner of adding the liquid manure both contributed to an environment where there was seldom any evidence of liquid manure odours. Similarly, there never have been the types of odours that some other compost operations have had to deal with. Because the levels were so low (or non-existent), no attempt was made to actually take air samples for "odour panel" analysis. The facility has had over 400 visitors in the first two years of operation and there has never been any mention of unacceptable odours - most people have been surprised at the lack of odour.

b) Management - During the first four batches, manure was added and the material was turned four or five times in the first week. After that, manure was only added if the material appeared to be drying out somewhat. The channels were turned when it appeared that the material was drying out on the surface, or every five days or so. Typically, manure was added six to eight times and each channel was turned 11 to 13 times during Batches 1 to 4. The first quantity of manure applied was very dilute, with a dry matter content of only 0.60 % (due to extra washwater in the particular storage source). Subsequent loads of manure had a higher dry matter content. The low dry matter content, however, meant that a much larger amount of liquid had to be dealt with in relation to the amount of N applied. From Batch 5 onward, manure was added three to five times, and the material was turned a total of five to seven times. The present recipe for straw consists of turning and applying manure in three passes on Day 1 (three passes does a better job of mixing the straw and manure), turning and applying manure twice on Day 4, and turning and applying manure once or twice on about Day 8. The material is currently being removed on Day 14 and placed into a pile or windrow where it finishes composting and curing.

Two quantities are especially important to farmers considering a composting system. The "**Manure per floor area**" represents the amount of manure per day that went into each channel. The amount of manure expressed as a function of time and compost channel area ranged from 3.2 to 9.7 L/day/m^2 during the first year of operation. During the past several months, however, more of an effort has gone into maximizing throughput of the system. Considering that manure is only added during the first two weeks of the process, if compost is removed from the channels at two weeks, it has the effect of at least doubling the amount of manure processed. As a result, as high as 28.5 L/day/m^2 has been achieved. For reference, a feeder pig produces about 6 to 8 L of manure per day - after the addition of dilution liquid.

The **ratio, by weight, of liquid manure to substrate** is also important. Farmers will want to maximize this number in order to minimize the amount of straw or other material that they must have available. The ratio ranged from 1.9:1 to 8.1:1 for straw, and was lower for wood fibre (average 1.1:1), corn stover (average 3.0:1), leaves (average 1.2:1), and corn cobs (average 2.0:1). A design target of 5.0:1 is achievable, especially for straw. It appears that it is possible to exceed a value of 8.1, but this involves applying manure to increase the moisture content of the compost in the channels to around 80%. This relies on high moisture losses during curing to bring the final moisture down closer to 60%. We experienced conditions that favoured this practice in the rather dry summer of 1999, with outside curing.

There were other differences between the substrates. The wood fibre needed to be turned more often than the other materials in order to keep it aerobic - the aeration air was not moving through the mass as easily. Also, because the wood fibre and corn cobs were more dense than the straw, the total loadings for the channels (carbon material and manure) were higher. Due to its lower initial density, the straw would shrink considerably in volume over the few weeks that each batch was composting. A summary of volume reductions during composting is shown in Table 1. In fact, the volume of straw after about 10 weeks of composting/curing was only about 5% of the initial volume - compared to 20 to 25% for corn cobs and leaves and 45% for wood fibre. Losses of total mass are summarized in Table 2, though not all data are available on losses after curing. Typical losses of mass in the channels (the period of most aggressive biological activity) are in the range of 45 to 65% of the total initial mass - mostly in the form of water vapour and carbon. More details on losses are given in Table 3. This shows losses of various components of the compost during the time spent in the channels. It shows differences between carbon materials. It shows that losses of total Nitrogen averaged less than 20% for all materials, which is less than typical losses of N for conventional manure systems.

An important issue for farmers is the total number of days to keep material in the composter. During the first several batches, the total time per batch was in the range of about four to six weeks (e.g. Batch 1- 39 days, batch 2-36 days, batch 3- 47 days, batch 4- 52 to 71 days, batch 5 - 42 days). It became obvious that the process was likely to be complete in about four weeks (for most materials). Most delays in the early batches in removing material from the channels were related to modifications to the turner - scheduling maintenance, waiting for repairs to be made, etc. Several batches were run where the compost created using straw was removed from two channels at week two and combined in the third channel for the following two weeks (while new batches were started in the first two channels). This had the impact of increasing throughput by 50% and it also created a greater depth of material - which allowed for better temperatures.

Table 1 - Reductions in volume during composting

Carbon Source	Average Total Amount Added (m3)	Average Total Amount Out of Channels* (m3)	Average Change %	Average Volume after 10 weeks (m3)	Average Change from Initial Volume %
Corn Cobs	72.4	18.4	-74.5	14.5	-79.8
Corn Stover	69.4	20.2	-70.6	NA	NA
Tree Leaves	78.6	18	-77.1	18	-77.1
Straw 2 Weeks	70.9	20.2	-71.5	3.5	-95
Straw 4 Weeks**	137.9	17.4	-87.4	8.6	-93.8
Wood Fibre	51.5	22.6	-54.5	24.7	-54.5

* removed at about 4 to 6 weeks except straw, as noted

** 2 channels of straw were combined after 2 weeks and composted in channel for 2 more weeks

Table 2 - Changes in total mass during composting

Carbon Source	Average Total Amount Added (kg)	Average Total Amount Out of Channels * (kg)	Average Change in Mass %	Average Mass after 10 weeks (kg)	Average Change from Initial Mass %
Corn Cobs	24988	8952	-64.2	NA	NA
Corn Stover	13215	6965	-45.2	NA	NA
Tree Leaves	18422	10090	-45.2	NA	NA
Straw 2 Weeks	12115	4455	-43.9	NA	NA
Straw 4 Weeks**	23767	8142	-65.1	5640	-75.3
Wood Fibre	22866	14096	-39.8	NA	NA

* removed at about 4 to 6 weeks except straw, as noted
** 2 channels of straw were combined after 2 weeks and composted in channel for 2 more weeks

Table 3 - Average losses of various compost constituents during the period of time in the channels for a variety of carbon materials - expressed as a percentage of the total mass added that has been lost during the compost process - for Batches 1 to 15

Constituent	**Straw**	**Corn Cobs**	**Corn Stover**	**Wood Fibre**	**Leaves**
Total Mass	55.8%	69.6%	45.2%	38.4%	45.2%
Dry Matter	49.6%	58.2%	17.6%	22.2%	41.8%
Carbon	54.6%	69.3%	31.4%	32.6%	54.3%
Organic Matter	56.8%	66.2%	29.4%	25.2%	53.5%
Total N	17.9%	14.4%	13.2%	-9.1%	9.1%
Average # days	31.8	52	31	38.7	51

Loss of mass for the compost created using straw is shown in Figure 2. This shows the wide variability from one batch to the next. Part of the reason for this is due to the experimental nature of the setup - a variety of management options are being tried to develop the most efficient approach. Part is due to the fact that the first year's emphasis was on perfecting the turner. A further reason may be due to the fact that manure having different properties was used for several of the batches - discussed later.

The next modification to the management involved removing the material at week two and stacking it outside where it could finish composting/curing. This basically removed our ability to aerate and turn the compost, but the process appears to have had no detrimental effect. It has not created an odour problem. It has allowed an increase of 100% in throughput of manure compared to early batches. This practice has not been used in the winter months so far.

Normally, the C:N ratios should be in a range of about 12 to 22 for finished compost. When it is higher, composting takes longer. When it is lower, there is often a loss of nitrogen to the air in the form of ammonia. There can also be an increase in odour. As we have learned how to run the system we have been able to keep the final C:N levels in the desired range. The highest final C:N was for the wood chips in Batch 4. C:N values typically start off high, and as manure is added (thus more N), the values drop.

The temperatures of the various batches were recorded. This temperature data revealed two things: A - The average temperatures were behaving as expected - rising to about 40 ^{o}C after one day, to 50 ^{o}C after 2 days and staying in the range of 55 to 65 ^{o}C for the next few weeks; and B - temperatures within the channels varied from location to location, and from day to day, especially during the first week. Of the six thermocouples in each channel, at a given time, the temperatures could be spread out over a 20 degree range. The most likely reasons seem to be

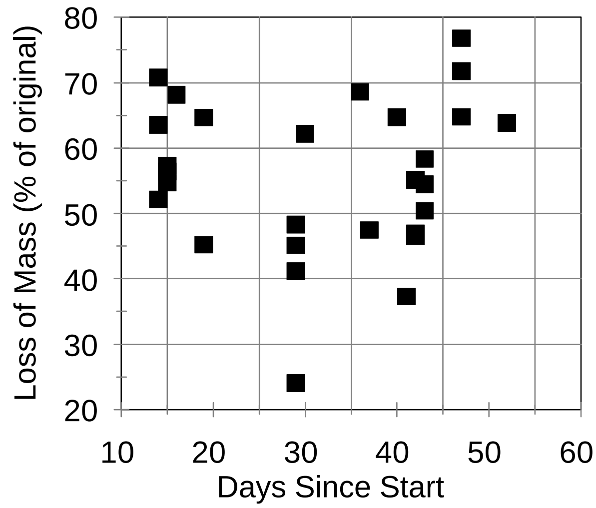

Figure 2 Loss of mass over time for various batches of compost created using straw and liquid swine manure

related to variations in moisture level, as it was difficult to be completely uniform with manure applications. These differences became less pronounced as the composting/mixing progressed. The system was quite responsive to additions of manure. If the temperature appeared to be dropping prematurely, addition of manure was all that was needed to restart the heating process. This rapid temperature response to fresh manure has been found on several occasions, and even when compost temperatures have dropped to near freezing (e.g. January, 1999).

At the start of the project, there was some fear that winter air temperatures would be so cold that it would be difficult to maintain the high temperatures needed in the compost. That did not appear to be the case during the cold weather of December, 1998, and January, 1999. We dropped back our aeration schedule to prevent freezing the compost but found no problem in maintaining high temperatures. The key was related to additions of manure and frequency of turning - any time we needed to boost the temperature, we simply added manure. The temperature rose within 24 hours.

c) Nutrients - At regular intervals, composite samples of substrate, liquid manure, and composting material were gathered from each channel and sent to the Land Resource Science Lab at the University of Guelph. Measurements included: carbon, ammonium-N, total N, P, K, pH, ash and moisture content. Whenever possible, sampling of the compost was done just after the turner had mixed the channel contents. Total amounts of substrate and liquid manure added, and total weights of compost coming out were measured.

Selected results of the nutrient analysis are given in Table 4. This shows concentrations of nutrients in the compost, compared to what was in the raw manure and substrate. There was very good conservation of N (see also Table 3). In raw manure, nitrogen typically is in the ammonium form. This is very volatile - while it is readily available to plants, it is also easily lost to the air if not covered with soil immediately after spreading. It also can cause serious environmental problems if it enters surface water. As a nutrient source, compost will therefore provide a more “slow release” form of nitrogen. When considering total N losses from a manure system, there is a potential for lower losses with composting, since many current systems have high losses of ammonia-N to the air (during storage, during spreading, before incorporation).

Table 4 - Average nutrient content of raw materials and composted materials

Material	NH_4-N mg/kg	NO_3-N mg/kg	N %	P %	K %	Dry Matter %	Ash %	pH	Total C DM Basis %
Raw Materials									
straw	46.9	25.2	0.45	0.07	1.22	90.3	6.13	7.7	43.7
building	7.1	0.58	0.2	0.02	0.13	64.7	38.6	7.7	35
slab wood	15.0	1.25	0.19	0.02	0.11	67.4	5.45	6.55	48.3
tree limbs	105.1	18.8	0.22	0.02	0.11	66.9	41.9	7.4	29.9
corn cobs	38.8	3.28	0.39	0.05	1.27	79.1	3.55	7.6	46.2
leaves	32.4	7.35	0.60	0.08	0.55	58.8	15.3	6.4	46.7
stover	14.0	11.5	0.44	0.08	0.4	72.5	11.3	7	43.4
manure 1*	957.6	1.69	0.17	0.04	0.18	1.38	44.7	7.1	31.2
manure 2**	2216	4.38	0.36	0.07	0.22	2.26	42.4	7.5	37.5
Compost Using:									
straw man1	211.8	145.9	0.6	0.24	0.74	26.3	21.2	7.9	39.6
straw man2	155.9	79.6	1.15	0.56	1.45	40.5	23.0	8.4	36.3
corn cobs	126.8	118.3	0.96	0.40	0.99	46.4	35.0	6.74	33.7
building	367.7	87.3	0.31	0.09	0.23	45.7	45.2	6.8	29.6
slab wood	639.5	35.3	0.43	0.17	0.27	38.8	18.2	7.7	39.4
tree limbs	564	131.6	0.51	0.12	0.35	38.1	39.2	8.5	30
leaves	237.6	88.9	0.65	0.21	0.42	29.2	35.7	8.3	36.3
stover	215.5	33.2	0.58	0.27	0.66	28.6	26.8	8.01	37.4

* manure 1 from college swine herd
** manure 2 from local farmer with wet dry feeders

The nutrients in the compost are more concentrated than in the raw materials, because so much moisture and carbon have been given off during the process. This needs to be considered for farmers creating nutrient management plans for their farms. The higher concentration of nutrients affects spreading rates and makes transport to different properties a more viable option - currently, travel time represents a significant cost of spreading for many farmers.

Table 4 shows the difference in nutrient content for the original liquid manure used (originating from the swine herd at the college), compared to manure from a local swine producer. The local producer uses a type of feeder which is popular among swine farmers in

Ontario. These wet/dry feeders lead to less spilled water in the pen, which reduces the moisture content of the manure (increases the dry matter content). This reduction in added water results in a higher concentration of nutrients. With composting, the manure supplies all the moisture needed plus most of the nitrogen. If the volume of manure added is enough to result in the correct moisture content, it seems possible that N may be over-applied. We have not fully analysed this, but early results suggest that the thicker manure works well, with similar losses of N to the more dilute manure. Less water in the manure has an impact on the farmer, in that more animals can be handled using the same size of compost building.

d) Curing - An important aspect of the process is the curing of the compost after removal from the channels. It can undergo further breakdown of organic matter if allowed to "cure". The material taken out of the channels at four weeks (for example) still showed signs that much of the substrate material had not completely broken down. By sitting in a pile for a up to two additional months, most of the initial structure was eliminated, leaving a "finished" compost material - especially for straw, tree leaves and corn cobs.

The curing piles were located on a concrete pad. For some of the time, the piles were covered with a tarpaulin, to keep rainfall out, though it was not clear how important it was to cover the material. Further breakdown occurs, so there is a further reduction in total mass - and slight further concentration of nutrients. Covering the piles with tarps tended to retain moisture when curing which seemed to help with the breakdown of the straw particles. Some method of leachate recovery should be in place if an uncovered storage is used.

No odours were associated with the curing in our study.

e)Pathogen Testing - We have tested the finished compost for the presence of weed seeds in a greenhouse study in which a number of finished composts were compared to sterilized soil and field soil. It appears that the composting process kills virtually all weed seeds but compost once cured must be stored in areas that prevent re-contamination.

We have also tested the compost for *E. coli* over the curing process. The raw manure tested at up to 5,000,000 *E. coli* per 100 mL. In all batches of compost tested levels dropped off to 0 detected when cured. In 12 of 19 batches the *E. coli* levels stayed at 0, 3 of 19 batches levels of *E. coli* were detected at the threshold level, and 4 of 19 had levels rebound to up to 2300 *E. coli* per 100 mL.

Further testing is required on both the *E. coli* and the weed seeds to determine the effectiveness of composting in eliminating these pathogens.

CONCLUSIONS

1. With monitoring of the C:N ratio, moisture level and aeration level, we have had very good success in controlling odours from liquid pig manure.

2. The compost turner (Marvel) has evolved to the point where it is now capable of handling a range of materials and can function in an automatic mode, thus reducing labour needs somewhat.

3. The ratio, by weight, of liquid manure to substrate ranged from 1.9:1 to 8.1:1 for straw, and was lower for wood fibre (average 1.1:1), corn stover (average 3.0:1), leaves (average 1.2:1), and corn cobs (average 2.0:1). A design target of 5.0:1 should be achievable, especially for straw.

4. The amount of manure processed expressed as a function of time and compost channel area ranged from 3.2 to 9.7 L/day/m^2 for compost left in the channels for four weeks. When a two-week cycle was used, this number was increased to a high of 28.5 L/day/m^2. (For reference, a feeder pig produces about 6 to 8 L of manure per day - after the addition of dilution liquid).

5. The compost should cure for a period of at least 2 months after removal from the composter. This will allow it to break down to the point where it can be marketed (i.e. off-farm uses).

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