Final Report

Feasibility of Using Composting Technology as an Environmentally Sustainable Option for the Treatment of Barnyard Runoff, Dairy Farm Milk House Washwater and Silage Juices

Submitted to

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

STUDY SUMMARY

The purpose of this study was to examine and demonstrate the feasibility of using composting technology as a treatment option for barnyard runoff, dairy farm milk house washwater and silage juices. The success of this treatment technology was anticipated to provide an environmentally sustainable and economically viable treatment option for barn yard runoff, milk house washwater and silage juices.

Turned pile composting technology was used for research purposes during this project. It is easily implemented, requires a minimum of labour and capital, and has a high potential for widespread implementation on Ontario farms. Composting activities were conducted on a an enclosed concrete pad. Barnyard runoff was used for experimentation purposes to demonstrate the evaporative capacity of the process. Although barnyard runoff water was used for demonstration and experimentation purposes, the information obtained was anticipated to enable the process to be extended to the treatment of milk house washwater and silage juices without the need for further research. Approximately 83 percent of all livestock manures are handled as a solid in southern Ontario (Coleman, 1987). Therefore, this process was anticipated to be suitable for implementation on a major number of farms in Ontario.

The energy released during composting of beef cattle manures was observed to be insufficient to compensate for heat losses which occur as a result of a combination of cold runoff addition and loader tractor mixing under cold ambient temperature conditions experienced during winter conditions.

In order for composting manures to be an effective liquid treatment technology they must have a high process temperature to provide high evaporative capacity. The low process temperatures observed during the study were not sufficient to provide an effective evaporative capacity.

At low process temperatures organic matter oxidation is believed to have been equivalent to moisture losses resulting in no net decrease in process moisture concentrations even though moisture losses were occurring. Composting under enclosed conditions is believed to be less effective at maximizing moisture losses because the increased evaporative potential from wind currents is negated. It is believed that composting under a roof canopy with open sides would provide a higher evaporative capacity. This combined with the use of a commercial windrow turner to reduce mixing

heat losses has potential to provide more appropriate levels of moisture loss during winter conditions.

1.0 LITERATURE OVERVIEW

Ecologistics Limited has been actively involved with composting research over the past five years. Literature searches have been conducted as part of past composting projects, and to-date no research work has been found pertaining to the use of composting manure or other organic matter as a waste treatment process for barnyard runoff, milk house washwater, or other agricultural liquid organic waste streams. However composting has been demonstrated to be a suitable treatment technology for contaminated soil remediation. As early as the 1940's, composting of sludges with a solids content of 4-5 percent in conjunction with a secondary bulking material, has been practiced. Based on the successful use of compost technology to date, as a waste treatment technology, its use as a barnyard runoff and milkhouse washwater treatment technology was anticipated to be very favorable.

The evaporative potential of composting organic matter is not documented in literature and is an important factor in the successful application of compost technology for the treatment of farm generated liquid wastes (ie: barnyard runoff, milkhouse wash water and silage juices). The only reference found, related to the evaporative potential of biologically active compost, noted that approximately 570 m3 of air diffuses through each tonne of compost daily during raised bed (passive aeration type) composting (Martin, L., et al 1992).

Approximately 80 percent of the dairy farms in Ontario still discharge milk house washwater directly to streams via subsurface drainage connections (Grand River Conservation Authority, 1992). These discharges result in high phosphorus and BOD loadings to streams and rivers. Using composting manure, something which can be readily produced on most dairy farms, was anticipated to provide a low-cost treatment alternative for liquid wastes generated onfarm.

Approximately 83 percent of all manures produced in southern Ontario are handled as solids (Coleman, 1987). Runoff from livestock facilities and manure storage is a significant source of groundwater and surface water contamination. Composting a portion of the manure to treat the runoff could offer low-cost on-farm environmental protection benefits and conserve plants nutrients for use in crop production.

Turned Pile Composting is well suited to solid manure, and with the high proportion of livestock manures handled as a solid, this technology can be easily implemented on a high percentage of Ontario farms. Widespread implementation of composting as a barn yard runoff and milk house washwater treatment technology was anticipated to significantly reduce the levels of ground and surface water contamination originating from agricultural activities.

1.1 Introduction

Nitrate contamination of groundwater from agricultural activities has become a provincial and an international concern. Agricultural manure and fertilizer management practices have been identified as significant contributors to the problem. Research on appropriate methods to reduce and eventually eliminate nitrate contamination of groundwater from manure and fertilizer management practices is being addressed. The need exists to extend this research to barnyard runoff, dairy farm milk house washwaters and silage juices. All three waste streams are highly susceptible to organic degradation. A demonstration of the evaporative capacity of composting processes was lacking in order to confirm that composting technology could be used to treat the volumes of waste generated by a typical farm setting.

Ontario currently has approximately 9,000 dairy farms with 80 percent of these farms discharging up to and in some cases in excess of 900 litres of milk house washwater directly to streams daily. As well, between 10 and 20 percent of the 9,000 dairy farms use washwater septic systems which can also be a potential source of groundwater nitrate contamination. Septic system weeping beds are not suited to high BOD loadings, and a large number of dairy washwater septic systems have failed because of this.

Current technology for the treatment of milk house washwaters includes systems comparable to domestic septic systems with weeping beds. Some farms on liquid manure systems also discharge their milk house washwater to their manure storage facilities. Recent research has shown that residential septic systems are a potential source of groundwater nitrate contamination (Cherry, LA., 1990). Cherry found that the discharge from septic system weeping beds travels as a plume, with little or no dilution or dispersion from other groundwater sources, as it moves downward and horizontally to the groundwater table. He reported that nitrates in the discharge plume, emanating from domestic septic system weeping beds, can exceed the allowable limit for drinking water of 10 mg/1 of nitrate nitrogen.

The disposal of dairy farm milk house washwater through sub-surface drainage has been a known practice on Ontario dairy farms. Studies have suggested that approximately 80 percent of the dairy farms in Ontario still discharge milk house washwaters directly to open ditches, creeks or streams via sub-surface drainage connections. (Down to Earth, Jan/Feb, 1992). The limited number of treatment alternatives is a main reason for the slow adoption of improved milk house washwater management practices by farmers.

Milk house washwaters contain high levels of bacteria, phosphorous and have a high Biochemical Oxygen Demand (BOD). The high BOD results in rapid depletion of oxygen in bodies of water to which the washwaters are discharged. This oxygen depletion and high phosphorous loadings can result in the rapid eutrophication of streams and water courses receiving milk house washwaters. Untreated milk house washwater can also be a health risk to livestock and humans drinking waters contaminated by the untreated washwaters.

2.0 BACKGROUND

Ecologistics Limited carried out a study, under funding from the National Soil Conservation Program, to study three composting processes which are farm oriented. These include turned pile composting, forced aeration mechanically mixed composting and passively aerated composting. The three processes were evaluated in terms of their environmental impact, nitrogen conservation potential, crop nutrient value and economic viability. Data collected from previous composting research indicated that composting manure has the potential to serve as a viable waste treatment option for barnyard runoff and milk house washwater. It was anticipated that once composting was demonstrated as a viable treatment option for barnyard runoff, its application could be extended to the treatment of dairy milkhouse washwater and silage juices. Moisture from barnyard runoff was anticipated to actually be of benefit to the composting process in maintaining optimum moisture levels during bacterial degradation. At the same time, the high bacterial activity in the active compost was anticipated to rapidly degrade and stabilize any organic compounds in the liquid waste stream being treated. The high temperatures of composting manure, which reach in excess of 60 f,

degrees C, has the potential to destroy pathogens present in liquid waste streams being treated. The degraded organic compounds also have the potential to provide additional nitrogen and phosphorous to the compost, increasing its crop nutrient value.

Composting, in general terms, is the biological degradation of organic substances to a stable humus rich material. The micro-organisms, which are involved in composting, break down organic materials to obtain the necessary elements for microbial biomass synthesis. Composting is a natural process. It occurs in nature, in every part of the world, every time any living plant or animal dies or defecates and the resulting organic mass decomposes. References to composting as a part of mans activities can be found back to Biblical times. In recent years sophisticated systems have been developed to promote rapid aerobic composting of a variety of organic wastes ranging from municipal sludges and solid municipal waste to food processing wastes and livestock manures.

Land treatment of organic wastes such as sewage sludge, cannery wastes, cheese whey and manures has been a practice carried out for many years and in some cases centuries. The organic materials are spread relatively thin on the soil surface and then incorporated into the soil. They are degraded by micro-organisms which occur naturally in the soil. Provided the soil has adequate porosity, degradation occurs aerobically without odour. If sufficient oxygen for aerobic activity is not present, degradation occurs under anaerobic conditions which results in putrid odours being generated. The aerobic bacteria responsible for organic matter degradation in soils are also responsible for the degradation which occurs under controlled composting.

The theoretical capability of treating organic matter in liquid organic waste streams (ie: barnyard runoff, milk house washwater and silage juices) using composting manure can be well substantiated by the success of existing land treatment and more sophisticated controlled waste treatment systems in existence, which rely on bacterial degradation as a treatment process. The treatment of farm-generated liquid wastes using composting manure, combined with effective crop application of the finished compost has the potential to produce a system which promotes maximum recycling of nutrients and is environmentally sustainable. This project was anticipated to demonstrate the feasibility of treating barnyard runoff using composting manure which could then be extended to milk house washwater and silage juices.

The success of this project was anticipated to provide an environmentally sustainable alternative for the treatment of such farm-generated liquid runoff and effluent. Currently, approximately 83 percent of all southern Ontario farms handle manure in the solid form, (Coleman, 1987). Therefore, the potential exists to implement composting on a large number of farms. Passive aeration composting has been estimated to generate an air flow of approximately 570 m^3/day per tonne of composting manure. Depending on the frequency of mixing and the turned pile configuration, turned pile composting was expected to generate air movement at an equivalent or greater level. The high air flow and heat generated during composting was anticipated to have a high evaporative capacity, making the process ideal for liquid treatment. In essence, the technology was being used as an evaporative process as well as an organic matter stabilization process.

As more farmers adopt environmentally sustainable practices, the spreading of liquid manure may diminish. Farmers are now taking a closer look at soil management as a means of increasing crop productivity. They are adopting tillage practices to improve soil structure. They are also examining and adopting methods to increase soil organic matter, reduce farm inputs and maximize recycling of farm nutrients through effective use of manures. Studies in recent years have shown that continued liquid manure applications can decrease soil organic matter, (Ndayegamiye et al, 1989) reducing soil productivity. Heavy applications of liquid manure have also been cited in massive earthworm mortalities and the depletion of soil oxygen to the point of being detrimental to crop growth. As well, recent research by Dean and Foran, 1991, indicates that the use of liquid manure either surface applied or injected poses a threat to groundwater by virtue of rapid contaminant movement through macropores to tile drainage waters, and where not intercepted, to groundwater.

Composting is already being carried out on numerous farms as part of a manure management strategy to effectively recycle nutrients. Such systems employed on Ontario farms, in conjunction with other acceptable manure management practices, were anticipated to provide an environmentally sustainable alternative treatment process for barnyard runoff, dairy milkhouse washwater and silage juices.

3.0 PURPOSE AND OBJECTIVES OF STUDY

The overall purpose of the on-farm investigation was to develop expertise which would facilitate the use of composting as an environmentally sustainable treatment technology for barnyard runoff, milk house washwater and silage juices. The specific objectives are as follows:

1. Study the feasibility of using manure composting technology for treatment of barnyard runoff, and extend this to treatment of dairy farm milk house washwater and silage juices.

2. Determine moisture evaporative capacity of composting manure to confirm the volumetric treatment capacity per tonne of composting manure.

3. Establish criteria for rural stakeholder organizations, government agencies, extension staff and farmers to use in implementing composting as a technology for the treatment of barnyard runoff, milk house washwater and silage juices.

3.1 Relevance of Proposed Study and Benefits to Ontario's AgriFood Sector

The Ontario Farm Environmental Coalition have expressed concerns relating to water quality and supply as affected by current agricultural practices as expressed in the document titled "Our Farm Environmental Agenda", and are dedicated to protecting both surface and ground waters in Ontario. Milk house washwater and manures have been identified by the OFEC as significant sources of potential water contamination. The farming community of Ontario itself has frequently identified milk house washwater, barnyard runoff and silage juices as potential sources of water contamination. Under such programs as the CURB and Land Stewardship programs, Ontario government agencies are actively striving to assist farmers in reducing water pollution from farming activities.

The successful demonstration and subsequent widespread implementation of the proposed treatment strategy was anticipated to provide farmers with an environmentally sound method of handling barnyard runoff, milk house wastewater and silage juices that would maximize on-farm nutrient recycling, and eliminates significant sources of water contamination from farming activities.

Presently, 80 percent of all milk house washwater is discharged directly to streams via subsurface drainage (Down to Earth, Jan/Feb, 1992). At the same time, 83 percent of all livestock operations in southern Ontario, handle manure as a solid (Coleman, 1987). The potential exists for widespread implementation of the proposed technology. Implementation of this strategy was anticipated to enhance the advancement of the OFEC's "Our Farm Environmental Agenda" by directly addressing issues of water contamination from manures and milk house washwater.

4.0 Experimental Procedures

The project was carried out as a series of four composting experiments using barnyard runoff as the waste stream being treated for all four experiments. All experiments were conducted on an enclosed concrete surface to eliminate precipitation from the composting manures. The procedures followed for the four experiments are outline in separate sections. Section 4.1 provides details of the first experiment which involved the use of compost material which had completed the initial high temperature phase of composting, prior to runoff addition. Section 4.2 describes the procedures followed for the second experiment which involved the addition of barnyard runoff to manures which had been allowed to undergo three weeks of composting prior to runoff addition. Section 4.3 describes the third experiment which involved the addition of barnyard runoff to composting manure as soon as the composting temperatures peaked. The procedures followed in the fourth experiment are described in section 4.4 and again involved the addition of barnyard runoff to composting manures as soon as the composting temperature peaked, but at a decreased volume.

4.1 Experimental Procedures - Experiment One

Manures which had undergone the initial high temperature composting phase were used for the first experiment. The composted manure was used to determine if reheating could be initiated as a result of runoff addition, to a degree which would be sufficient to provide evaporative capacity for treatment of barnyard runoff.

approximately 10 tonnes of compost material with an average moisture content of 55 percent was used for the experiment. Runoff was added to the compost material to raise the moisture content to 60 percent. This was accomplished by adding 1230 litres of runoff.

The compost material was then mixed regularly on a two and three day cycle to promote evaporation and reheating.

The temperature of the compost material was taken and recorded daily using a 1 metre long probe thermometer. A daily ambient temperature was also recorded.

4.2 Experimental Procedures - Experiment Two

Manure from a one month old manure pack accumulated from beef cattle bedded with wheat straw was used for the second experiment. A composting windrow was formed with approximately 12 tonnes of manure taken directly from the manure pack. The manures were allowed to compost for a three week period prior to runoff addition. The manures were mixed on two and three day cycles for the period before runoff addition, during runoff addition and following runoff addition to promote evaporation. Runoff was added in 200 litre volumes. Four composite manure samples were taken before each mixing and prior to each runoff addition, and analyzed for moisture content.

The temperature of the compost material was taken and recorded daily using a 1 metre long thermometer probe. A daily ambient temperature was also recorded.

4.3 Experimental Procedures - Experiment 3

Manure from a three month old manure pack accumulated from beef cattle bedded with wheat straw was used for the third experiment. A composting windrow was formed with approximately 12 tonnes of manure taken directly from the manure pack. The manures were allowed to compost until the temperatures peaked, and then runoff addition was commenced. The manures were mixed on two and three day cycles for the period during runoff addition to promote evaporation. Runoff was added in 50 litre volumes. Four composite manure samples were taken before each mixing and prior to each runoff addition, and analyzed for moisture content.

The temperature of the compost material was taken and recorded daily using a 1 metre long thermometer probe. A daily ambient temperature was also recorded.

4.4 Experimental procedures - Experiment 4

Manure from a four month old manure pack accumulated from beef cattle bedded with wheat straw was used for the fourth experiment. A composting windrow was formed with approximately 12 tonnes of manure taken directly from the manure pack. The manures were allowed to compost until the temperatures peaked, and then runoff addition was commenced.

The manures were mixed on two and three day cycles for the period during runoff addition to promote evaporation. Runoff was added in 25 litre volumes. Four composite manure samples were taken before each mixing and prior to each runoff addition, and analyzed for moisture content.

The temperature of the compost material was taken and recorded daily using a 1 metre long thermometer probe. A daily ambient temperature was also recorded.

5.0 Experiment Results

The results of the four experiments conducted for this project are presented in four sections. Section 5.1 provides results for the first experiment which involved the use of compost material which had completed the initial high temperature phase of composting, prior to runoff addition. Section 5.2 describes the results for the second experiment which involved the addition of barnyard runoff to manures which had been allowed to undergo three weeks of composting prior to runoff addition. Section 5.3 presents the results of the third experiment which involved the addition of barnyard runoff to composting manure as soon as the composting temperatures peaked. The results of the fourth experiment are described in Section 5.4, and again involved the addition of barnyard runoff to composting manures as soon as the composting temperature peaked, but at a decreased volume.

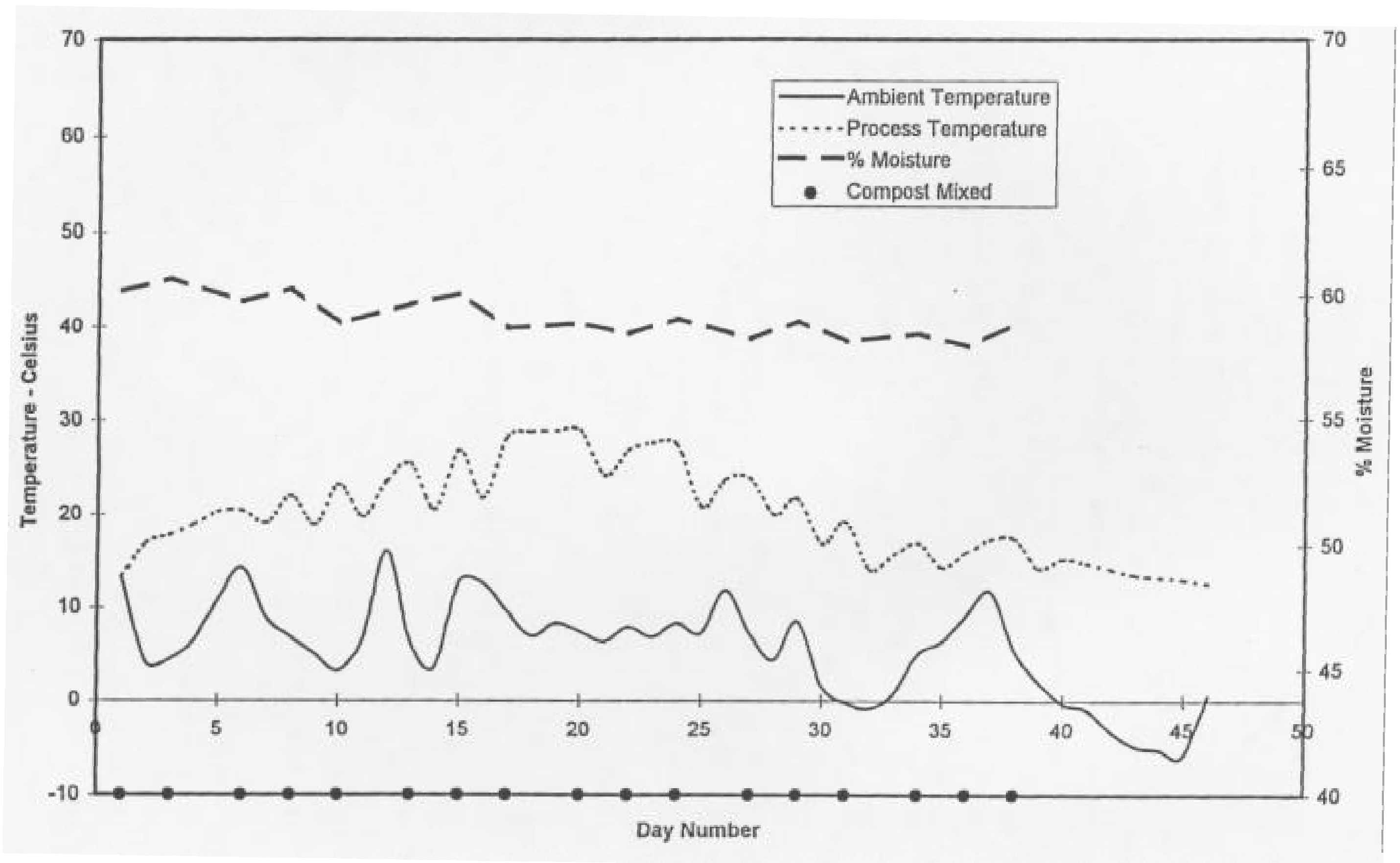
5.1 Results - Experiment One

Table 5.1 shows the compost temperature, the compost moisture content, the ambient air temperature and the mixing frequency for experiment 1. The temperature of the compost material was observed to increase to approximately 30 °C as a result of runoff addition and mixing. The low temperature peak is believed to be partially the result of relatively low ambient temperatures during the experiment period. The observed temperature peak was not high enough to provide the evaporative capacity necessary for treatment of liquid waste streams. It was concluded from this experiment that composted manures could not be stimulated sufficiently by the addition of runoff to provide temperature levels necessary for high evaporative capacity. As a result, the use of composted manure was concluded to be an inappropriate media for treatment of farm generated liquid waste streams.

5.2 Results - Experiment 2

Figure 5.2 shows the compost temperature, compost moisture content, compost mixing frequency and timing and volume of runoff addition. The compost windrow for the second experiment was set up at ambient temperatures slightly above freezing and yet within three days the composting manure had reached a peak temperature of 65°C. This indicated that low ambient temperatures are not a limiting factor in achieving initial peak compost temperatures sufficiently high to facilitate high rates of evaporation.

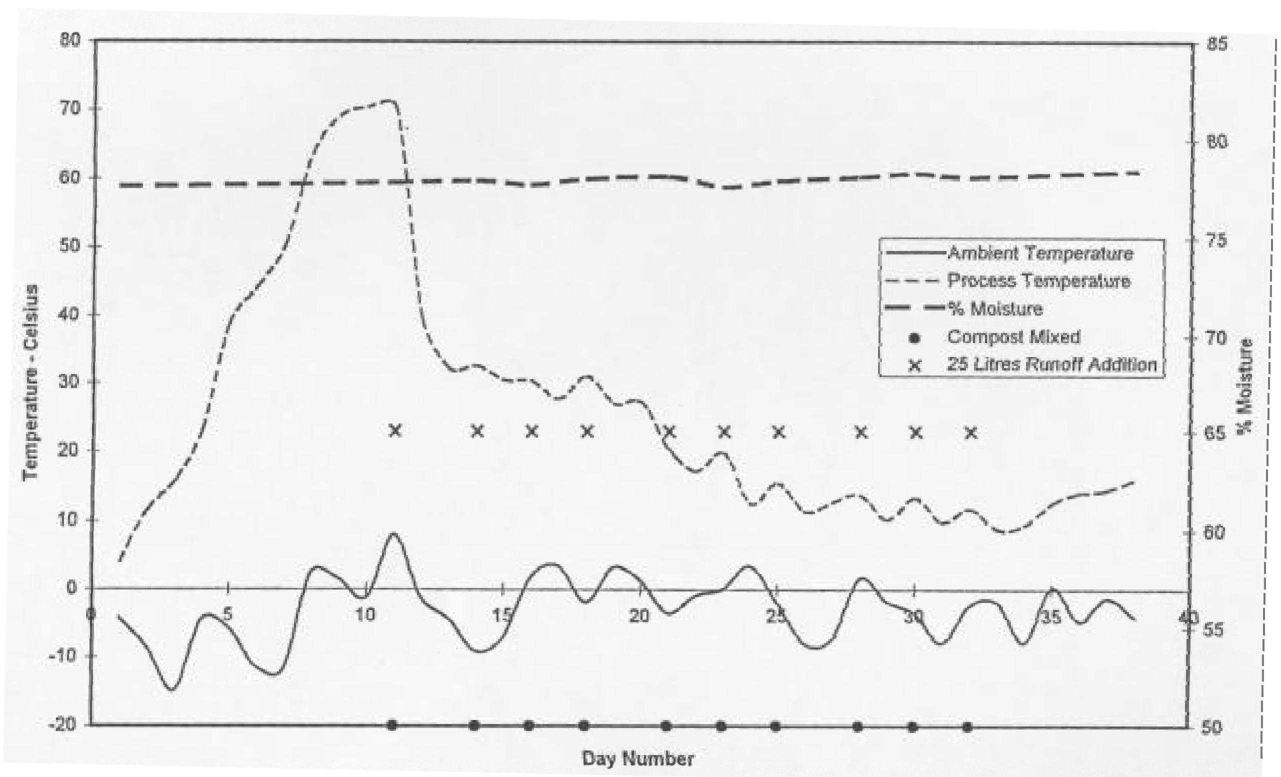
Figure 5.1 Process Results for treatment of Barnyard Runoff Using Compost as the Treatment Media - Experiment 1



During the three week period prior to runoff addition, mixing was observed to result in process temperature drops of 5 to 10 °C. The process temperature was observed to recover over a 1 to 3 day period. After runoff addition and mixing, the process temperature was observed to drop by up to 24 °C, substantially more than was observed strictly do to mixing. This was do to a combination of below freezing ambient temperatures and the cooling effect caused by adding cold runoff. After adding 200 litres of runoff for the second time, seepage was observed around the edges of the compost windrow and runoff addition was suspended to allow the process to recover temperature wise and to allow time for additional evaporation. The process was mixed and monitored for an additional 3 week period after runoff addition was suspended. The process was observed to make substantial temperature recovery after each mixing, but remained at least 15 °C below the original peak temperature. It was also noted that the level of temperature recovery declined gradually over time, after each mixing. Moisture levels did not decrease during this period either and after six weeks of process activity the process was terminated. The lack of moisture decrease was believed to be the result of low process temperature and the result of organic matter oxidation rates equivalent to the moisture loss occurring through evaporation. As a result the moisture levels of the compost remained constant or tended to increase slightly as process time continued. Based on the results of this experiment the process strategy was modified and runoff addition was commenced at lower volumes and as soon as the process reached peak temperature.

Mixing of the composting manures under cold weather conditions was noted to result in an inversion of released vapours during the mixing process in enclosed facilities with one end of the building open and roof vents. These vapours were found to be of concern because they caused nausea and headaches and it was believed that the high levels of ammonia released during the early phases of composting were the cause. The use of a face respirator with ammonia and amine filters reduced the health effects but did not eliminate them and it is believed that secondary compounds are present which pose a health risk. As a result the composting manures were moved to an outdoor concrete pad for mixing and returned to the enclosed facilities after mixing.

Figure 5.4 Process Results for treatment of Barnyard Runoff Using Composting Beef Cattle Manure as the Treatment Media - Experiment 4.



5.3 Results - Experiment 3

Figure 5.3 shows the compost temperature, compost moisture content, compost mixing frequency, and timing and volume of runoff addition for the third experiment. The compost windrow for the third experiment was set up at ambient temperatures below freezing and yet within seven days the composting manure had reached a peak temperature of 72 °C. This again indicated that low ambient temperatures are not a limiting factor in achieving initial peak compost temperatures sufficiently high to facilitate high rates of evaporation. Substantial temperature decreases were observed after runoff addition and process mixing. Fifty litres of runoff was applied to the composting manure on five occasions. Slight temperature recoveries were observed after each runoff application and mix. however the temperatures remained 30 to 40°C below the peak temperature. As a result of the low process temperature, evaporation was not sufficiently high to result in a decrease in process moisture levels. After the fifth application of runoff the process was allowed a three week period to recover temperature wise. Process temperatures were observed to gradually increase but did not climb above 25 °C over a three week period and the process was terminated after six weeks. Based on the results of this experiment a fourth experiment was conducted with run off addition volumes reduced to 25 litres.

5.4 Results - Experiment 4

Figure 5.4 shows the compost temperature, compost moisture content, compost mixing frequency, and timing and volume of runoff addition for the fourth experiment. The compost windrow for the fourth experiment was set up at ambient temperatures below freezing and yet within seven days the composting manure had reached a peak temperature of 72 °C. This again indicated that low ambient temperatures are not a limiting factor in achieving initial peak compost temperatures sufficiently high to facilitate high rates of evaporation during winter conditions. Substantial temperature decreases were observed after runoff addition and process mixing. Twenty five litres of runoff was applied to the composting manure on 10 occasions. Slight temperature recoveries were observed after each runoff application and mix. However, the temperatures remained 30 to 60 °C below the peak temperature. As a result of the low process temperature, evaporation was not sufficiently high to result in a decrease in process moisture levels. After the tenth application of runoff the process was allowed a one week period to recover temperature wise. Process temperatures were observed to gradually increase but did not climb above 20 °C and the process was terminated after approximately six weeks. A combination of low ambient air temperatures and the addition of low temperature runoff are believed to be the cause of the low process temperatures observed. As well, loader tractor windrow mixing although effective for mixing is believed to result in higher temperature losses than would be experienced with a commercial type windrow turner. This is because of the increased time that small volumes of composting material are exposed to low ambient temperatures during tractor windrow mixing.

5.5 Nutrient Analysis Results

Table 5.1 shows the total nitrogen phosphorus and potassium analysis results of the compost and raw manures used for the runoff treatment experiments, and the nutrients in the partially composted manures after runoff addition and composting.

Table 5.1. Nutrient Analysis Results

Experiment Number		Nitrogen D.M. Basis	Phosphorus D.M. Basis	Potassium D.M. Basis
Experiment 1	Start	2.69	0.55	5.82
Compost media	Finish	2.93	0.67	5.95
Experiment 2 Manure media	Start	2.08	0.30	2.57
	Finish	2.07	0.56	4.16
Experiment 3 Manure media	Start	3.27	0.34	3.57
	Finish	2.55	0.53	4.82
Experiment 4	Start	2.18	0.37	4.45
Manure media	Finish	2.36	0.47	4.44

Organic matter loss occurs during composting which results in a concentration of the mineral nutrients. This is generally reflected in the analysis results. The amounts of runoff added to the three processes which used raw manure as the treatment media was very low because of the high moisture levels experienced through out the processes. As a result nutrient differences do to runoff addition were not observable. The higher nutrient levels experienced at the completion of Experiment 1 which used compost as the treatment media are attributed to a combination of runoff addition and possibly continued organic matter loss during the experiment which resulted in a nutrient concentration.

6.0 Conclusions

The energy released during composting of beef cattle manures was observed to be insufficient to compensate for heat losses which occur as a result of a combination of cold runoff addition and loader tractor mixing under cold ambient temperature conditions experienced during winter conditions.

In order for composting manures to be an effective liquid treatment technology they must have a high process temperature to provide high evaporative capacity. The low process temperatures observed during the study were not sufficient to provide an effective evaporative capacity.

At low process temperatures organic matter oxidation is believed to have been equivalent to moisture losses resulting in no net decrease in process moisture concentrations even though moisture losses were occurring. Composting under enclosed conditions is believed to be less effective at maximizing moisture losses because the increased evaporative potential from wind currents is negated. It is believed that composting under a roof canopy with open sides would provide a higher evaporative capacity. This combined with the use of a commercial windrow turner to reduce mixing heat losses has potential to provide more appropriate levels of moisture loss during winter conditions.

7.0 REFERENCES

Cherry, J. A. 1990. Septic Systems and Ground Water, Synopsis of the Waterloo Research Program. Septic Systems and Ground Water Conference, Toronto, Ontario.

Coleman, D., P. Roberts. 1987. Cropping, Tillage and Land Management Practices in Southwestern Ontario, Soil and Water Environmental Enhancement Program Report.

Foran, M. and D. Dean. 1991. The Effect of Farm Liquid Waste Application on Receiving Water Quality. Final Report, RAC Projects 4306 and 5126, Ontario Ministry of the Environment.

Grand River Conservation Authority. 1992. Down to Earth, January/February, Volume 4 Number 1.

Gresham, C. Composting Observations in the Rodale Research Centre Demonstration Garden, 1988 Summary. Rodale Press, 1988.

Haug, R.T. Compost Engineering Principles and Practice, Ann Arbor Science Publishers Inc., Michigan, 1980.

Hayman, David G. 1992. Personal Communication. Upper Thames River Conservation Authority.

Kay, B.D. Land Resource Science 1989 Annual Report. University of Guelph.

Malcolm, I. 1992. Personal Communication. Alfred College of Agricultural Technology.

Martin, L., G. Gershuny. 1992. The Rodale Book of Composting. Rodale Press, Emmaus.

Mathur, S.P., et al. Static Pile Passive Aeration Composting of Manure Slurries Using Peat as a Bulking Agent, Biological Wastes, Volume 34, 1990.

Metcalf & Eddy Inc. 1979. Waste Water Engineering: Treatment, Disposal, Reuse, McGraw-Hill Inc., New York.

M. M. Dillon Limited. Composting A Literature Study. Prepared for the Ontario Ministry of the Environment, May 1990.

Ndayegamiye, A. and D. Coté. 1989. Effect of Long Term Pig Slurry and Solid Cattle Manure Application on Soil Chemical and Biological Properties. Canadian Journal of Soil Science, 69:39-47.

Our Farm Environmental Agenda Steering Committee. 1992. Our Farm Environmental Agenda. Ontario Federation of Agriculture, Toronto.