Research priorities for the storage of solid dairy manures in Quebec

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Barrington, S.F., and Piché, M. 1992. **Research priorities for the storage of solid dairy manures in Quebec**. Can. Agric. Eng. **34**:393-399. The concentration of livestock operations in Quebec, as well as their proximity to most river systems, has brought about water quality problems. Substantial subsidies are being disbursed to correct manure storage practices; however, environmental authorities have been alarmed at the number of dairy cattle producers taking advantage of this financial help to change over their handling system from a solid to a liquid type. A survey was, therefore, conducted among dairy producers of the Montreal area to identify improvements which could make solid systems more attractive. Two main points came out of this survey: the dairy farmer considers that the practicality of a handling system is more important than its cost; the handling of seepage is the main problem associated with solid systems.

La concentration des exploitations animales au Québec, ainsi que leur proximité des rivières, ont engendré des problèmes de qualité d'eau de surface. Afin de corriger cette situation, des sommes importantes furent octroyées pour la construction d'entrepôts étanches à fumier. Mais, les autorités environnementales se sont inquiétées du nombre important d'agriculteurs laitiers qui se sont prévalus de ces subventions pour passer d'un système de manutention solide à un système liquide. Une enquête fut donc réalisée auprès d'agriculteurs laitiers de la région de Montréal dans le but d'identifier les points à améliorer afin de rendre les systèmes de manutention de fumier solide aussi intéressant que ceux au liquide. Deux points principaux furent identifiés par cette enquête: l'agriculteur laitier pense à la commodité du système et à sa propreté bien avant de se préoccuper de son coût: les purins à entreposer avec l'amas occasionnent des problèmes associés à la manipulation des fumiers solides.

INTRODUCTION

The concentration of livestock operations in Quebec, as well as their proximity to most river systems, has brought about water quality problems. This, in turn, has lead to corrective measures for the storage and disposal of animal wastes. As a result, the Quebec government introduced a substantial subsidy program in 1987 to encourage the construction of storage facilities. Two years after the introduction of this program, a significant proportion of dairy farmers had opted for liquid manure handling facilities whereas, before, their manures were stockpiled as solids on the ground. This changeover indicated a definite interest in liquid systems over those presently available for solids. Because solid manures offer some agronomic advantages over liquid wastes, some engineering considerations should be given to the improvement of their handling and storage systems.

A survey was, therefore, conducted among dairy farmers of the Montreal area to establish what changes are required in order to make solid manure handling facilities as attractive as the liquid systems.

LITERATURE REVIEW

In the Province of Quebec, the agricultural industry has gravitated towards livestock production. The dairy industry ranks first, contributing 35.3% of all gross agricultural revenues. The pork industry stands in second place, since 1975, with 19% of all agricultural gross revenue and is followed by the poultry and beef industries contributing, respectively, 10.5% and 9.5% of these revenues. Horticultural and crop productions follow in fifth and sixth place with 7.8% and 3.9% of the gross revenues (Paradis et al. 1989).

The concentration of livestock operations is another important aspect differentiating Quebec's agriculture from the other Canadian provinces. Whereas Quebec possesses only 5.5% and 5.1%, of the total and improved farm land in Canada, respectively, it holds 11.5% of all livestock and 33% of all dairy cows. It also possesses 28.2% of all pigs and 23.2% of all poultry. Livestock operations are slightly less concentrated in Ontario which holds 8.9% of the Canadian tillable land base with 18.3% of all cattle, 30.2% of all pigs and 34.9% of all poultry (Agriculture Canada 1991).

The configuration of farms in Quebec, and especially in the Montreal area, is also an important factor contributing even more to the impact of manure management on the quality of the surface waters. Most lots have been subdivided in such a way as to have water frontage. The lots are, therefore, very long and narrow extending generally from a river. Furthermore, all farm buildings are built on the lot frontage and are generally drained directly into the adjoining natural drainage system. As a consequence, all manure storage facilities are located close to rivers and, where the storage facility is nothing but a solid pile on the ground, its drainage is directly discharged into the frontal water course.

The concentration of livestock facilities has resulted in the deterioration of Quebec surface waters. The main areas of concentration are located just north and southeast of Montreal (the L'Assomption and the Yamaska River basins) as well as south of Quebec city (the Chaudière River basin). Normal river water nitrogen concentrations, according to Environment Canada (1980), are of the order of 0.1 to 0.5 mg/L, if no organic matter contamination is occurring. North

of Montreal, for example, the L'Assomption River has a nitrogen concentration exceeding 1.2 mg/L. The Yamaska River, southeast of Montreal, has a nitrogen concentration of 1.5 mg/L and is considered the most contaminated river in Quebec (Ministère de l'Environnement du Québec 1989).

This contamination of Quebec surface waters has led to environmental regulations as well as financial incentive programs to improve the storage and land disposal of livestock wastes. The dairy farmers of the province took advantage of these programs to change over from solid to liquid handling systems. Such a trend has alarmed environmental authorities, especially in consideration of the organic matter content of the manures, the possible leaching of nutrients after the land disposal of the waste, and the introduction of soil compaction as well as odor problems.

Because all cropping practices generally result in the loss of soil organic matter of the order of 0.7 to 1.0 $t \bullet ha^{-1} \bullet y^{-1}$ (Gosselin 1986), the most logical treatment for manures is their disposal on tillable land. Livestock wastes are excellent soil conditioners. Their organic matter increases the number of earthworms (Unwin and Lewis 1986), improves the aggregation as well as the structure of the soil (Weill at al. 1988; Mbagwu 1989; Mbagwu and Piccolo 1990) and increases the water holding capacity, a beneficial effect especially during dry growing seasons (Ndayegamique and Côté 1989; Dormaar et al. 1988). Nevertheless, the treatment of livestock wastes through soil applications must not diminish the productivity of the system. As compared to slurries, solid dairy manures are generally known to have less environmental impact on the soil medium. This environmental impact occurs especially during the decomposition of the organic matter, a process susceptible of causing anaerobic conditions in the root zone.

Liquid manures, to a larger extent than solid manures, are known to alter the aerobic conditions of the soil following their application. The decomposition of the manure's organic matter can cause some oxygen limitations and favour the development of anaerobic micro-organisms at the expense of the aerobic populations (Doran et al. 1976). The decomposition of any fresh organic matter in the soil requires the breakdown by a complex chain of aerobic organisms starting with bacteria and fungi, carried on by actinomycetes, cyanophyces, algae, protozoa, anthropoids, and nematodes; and completed by insects (Mustin 1987). As soon as the soil becomes anaerobic, this chain of oxygen-requiring organisms is broken and organic matter decomposition is slowed. Other consequences then follow, such as increased nitrogen losses through denitrification and the depletion of oxygen for the plant, in the root zone. Reddy et al. (1980), as well as Paul and Beauchamp (1988), demonstrated that denitrification occurring after the application of cattle manure is related to its volatile fatty acid content (VFA). Liquid cattle manures are rich in VFA as compared to their solid or composted counterpart. Reports of a change in the soil's microbial population from aerobic to anaerobic have been reported by Acea and Corballas (1990). This changeover can last for a period of 45 days following the application of cattle slurries. A review of the beneficial effect of manures over chemical fertilizers is presented in Table I. There is some evidence that solid cattle manures, with bedding, have a greater positive effect on yield at lower application rates, as compared to cattle slurries. This advantage in efficiency with solid manures containing bedding may result from lower N losses, such as through denitrification, and from an improved soil structure.

Solid dairy manures also emit less odors than their liquid form (Sobel at al. 1988). Skarp (1975) measured levels of odors escaping from solid and liquid dairy manures and found that both types of waste released certain quantities of gas, but that liquid manures emitted gases lethal in nature as opposed to solid manures. Klarenbeek (1985) reports similar findings with poultry manures, where the liquid wastes emit a much higher level of obnoxious odors.

Because solid manures seem to offer many agronomic advantages over slurries, some engineering considerations should be given to improving the design of solids dairy manure systems. To better grasp the problems associated with solid systems, as compared to the liquid ones, a survey was conducted among the dairy farmers of the Montreal area. The basic objective of this survey was to identify the areas which could be improved in order to make the solid manure system more acceptable. From this survey, handling problems and research priorities could be identified.

METHODOLOGY

The study was initiated by finding a list of cattle producers who had changed their manure handling from a solid to a liquid system. This job was facilitated through the Montreal office of the Quebec Ministry of the Environment, which provided a list of producers who had benefited from the manure storage subsidy program during 1988 and 1989. This list, containing 160 names of cattle farms (beef, veal and dairy), was used to randomly select 40 farms having made the transfer from solid to liquid systems. These 40 farms were initially contacted by telephone to further restrict the survey to the dairy farmers. Thus, 15 of the selected 40 names were dropped during this first operation, because:

1) they operated either a beef or veal operation;
2) they were no longer in operation; or
3) they had been misclassified as cattle producers when they were hog or poultry producers.

The remaining 25 dairy farms were visited in order to complete a questionnaire.

The questionnaire, formulated for this study, was designed to identify the reasons behind the changeover from a solid to a liquid manure handling system. To formulate the questions, assumptions had to be made as to the possible influencing factors:

1) solid manure handling facilities are more expensive;
2) solid manure systems are not as practical as their liquid manure counterparts;
3) dealers and storage contractors influence the choice of manure handling systems;
4) liquid manure systems result in more odor problems;
5) liquid manure disposal on fields leads to more soil compaction problems;
6) liquid manures have a greater tendency to leach once applied to soils and must therefore exhibit a lower fertilizer efficiency.

Table I. Effect of manure rate on crop yield

Reference	Soil fertilization		Average yield improvement over chemical fertilizer treatment (%)	Trial (yr)	Soil type	Note
	Type	Rate (m^3/ha) or (t/ha)				
Swanson 1954	dairy manure compost local peat moss sheep manure tobacco stalks	5.5 t/ha (dry matter)	+40 +30 +25 +25	9	silty loam	crop: cabbage location: Connecticut dairy manure compost contributed to the highest soil enrichment in organic matter
Cordukes et al. 1955	solid dairy manure	45 t/ha	+ 3 to + 5	3	clay loam	crop: cereals and alfalfa location: Ottawa, Ontario
Bunting 1963	manure and bedding fresh sludges treated sludges sludge/straw compost N/straw compost	17.5 to 35 28 to 56 21 to 42 17.5 to 35 17.5 to 35 t/ha	+28 to +43 +11 to +15 +18 to +10 +21 to +28 +13 to +17	7	sand to clay	crop: potatoes, cabbage location: England bedding in manure was found to improve soil structure
Mathers and Stewart 1980	solid beef manure	22 67 134 268 536 t/ha	+150 + 3 -13 -28 -80	3	silty clay	crop: sorghum location: Texas lower yields may result from salt and nitrate accumulation in the soil
Phillips et al. 1981	liquid dairy manure	95 230 370 m^3/ha	+ 4 + 5 + 4	6	silty loam	crop: grain corn location: Ottawa, Ontario yield improvement was not significant over that of chemical fertilizer
Beauchamp 1983	liquid dairy manure	24 48 96 m^3/ha	- 9 -10 + 5	6	silty loam	crop: grain corn location: Guelph, Ontario slurry injection in 250 mm strips at 100-150 mm depth
Safley et al. 1989	liquid dairy manure	80 160 m^3/ha	-27 -14	3	sandy silt	crop: grain corn location: North Carolina, lower yield may result from salt accumulation within soil receiving the injected manure

Based on these assumptions, 11 questions were formulated (Table II) and asked during the interviews. The responses were recorded on the forms. To analyze the importance of each response, they were categorized by meaning. In some cases, farmers gave more than one answer, which implies that for some specific questions the total number of responses adds up to more than 25. To identify the answers which carry the most weight among dairy producers, non-parametric statistics were used (Daniel 1978). The Chi-Square, goodness of fit test method was used with nominal statistics to differentiate between preferred responses. This method also gives a level of probability that all answers are equal in frequency. To identify answers which were significantly more frequent, a confidence level of 95% was used.

RESULTS AND DISCUSSION

Examination of the list of newly constructed manure storage facilities in the Montreal area indicated that out of 160 farms,

Table II

Question	Answers Received	Frequency of the Answer
For what reasons have you changed over to a liquid system when your previous system was solid?		
	1. With liquid manures the handling is easier in the barn and from the storage.	15*
	2. I use a pneumatic manure evacuator which can easily be used in combination with a liquid storage facility.	4
	3. As compared to solid manures, liquid manure handling operations are cleaner.	4
	4. Liquid storage facilities take less room.	3
	5. To be able to spread the manure by irrigation.	2
	6. I feed lots of haylage and the manure tends to be more liquid.	1
	7. I already had all the equipment to handle liquid manures from storage.	1
Are liquid manure handling systems more economical than the solid ones?		
	1. The costs are the same.	11
	2. Yes, the solid manure storage facilities are more expensive: custom operators charge less for liquid manures.	11
	3. Liquid systems are more expensive because I had to change all my field disposal equipment.	3
	4. Liquid systems are cheaper because custom operators charge less to spread the manure on tillable land.	3
Is it easier to handle liquid manure as compared to solid manures?		
	1. Yes, the handling operation from the tank is cleaner and faster.	17*
	2. Liquid manures can be spread on pastures and hay fields without leaving surface deposits.	7
	3. It is not easier.	4
	4. Yes, liquid manures are easier because they can be spread by custom operators.	3
	5. Yes, with an irrigation system, there is less soil compaction.	2
Have others influenced your decision to change over from a solid to a liquid system?		
	1. No, the decision was mine.	19*
	2. Yes, I was influenced by my neighbours.	5
	3. Environmental considerations have influenced my decision.	1
Did the sales representative for a manure storage contractor influence your decision?		
	1. No.	25*
Does a solid manure storage cost more than a liquid manure tank?		
	1. Yes, the solid manure storage facilities cost more and the subsidy is also smaller.	10
	2. I think the costs are about the same.	7
	3. No, the solid manure storage costs less.	5
	4. I do not know.	3
Are you satisfied with your changeover?		
	1. Yes.	22*
	2. No, the expenses are too high.	2
	3. I cannot say yet.	1

Have you had more complaints because of odor problems?

1. Not more than before.	15*
2. Yes, because I am close to public facilities.	2
3. Not as of yet.	2
4. I have had less complaints than before.	1
5. No answer.	5

Have you observed any soil compaction problems since you started spreading your liquid manures?

1. No manure can be spread on hay fields.	19*
2. It is too early to tell yet.	5
3. Less problems have been observed because an irrigation system can be used to spread the manure.	1

Have you observed a difference in the fertilizer value of the manure?

1. Yes, because all the manure is retained whereas with a pile on the ground, a lot of seepage is lost.	14*
2. I cannot tell yet.	6
3. No, I have not observed any difference.	3
4. I use less chemical fertilizers, especially on my hay fields.	2

What improvements could make solid manure handling systems more interesting?

1. Store the seepages in a tank separated from the platform.	13*
2. Reduce to one the use of two types of disposal equipment (liquid for the seepages and solid for the pile.)	9
3. Separate the seepages from the solids to make the handling out of storage a cleaner operation.	9
4. I do not know.	5
5. A manure pile attracts flies and is not aesthetically appealing.	2

Why did you build your manure storage facility?

1. I was obliged by the Quebec Ministry of the Environment.	13*
2. To clean the site and facilitate the handling out of storage.	7
3. Because I could get a subsidy and it would facilitate the handling out of storage.	5

Note: * implies a 95% confidence level that this answer is preferred within the group.

from 1988 to 1989, 60% had opted for a change in manure handling system, from solid to liquid. Twenty five of the farms selected for the initial contact by telephone were among this 60% group who had made the changeover. These 25 dairy producers were visited and interviewed to complete the questionnaire.

The 11 questions asked during the interviews are listed in Table II, along with all the elements of answers received and the frequency or number of producers who gave the same answer. The most interesting elements of answers are those with a 95% confidence level. This confidence level tests the hypothesis that a specific answer is more frequent than the others. Thus, the answers with a high confidence level identify the most popular problems associated with solid manure handling systems.

The survey identified two major problems associated with solid manure systems: the cleanliness of the system and the requirement of dual equipment for the field disposal of the solid manures. Most dairy farmers agreed that solid manure systems are not as clean as their liquid counterparts. This problem stems from the fact that solid manure holding facilities (platforms) require the storage of the solids as well as their seepage. When removing the manure from the platform, the seepage can never be completely pumped out before-hand and the machinery must circulate in 150 mm of slurry. The operation is therefore messy. Solid manure storage systems also require dual handling equipment during the field disposal operations, a first for the liquid seepage and a second for the solid manures. Those are two main elements which require design modification, according to the dairy farmers of the Montreal area.

The cost of one system, as compared to the other, does not seem to be a major factor since no clear cut answer came out more frequently, despite the two questions asked. This response either means that the producers did not look at cost before they selected their system, or, that this component varies widely among operations. If the first element is true, then it means that cost is secondary to dairy farmers; their primary concern is a system which will function properly. If the second element is true, then the cost of a changeover from a solid to a liquid system can vary widely among farms. Nevertheless, the lack of agreement concerning cost is inter-

esting as it clearly shows that the financial aspect is secondary or quite variable. This is contrary to many articles written recently by environmental and agricultural authorities. In an attempt to encourage dairy farmers not to make this changeover from solids to liquids, these articles concentrated on economical comparisons of both systems. These articles would have been more effective if they had pertained to the more practical aspects.

The fact that the decision to change over was not influenced by the dealers or the storage contractors raises another interesting point. Originally, contractors were suspected of playing a major role in the changeover since it is much easier for them to build closed circular manure tanks as opposed to round or square structures with an entrance (platforms).

The producers interviewed also gave elements of solution to the questions of odor, soil compaction and nutrient leaching problems. It seems that odors from liquid manure storage are not a problem as long as the operation is located away from public facilities. Soil compaction and nutrient leaching problems are alleviated through the spreading of liquid manures during the summer on hay fields, an operation which was not so practical with solid manures. Nevertheless, the changeover to liquid manures was recent in all cases and the answers given by the producers may have been premature.

CONCLUSION

A survey conducted among dairy farmers of the Montreal area identified two major problems associated with solid manure handling systems:

1) solid manure systems are not as clean and as practical as liquid facilities;
2) solid manure storages require two sets of equipment for their field disposal, a set for the solid pile and a set for the contaminated rainfall retained by the structure.

The cost of one system (solid or liquid) versus the other was less of an issue for the dairy farmers interviewed.

The two major problems associated with solid manure handling systems and identified by dairy farmers can be associated with the seepage and liquids stored along with the solids. Any concept reducing or even eliminating the presence of liquids with the storage would improve the popularity of solid manure handling systems. Furthermore, any extension work geared at improving the popularity of solid manure systems should emphasize the practical rather than the economical aspects.

The present investigation leads to further questions with respect to the development of solid manure systems. The following points could therefore be investigated during another interview:

1) how much more are dairy farmers willing to pay to be able to handle their manure as a solid but without seepage?
2) what inconveniences are dairy farmers willing to put up with (i.e. reduce farm machinery access due to the presence of roof) in exchange for a solid manure storage with little seepage accumulation?

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