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Moisture, Density, and Porosity Changes as Dairy Manure is Biodried

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Abstract. *The initial functioning of a biodrying process on an 85 cow dairy farm in the New York City (NYC) Watershed is described. This system started operation in the fall of 2001. The startup challenges and preliminary operational data on the forced air system, and establishing a procedure for processing the manure are described. The objective is to use the heat generated by aerobic composting to provide the energy to reduce 12% DM manure to a 60% DM residual. Forced air composting, under a roof, with the airflow controlled carefully should optimize this process. Using forced air to compost four foot high layers of manure/amendment mix in 21 days have shown the feasibility of this process. Moisture loss, density changes, and porosity changes are shown.*

Keywords. Dairy manure, Composting, Biodrying

Introduction

Society has recognized that animal agriculture can lead to excess nitrates in the ground water, pathogens and excess nutrients in the drinking water, Biological Oxygen Demand (BOD), and sediment in surface water. To avoid these problems, manure will increasingly be spread on dry soils in fields where the potential for runoff and leaching are low. Environmental agencies are prescribing these changes. There are now many state, provincial, and federal regulations on the timing and amounts of manure application. In many cases, manure storages that are sufficiently sized will be required to ensure spreading of manure on a growing crop. In 1997, only 10% of the dairy farms in New York State had more than 6 months of storage (Poe et al., 1999).

Manure from liquid storage is generating many complaints about odor. Stored liquid manure undergoes an anaerobic decomposition. The gaseous by-products of this process are offensive to humans. Society objects to bad odors as much as, if not more than, to poor water quality. Therefore, treatment for odor control will become more common as farms are required to store manure.

Phosphorous has been identified as the most common limiting nutrient in freshwater. States, provinces, and the federal government are responding by requiring phosphorous based nutrient management plans. Phosphorous based plans will require manure to be spread thinner and hauled longer distances to cover more fields. Therefore, there is an increased need for manure treatment that concentrates the phosphorous, making it easier to haul long distances. Treatment processes that reduce the mass of manure would meet this need as well.

Pathogens from manure can easily enter the environment (Geohring, 1998). Both society and regulators are increasingly trying to reduce the amount of pathogens or indicator organisms in drinking water and contact recreational water. Detection methods for disease-causing microorganisms have become more sophisticated. They are now able to trace the source of the pathogen. Treatment systems that reduce pathogens will be needed in the future.

Catastrophic failure of liquid storage system, such as failure of the storage or a large spill when applying, is a risk that farms and society want to avoid. Using an all solid treatment and storage will reduce the risk of major losses to the environment during storage and spreading.

Development of by-products that can be sold for profit off the farm could help maintain profitability while improving the environment. Compost or organic matter that can be used as a soil amendment may develop into a market that farms can take advantage of. Organic farmers and landscapers are growing businesses that may be looking for more of this type of material. Prices for compost material have been reported ranging from $5 per cubic yard to $30 per cubic yard (Bonhotal, 2000).

All these factors, odor control, phosphorous based spreading rates, pathogen reduction, catastrophic risk reduction, and by-product production, can be met using biodrying as described by Wright and Inglis (2001). This system would have the advantage over traditional composting of foul weather operation and reduced need for additional amendment. The roofed system keeps the compost operation drier, and the recycling of the dry finished compost reduces the amendment needs. This system should be able to produce a fairly dry, well mixed, compost that could be marketed off the farm to offset the costs of production and export phosphorus. Use on the farm would allow storage without the risk of spillage associated with liquid storage, odor control, and pathogen reduction. Most farms have solid handling equipment and expertise on the farm. Liquid handling equipment is an additional cost and management concern that needs to be considered when adopting a liquid storage system.

Objectives

The objective of this paper is to describe the initial functioning of a biodrying process on an 85 cow dairy farm in the NYC Watershed. Describing the moisture loss, density changes, and porosity changes will help designers as they propose new biodrying systems.

System Description

The farm where the system is installed has 85 cows in a tiestall barn bedded with sawdust and shavings, 100 heifers in a straw bedded pack three-sided barn, and 30 calves in a plastic covered calf facility bedded with straw. The building to compost the material was built 12.2 m wide by 30 m long based on piling the material 2 m deep. It was anticipated that 10.3 m^3 of compost would be needed to be mixed with the 17.4 m^3 of manure/soiled bedding produced daily. Each day 24.5 m^3 of compost plus manure would be placed in the compost building. This would produce 17.7 m^3 of compost at approximately 40% MC in 21 days. Taking away what was needed for recycling, there would be a daily production of 7.4 m^3, or 2,350 kg of compost per day. Yearly production would be 860 metric tons, or 2,700 m^3. This system consists of a three-sided composting shed with a forced aeration system installed in the floor. The composting shed is large enough to process the compost manure mix piled 2 m high for a 21-day period. Additional storage for the completed compost is provided on a pad with controls for rainwater runoff. This process is described in detail by Wright and Inglis (2001).

Although the start up of this system has demonstrated some problems, it is possible to have the system perform as designed as shown in Figure 1. During the winter the system has performed at a lower level as shown in Figure 2. Figure 1 shows a pile that was composed of fresh manure from the dairy barn, alfalfa hay, unfinished composted manure and moldy corn silage. The pile was 1.2 m deep. The mixture had a initial moisture content of 60% and a final moisture content of 30%. The performance of this pile was exactly what was anticipated. In hindsight the warm fall temperatures and low humidity for this time period may have contributed to the drying and excellent performance of this composting pile. The 1.2 m depth allowed the pile to reach high temperatures while still allowing the fans to control the temperatures of the pile. Air-drying allowed the moisture on the top few inches of the pile to be removed so no wet layer was present at the finish of the pile. The corn silage amendment may have given the pile more energy and porosity so airflow was maintained throughout the entire pile. This is the most successful run achieved with the composting process in this system.

The trial shown in Figure 2 was constructed of moldy alfalfa hay, unfinished compost manure and fresh dairy manure. The initial moisture content of this pile was 65% and ending moisture content was only decreased to 60%. The pile in Figure 2 was 1.8 m deep. Within 24 hours the pile settled to a depth of 1.2 m. The initial depth of the pile was increased from 1.2 m to 1.8 m and increased compaction resulted. The airflow in the pile became preferential and some areas of the pile did not get ample airflow. A 7.6 cm film of wet compost where moisture was leaving the pile formed on the top of the pile and may have restricted large amounts of moisture leaving the pile resulting in low moisture loss from the pile. The airflow to the pile did not affect the temperature of the pile and did not reduce the moisture of the pile as expected. Monometer readings showed 750 pa of air pressure. This is less than the 1200 pa of static pressure the system was designed for. Initially the fans came on as the temperature exceeded 55^oC. Continuous blowing did not reduce the temperature. At the end of the 14-day period there was about 1 day where the fans held the temperature at 55^oC. After 14 days the program set the fans to run continuously, yet it did not cool or dry the pile.

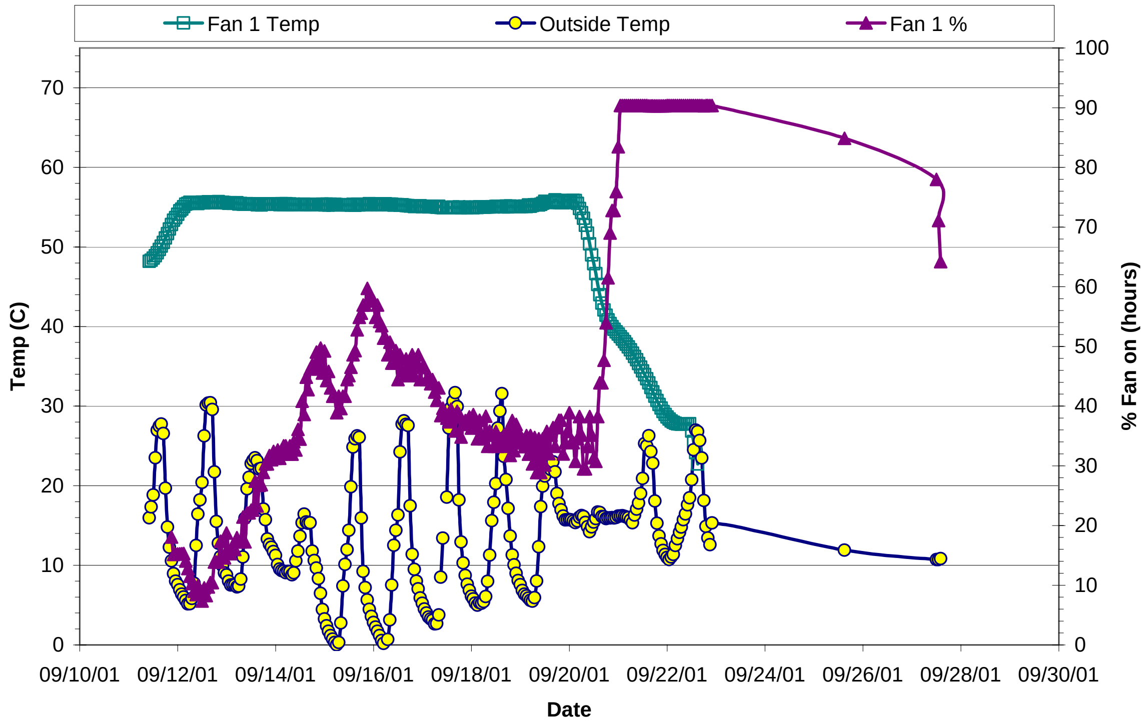

Figure 1. Successful composting run with good fan control and drying.

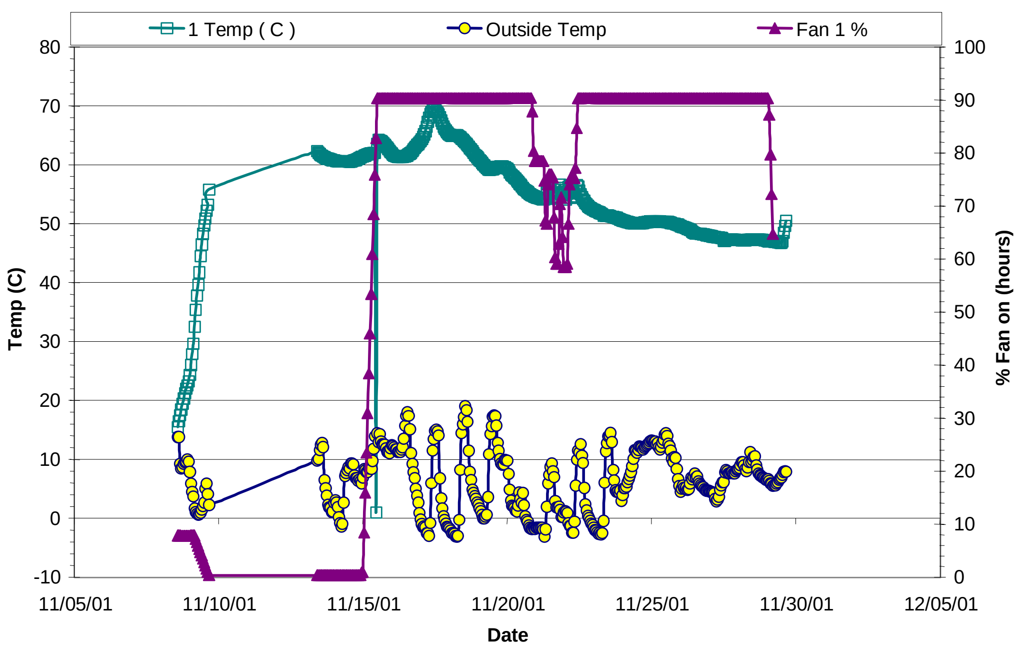

Figure 2. Unsuccessful composting run with inadequate air supply.

Discussion

The failure to get good air flow in Figure 2 is due to a number of factors. Increasing density, moisture content, and depth would tend to decrease the permeability of the compost material. These factors can be interrelated. As the moisture content increases, the density on a wet basis increases. Figure 3 shows a plot of density at different moisture contents compacted with 0, 0.29 and 1.45 kg/cm2 of pressure from Jewell et al (1984) biodrying experience. Obviously the higher densities at each moisture content are from the higher pressures.

Figure 4 shows the different densities at different moisture contents experienced during biodrying on this farm. Densities were measured by obtaining a disturbed sample then packing it into a known volume to the approximate density of the undisturbed material. The extra water fills voids that the air could travel through. The added moisture increases the weight of the compost, thereby increasing the potential for settlement. Wetter particles may also be reduced in strength so they do not hold each other apart as well or as long as dryer particles.

The depth of the compost increases the density of the compost by increasing the weight borne by the underlying layers of compost causing additional settling. The depth of the piles influences the density to a greater extent in wetter piles than in drier piles. Since dryer piles weigh less the depth needed to reach a given density is greater as the moisture content decreases. The increased depth also means less air per cubic meter of compost even if the same amount of air is blown up through the pile. Although the biodrying system was designed to hold the material at 2 meters the deeper piles do not seem to be getting the air flow they need.

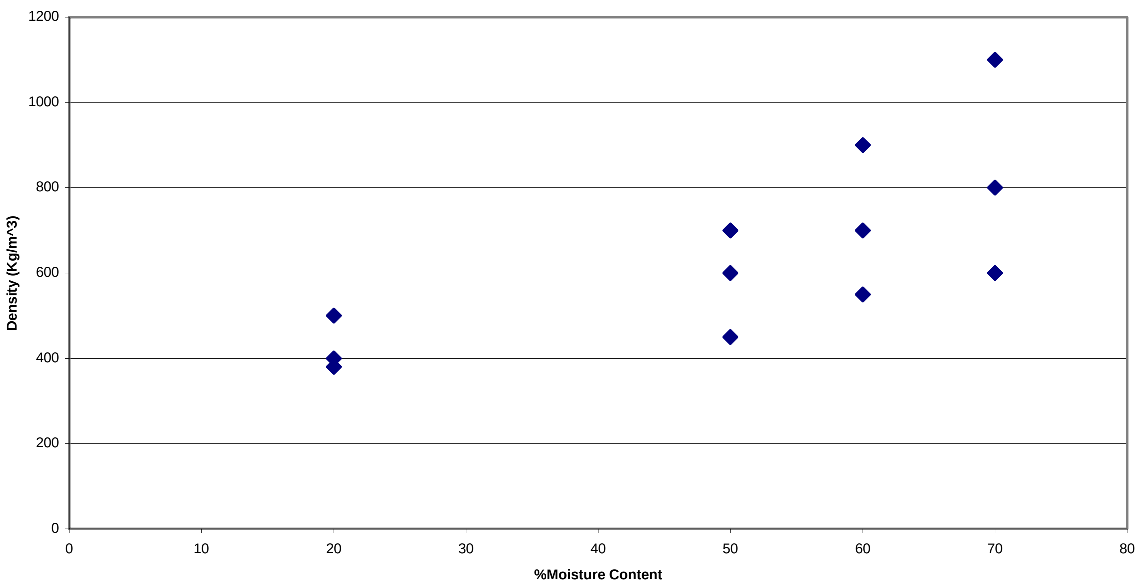

Figure 3. Density of dairy manure compost mix at different moisture contents with pressures of 0, 0.29, and 1.45 kg/cm2 (Jewell et al., 1984).

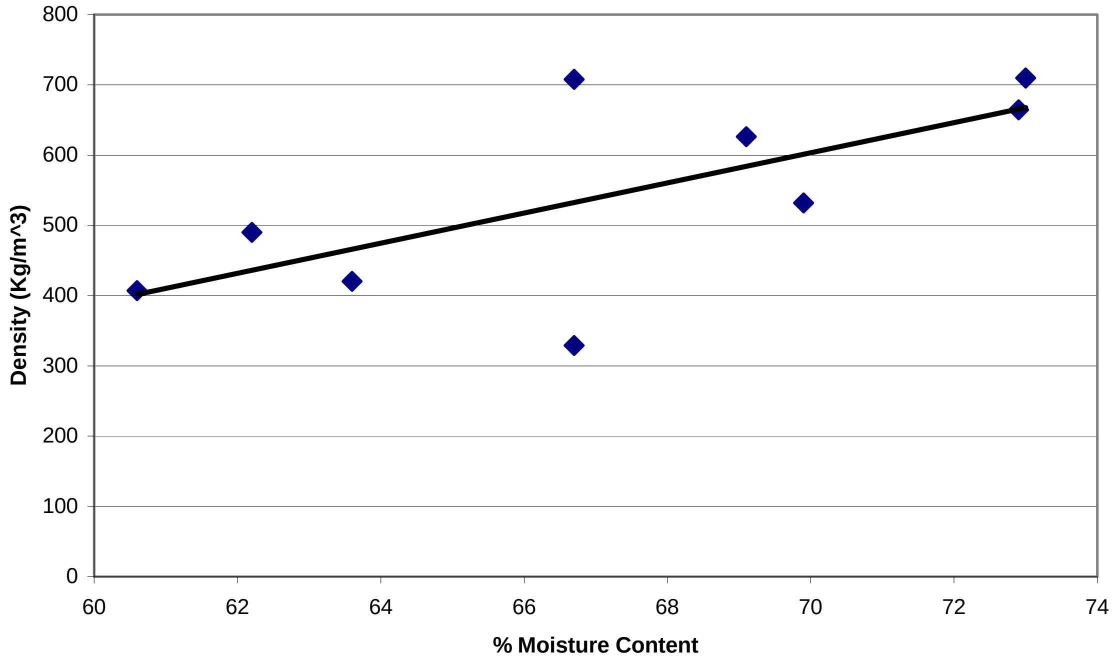

Figure 4. Density and moisture content of dairy manure and amendment mix while biodrying.

The compost mix is placed in the piles in the biodrying shed with a side sling manure spreader. The spreader has a mixing auger that is used to combine the amendment with the manure. The farm has tried to operate such that two loads of manure and amendment mix would equal one days manure. This has resulted in a moisture content of the mix averaging around 68% moisture. To get a lower moisture content the farm will have to go to 3 spreader loads per day. The biodrying shed was designed so material can be spread from the front of the building as well as along the back of the building to get an even pile height. A backstop on tracks was mounted along the back of the building to stop the compost mix from shooting through the building as material is unloaded. Wetter compost mix shoots straight out and hits the backstop. The dryer mixes spreads out better side to side but does not reach the back. In order to get an even pile depth two loads are put in the front and then one load is put in the back from the other side.

As the initial moisture content is increased the total amount of moisture removal needed per unit dry weight increases greatly. As shown in Table 1, material placed in the biodrying system at 70% moisture needs 1.66 kg of water per kg of dry compost removed to dry it down to 40% moisture. Material placed in the biodrying system at 65% moisture needs 1.19 kg of water per kg of dry compost removed to dry it down to 40% moisture. While material placed in the biodrying system at 60% moisture needs only 0.83 kg of water per kg of dry compost removed to dry it down to 40% moisture, or only half as much air and energy as the material starting at 70% moisture. Material at 60% moisture is also less dense and therefore more permeable than material at 70% moisture.

One solution to the high densities and low airflows would be to reduce the moisture content of the compost mix. Figure 5 shows the relationship between moisture content of the compost and static pressure of the air flow system. As the moisture content increases the amount of air that can be moved through the pile decreases. Since not enough air moves through the piles to lower the moisture content we have not seen the air pressure decrease and air flow increase as we would expect if the piles dried out. The 1.5 kilowatt fans have about 2.2 cm of static air pressure with no compost material over the discharge holes. These 1.1 cm holes spaced 0.3 meters apart were designed to apply a uniform pressure under the whole pile to discourage preferential flow.

Table 1. Percent moisture, weight, and removal needed per dry kg of compost.

% Moisture	kg of water per dry kg of compost	kg water removed to lower moisture content 5%
70	2.33	0.47
65	1.86	0.36
60	1.5	0.30
55	1.22	0.28
50	1	0.18
45	.82	0.15
40	.67	0.13

Since the compost mix has not dried, the piles show an increasing density and an increasing resistance to air flow over time as shown in Figures 6 and 7 respectively. If significant drying did occur the decreased moisture content from 70% to 40% might overcome increased density with age so that the compost would increase in permeability and more air would flow through the piles over time.

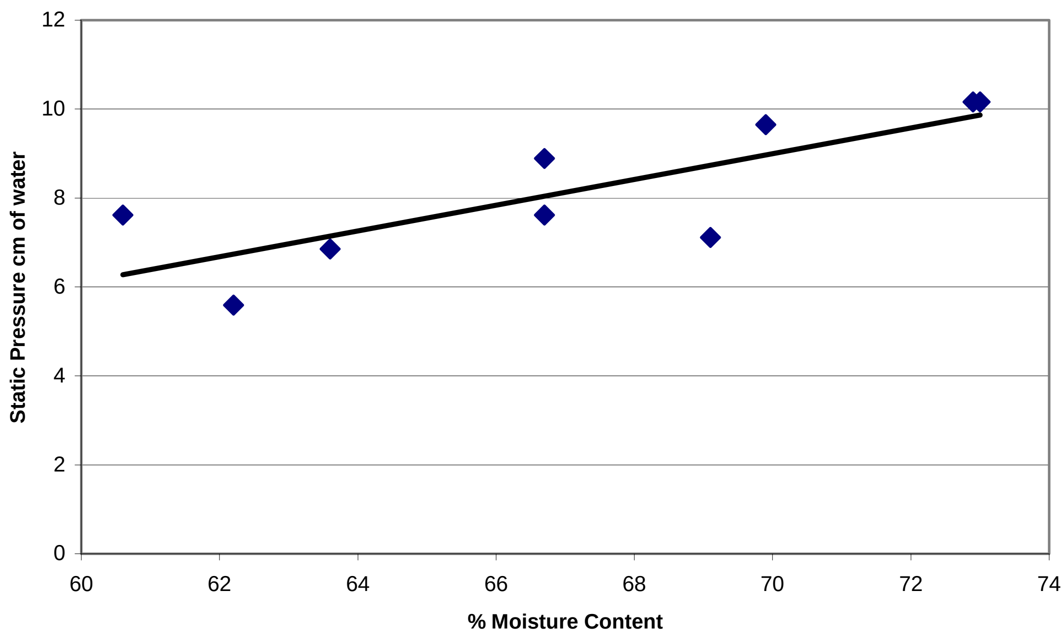

Figure 5. Static pressure of compost mix varies with moisture content.

Running the biodrying system at 60% moisture instead of 70% moisture effectively increases the surface area in the compost mix available for drying. This should also decrease the density and allow easier air flow. The extra recycled compost mixed in increases the total material in the biodrying shed. The needed amount of additional recycled amendment at 40% moisture content is substantial. Using 10,400 kg (22,933 lbs) of manure and bedding at 80% moisture produced at the farm daily, it takes 3,310 kg (7,304 lbs) of the recycled amendment to make the compost mix 70% moisture. Dropping the moisture content of the compost mix requires 10,170 kg (22,422 lbs) of recycled compost. This increases the volume of compost mix handled daily to

37 m^3 (1296 ft^3) from 24 m^3 (864 ft^3) or a 50% increase. There will be a labor cost to this increase as well as the need for a larger biodrying shed.

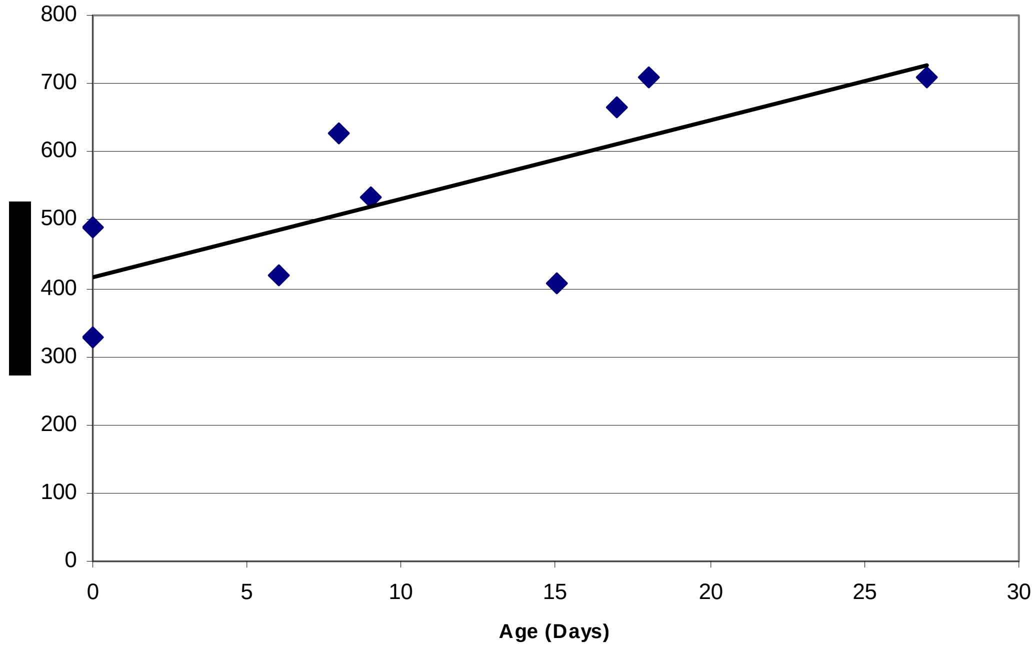

Figure 6. Density increases in the compost mix as settling occurs over time.

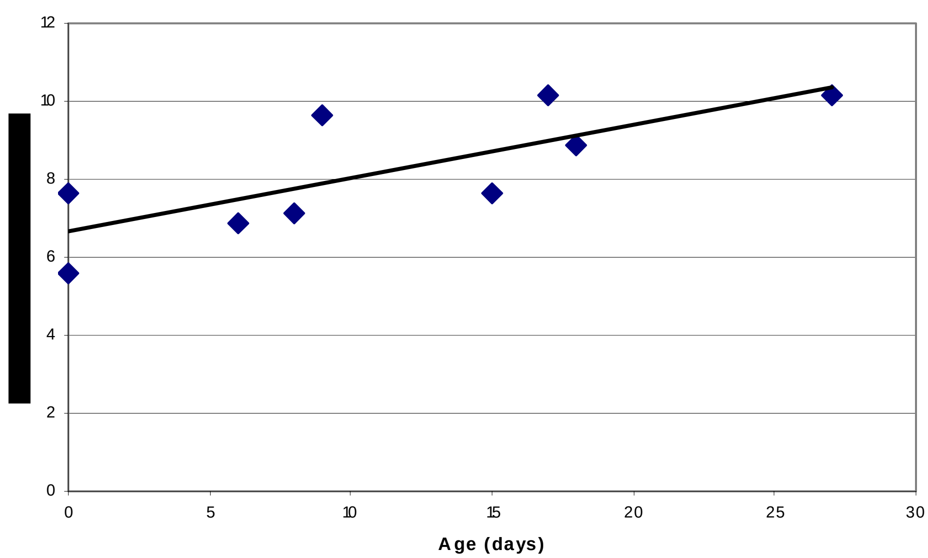

Figure 7. Static air pressure increases with time.

Another option to increase the air flow and obtain the moisture removal needed to create the recycle loop is to decrease the pile height. Lowering the initial pile height from 2 meters to 1.2 meters will also mean the biodrying shed will need to be larger. On this farm the composting shed would need to be increased about 12 meters in length to accommodate the extra floor space needed for lower piles.

There may also be more potential for preferential flow in the piles with lower head loss through them. Blown in snow would be a worse problem on shallower piles as the piles surface area to volume ratio would increase. During extremely cold weather shallow piles may not maintain the desired composting temperatures of 55°C.

Cold ambient air and snow blown in during the winter has also contributed to high moisture contents. The airflow system will allow for aeration of the composting piles in negative pressure. All the runs presented were aerated with positive pressure. This resulted in a 7.6 cm layer of wet compost at the top of the piles that may have restricted airflow and moisture loss from the pile. The reverse airflow will allow the moisture to condense in the air manifold of the system and run out the drain built into the system. This may produce greater moisture loss in the winter months where we have received poor results under positive pressure. Side wall curtains have been designed and will be installed to reduce the potential for snow to blow in the back. Next year we will see if these measures allow better winter time operation.

Conclusion

Although there are significant problems in achieving a recyclable 40% moisture content compost with the present biodrying system, reducing the moisture content initially from 70% to 60% and/or lowering the height of the compost piles from 2 m to 1.2 m should reduce the density and increase the air flow making drying more likely. These changes will increase both the operating cost of this system and increase the capital cost of future systems.

Continued work on this system is needed to determine if the benefits from the odor control, pathogen control, sales of compost, and phosphorous exporting potential will offset the capital and operating costs.

Disclaimer

This report was prepared by the Watershed Agriculture Council in the course of performing work contracted for the New York State Energy Research and Development Authority (NYSERDA). However, any opinions, findings, conclusions or recommendations expressed herein are those of the author(s) and do not necessarily reflect the views of NYSERDA.

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