A modified septic system for the treatment of dairy farm milk house wastewaters

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[1]*Faculty of Agricultural and Environmental Sciences, Macdonald Campus of McGill University, 21111 Lakeshore, Ste. Anne de Bellevue, Québec H9X 3V9, Canada; and* [2]*Cemagref, Rennes Regional Office, Rennes, France. *Email: suzellebarrington @sympatico.ca*

Morin, S., Barrington, S., Whalen, J. and Martinez, J. 2008. **A modified septic system for the treatment of dairy farm milk house wastewaters.** Canadian Biosystems Engineering/Le génie des biosystèmes au Canada **50***:* 6.7 - 6.15. In 2001, the Quebec Ministry of Environment modified its livestock waste management regulations and required dairy farms to treat or land spread their milk house wastewaters because of the contamination load exerted when discharged into a water course without treatment. For small dairy farms with fewer than 60 cows, conventional technologies implied an investment of at least $15 000 Can. The objective of the project was, therefore, to develop a modified, low cost and sustainable septic tank – seepage field system for the treatment and disposal of milk house wastewaters while fully valorizing the nutrients and using the water for irrigation. On two dairy farms with 40 and 50 cows, a sediment and milk fat trap was installed before, and a drained 0.45 ha seepage field was built after, the existing septic tank. The project consisted of checking the two modified systems for clogging by digging out sections of sewer pipes after two years of operation; measuring and sampling milk house wastewaters to establish the annual nutrient load; and comparing the contamination load of the seepage field drainage waters to that of a control area. The milk house wastewaters produced by the farms lead to an average field TN, TP, and TK loading of 60, 50, and 80 kg ha^{-1} y^{-1}, respectively. The average volume of wastewater generated, of 17.5 mm/month, did not saturate the soil as no sign of saturation was observed when excavating the sewer pipes. The accumulation of milk fat inside the sewer pipes on one farm resulted from the disposal of wasted milk into the septic system, the absence of a water softener, and the fact that this fat was not regularly removed from the trap as required. The modified septic system had no major impact on the quality of its drainage water. The low system modification cost of $4400 Can and the treatment efficiency achieved meant that the concept is a feasible solution for most small dairy farms. **Key words**: milk house, wastewater, milk fat, nutrient load, seepage field clogging.

En 2001, le Ministère de l'Environnement du Québec modifiait son règlement sur la gestion des fumiers à la ferme et exigeait le traitement des eaux usées de laiterie. Par conséquent, les entreprises laitières avec moins de 60 vaches se voyaient obligées d'investir plus de 15 000$ Can. pour l'installation d'un système conventionnel de traitement de ces eaux usées. L'objectif du projet était donc de modifier le système de fosse septique et champ d'épuration pour pouvoir traiter à coût raisonnable les eaux usées de laiterie, tout en valorisant ces eaux et leurs nutriments. Sur deux fermes avec 40 et 50 vaches, un basin de sédimentation et de captage de gras fut installé en amont de la fosse septique existante, et un champ d'épuration drainé de 0,45 ha fut construit en aval de la fosse septique. Le projet consistait à: faire le suivi des champs d'épuration pour évaluer leur colmatage après deux ans d'opération; mesurer et échantillonner les eaux usées de laiterie pour établir leur charge annuelle en nutriment, élément qui dimensionne le champ d'épuration pour un traitement durable, et; faire le suivi des charges de contaminants évacués par le système de drainage du champ d'épuration qui assure son opération. En effectuant la moyenne des deux fermes, les eaux usées de laiterie offraient une charge annuelle de NT, PT et KT de 60, 50 and 80 kg ha^{-1} an^{-1}, respectivement; le volume moyen généré était de 17,5 mm/mois, ce qui ne suffisait pas à colmater le champ d'épuration tel que constaté à la fin du projet. L'accumulation de gras dans les tuyaux du champ d'épuration d'une des fermes résultait de l'envoie de lait sale dans le système, l'absence d'adoucisseur d'eau dans la laiterie et le manque de nettoyage de la fosse à sédiments et gras. Le drainage du champ d'épuration assurait son bon fonctionnement sans décharger de charge contaminante dans les fossés environnants. Le système modifié ne coûtait que 4400$ Can., et réussissait à traiter de façon durable les eaux usées des fermes laitières. **Mots clefs**: laiterie, eaux usées, gras, nutriments, colmatage de champs d'épuration.

INTRODUCTION

In 2001, the Quebec Ministry of Environment modified its livestock waste management regulations and required all dairy farms to either treat or land spread their milk house wastewaters. With BOD_5 and TP (total phosphorous) levels of 300 to 10 000 and 6 to 183 mg/L, respectively, milk house wastewaters can cause environmental problems and odour nuisances when discharged into a water course without treatment (Table 1).

This modification meant that most Quebec dairy farms with a solid manure system had to invest in a milk house wastewater treatment system or a liquid storage system with land spreading. Most of these farms had insufficient storage capacity in their manure platform or a herd small enough to be allowed to stock

Table 1. Contaminant loading of milk house wastewaters.

Parameter	Equipment first rinsing*	Equipment second rinsing*	Average load**
BOD_5 (mg/L)	1164 (327)***	459 (280)	300 to 10,000
TSS (mg/L)	614 (74)	148 (70)	800 to 10,400
TP (mg/L)	31 (11)	26 (13)	6 to 183
pH	6.5 (0.6)	7.1 (0.7)	-
Fat (mg/L)	165 (185)	34 (20)	-
NH_4-N (mg/L)			5 to 625
NO_3-N (mg/L)			0.3 to 6.5

* Jamieson et al. (2002)
** Loerh (1983)
***Values in parentheses are standard deviations.

Table 2. Description of the two dairy experimental farms.

Description	Farm MH-1	Farm MH-2
Herd size (cows)	40	50
Type of enterprise	Biological	Conventional
Cow breed	Holstein and Jersey	Holstein
Manure management	Solid piled directly on the soil	Solids stored in a manure platform along with the seepage and contaminated rainfall
Septic tank size (m^3)	3.4	3.4
Milk butter fat (%)	4.0	3.5
Pipe line capacity (cows)	32	42
Soap addition for equipment washing	Manual	Manual
Soap used for equipment washing	Phosphoric acid (315 mL/d) Chlorinated detergent (420 mL/d)	Phosphoric acid (315 mL/d) Chlorinated detergent (420 mL/d) Antiseptic soap (120 mL/d)
Other water treatment		Water softener (250 - 300 kg salt/y)
Well water quality*		
TN (mg/L)	0.2	0.15
TP (mg/L)	0.0	0.0
TK (mg/L)	6.8	3.4
pH	7.2	7.5

*Sampled and analyzed during the course of the project

pile solid manure directly on the ground. Nevertheless, those farms with the proper storage capacity found that milk house wastewaters represented a large and costly volume to land spread, considering the limited nutrient value. The dairy farms with a liquid manure system were not affected by the modified regulations as milk house wastewaters were already used to make slurries.

Several treatment technologies were available for small dairy farms with generally fewer than 60 cows and the equivalent number of replacement head. Artificial wetlands were introduced in the Canadian Maritime Provinces and the New England States (Newman et al. 2000). A wastewater flocculation system was developed by the Ontario Ministry of Agriculture, Food and Rural Affairs and later on marketed by Premier Tech (Rivière du Loup, Québec). In the U.S.A. and Europe, reverse osmosis, aerobic reactors, and anaerobic digesters were also tested as treatment processes (Schaafsman et al. 2000; Reimann 1997; Craggs et al. 2003; Luostarinen and Rintala 2005; Mason and Mulcahy 2003; Li and Zang 2004). Besides being expensive or requiring a large herd size (over 100 cows) to justify the investment and operating costs, most of these systems lead to limited use of the wastewaters and their nutrients.

Many small dairy farms in Quebec still treated their milk house wastewaters using a conventional septic tank system discharged into a ditch because of a system failure, resulting from the clogging of the seepage field. Clogging of the seepage field generally resulted from the accumulation of milk fat and soil saturation around the sewer pipes (Urgel Delisle et Ass. 1994).

The aim of the present project was therefore to introduce and test a modified system with a sediment and milk fat trap installed before, and an enlarged seepage field built after, the septic tank (Morin et al. 2004). The trap was designed to facilitate the removal of milk fat and sediments susceptible of accumulating and overloading the septic tank while the enlarged seepage field was designed to reduce risks of soil saturation and loss of permeability. The sediment and milk fat trap was sized to retain the wastewater produced during one milking, thus allowing for the cooling and hardening of the milk fat and the settling of sediments. The seepage field was designed to prevent the build up of soil nutrients such as phosphorous, by extending over sufficient cropped land to provide a wastewater nutrient load equivalent to that of the crop uptake. Finally, the enlarged seepage field was drained by a subsurface system installed between and slightly deeper than the runs of sewer pipe to control the watertable and force the soil to filter the wastewaters.

The modified system was designed to use the full nutrient value of the milk house wastewaters while treating them in a sustainable fashion. Valorizing both the nutrient and water content of the wastewaters resulted from their application to a cropped field. In the winter, the soil was presumed to adsorb the wastewater nutrients for crop uptake during the following growing season. Crop uptake assured the sustainability of the system and the removal of the nutrients accumulated during the year. A conventional septic tank-seepage field system is not sustainable because most do not prevent soil accumulations or build up, especially for the non-volatile nutrients. For example, conventional systems apply wastewaters at a rate of 20 to 40 L m^{-2} d^{-1}, which bring a total annual P load in the range of 0.45 kg/m^2 when a typical grass cover uses 22 kg of P ha^{-1} y^{-1} (50 kg of P_2O_5 ha^{-1} y^{-1}) or 0.022 kg m^{-2} y^{-1}; thus, a conventional system can forever build soil P loads at a rate of 450 kg ha^{-1} y^{-1}.

The objective of the project was therefore to:

1. build a modified system on two small Québec dairy farms and to monitor these systems for solids accumulation and sewer pipe clogging;
2. quantify the nutrient soil load and wastewater volume, and;
3. monitor the impact of the modified seepage system on drainage water quality.

METHODOLOGY

The experimental farms and their septic installation

Two small dairy farms in the southwest region of Montréal were selected for this project, because they already had septic tank installations. The new seepage field was built to bypass the existing clogged seepage field. The size and general operations of Farms MH-1 and MH-2 are described in Table 2. On both farms, the modified seepage field was built in a pasture, next to the dairy cow barn. On Farm MH-1, the seepage field site had

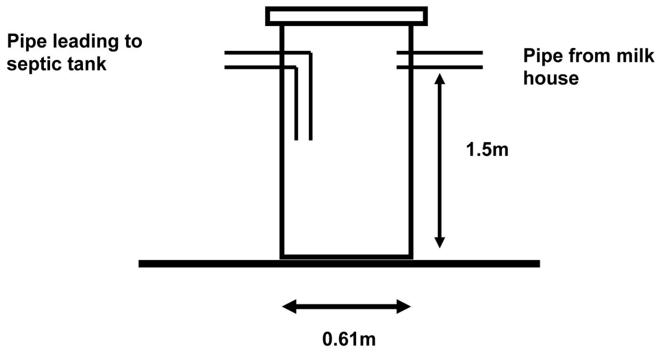

Fig. 1a. Description of the sediment and grease trap.

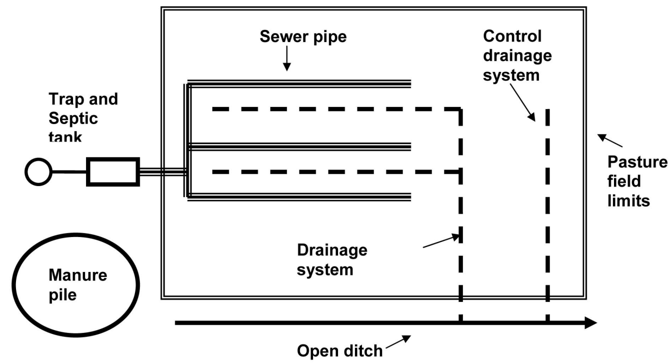

Fig. 2a. Experimental seepage field on Farm MH-1.

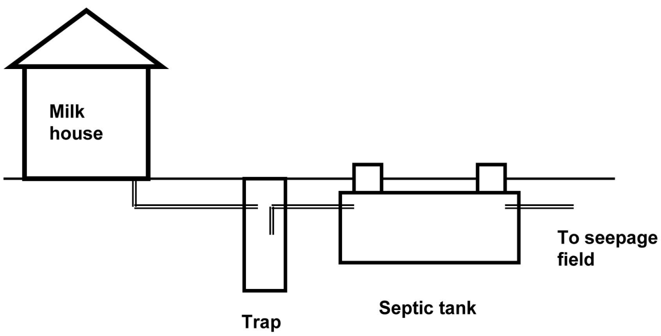

Fig 1b. Typical trap and septic tank installations on both dairy farms.

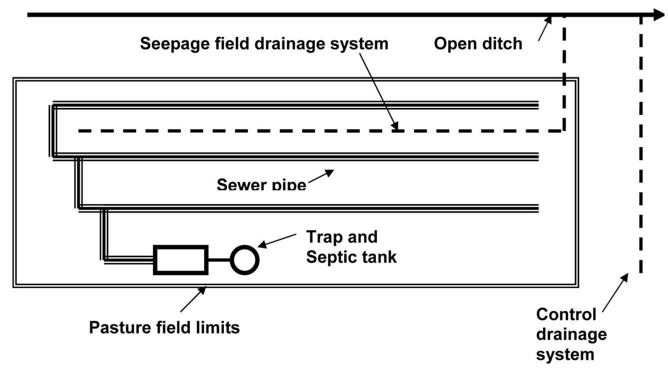

Fig. 2b. Experimental seepage field on Farm MH-2.

a relatively flat topography sloping away from the barn at 0.5%; the soil profile consisted of 1.5 m of silt overlaying a marine clay. On Farm MH-2, the seepage field site offered a topography sloping away from the barn at 1%; the soil profile varied in texture from a gravely silty clay at the top to a silty loam at the bottom of the slope.

In early July 2003 and on each farm, a sediment and milk fat trap (Fig. 1) was installed before the existing septic tank. Each trap consisted of a reinforced concrete manhole with an inside diameter of 0.61 m and a useful depth (wastewater storage depth) of 1.5 m for a water holding capacity of 440 L. This holding capacity slightly exceeded the volume of wastewater produced during one milking, calculated as 7.5 L/cow per milking or 15 L/cow per day. Therefore, the design was based on a wastewater retention time of 8 to 14 h, when 2 hours are generally required to settle sediments and solidify fats (Metcalf and Eddy 1991). A shorter retention time is not possible for milk house systems because wastewaters are produced in large batches every 8 to 14 h, corresponding to the milking schedules. The trap's T-shaped outlet pipe was designed to prevent the milk fat from flowing into the septic tank. Each trap was equipped with a concrete cover which could easily be pushed aside to remove the accumulated milk fat and sediments using a sewer spoon.

Also in early July 2003, each modified seepage field was built of three runs of sewer pipe installed at a spacing of 15 m (Fig. 2). Each sewer pipe run measured 100 m in length and was installed at 0% slope and 550 to 700 mm depth. The ABS sewer pipes had an inside diameter of 75 mm and were perforated with 12-mm holes spaced every 305 mm. Because of the silty texture of the soils on both farms, a geotextile was manually installed around the sewer pipes. The sewer pipes were installed at 0% slope and their length was limited to 100 m, to allow the wastewaters, when discharged in large batches, to reach the end of each pipe. In conventional systems, the slope is also 0% but the maximum length is limited to 18 m because wastewater is produced on a more continuous basis. In the present design, 350 m of sewer line were installed, which meant filling them to one quarter of their capacity within one hour after each milking. To maintain 0% slope despite the natural ground topography, the pipes were installed parallel to the contour lines, as much as possible, and a 2.4-m section of sewer pipe was installed at a sharp slope, at one or two places along the full 100-m length, between sections with 0% grade. All sewer pipes were installed directly on the soil, without using a bed of crush stone, to reduce construction costs.

On both farms, the seepage field covered a surface of 0.45 ha. Using a slope equivalent to that of the natural topography, a subsurface drainage pipe (perforated corrugated polyethylene tubing with an inside diameter of 100 mm) was installed between and 150 mm deeper than the sewer pipes. Draining into a nearby ditch, this subsurface system controlled the watertable height and forced the wastewater to seep into the soil. The water collected from this drainage system was sampled and analyzed for contaminant emissions from the modified seepage field.

Monitoring the modified system

To measure the volume of milk house wastewater produced and its nutrient load, two operations were conducted. First of all, a water meter was installed on the water line feeding the milk house and the volume of water used was recorded and averaged per cow on a monthly basis. Samples of wastewater were also

Table 3. Monthly production of wastewater.

Month	Farm MH-1		Farm MH-2	
	L/d	L/cow per day	L/d	L/cow per day
<u>2003</u>				
September	618	14.7	473	14.8
October	676	16.1	516	16.1
November	634	15.1	514	16.1
December	757	18.0	497	15.6
<u>2004</u>				
January	922	22.0	512	16.0
February	636	15.1	519	16.2
March	566	13.5	529	16.5
April	590	14.1	578	18.1
May	587	14.0	524	16.4
June	595	14.2	552	17.3
July	652	15.5	617	19.3
August	644	15.3	500	15.6
September	631	15.0	512	16.0
October	683	16.3	461	14.4
November	786	18.7	461	14.4
December	918	21.8	462	14.4
<u>2005</u>				
January	623	14.8	440	13.7
February	585	13.9	442	13.8
March	641	15.3	448	14.0
April	617	14.7	496	15.5
May	514	12.2	474	14.8
June	570	13.6	424	13.3
Average (L/cow stall per day)*		15.6 (2.5)***		15.6 (1.4)
Average (L/cow per day)**		13.1		12.5
Wastewater applied by seepage field (mm/month)		16		19

* Production of wastewater based on cow stalls equipped with a pipeline outlet
** Production of wastewater based on total number of cows in herd
***Values in parentheses are standard deviations.

collected from the trap on a monthly basis, except during the cold winter months. Because sediments tended to accumulate at the bottom of the trap, while milk fat solidified at the top, these were sampled and analyzed separately.

The yearly nutrient load supplied by the milk house wastewater was computed by adding up the multiple of the monthly volume produced by the monthly analytical result. This load excluded the contribution of milk fat and sediments, because their rate of accumulation varied during the two years of monitoring. Milk fat accumulation rate was measured by observing its thickness inside the trap. Sediment accumulation was measured by first sampling the wastewaters inside the trap, then thoroughly mixing with the sewer spoon and taking another wastewater sample.

To verify the level of water contamination produced by the modified seepage system, the water flowing out of its drainage system was sampled and analyzed along with that of a control drainage system. On Farm MH-1, the control drainage system was a single subsurface drain installed further down the pasture field; because of its limited length, it produced less drainage water than the drainage system of the modified seepage field. On Farm MH-2, the control drainage system was that already in operation in a cropped field adjacent to the pasture where the modified seepage system was installed. Both modified seepage fields were exposed to outside sources of contamination. On Farm MH-1, the solid manure was piled directly on the ground and its contaminated runoff seeped into the upper corner of the area occupied by the modified seepage system. On Farm MH-2, the control field received no manure while a pasture covered the modified seepage field and received manure continuously during six months of the year.

Monitoring the seepage fields for clogging

In September 2005, after two years of operation, five randomly selected sections of sewer pipe were dug out and opened to check for any accumulation of sediments and milk fat. The soil around the sewer pipes was checked for any signs of gleying, a microbiological process occurring as a result of soil saturation and exposure to organic matter (Russell 1961). This phenomenon commonly results in the reduction of iron, which then becomes soluble and leads to the loss of soil structure and permeability, and the development of the soil's blue-grey colour.

The septic tanks were cleaned in July 2003, just before using the newly installed trap and modified seepage field, and in August 2004, to check for any milk fat accumulation.

Analytical procedures

All wastewater analyses were conducted using standard methods (APHA 1998). Total solids were determined gravimetrically after drying for 24 h at 103°C. After digesting samples at 500°C using 18 M sulphuric acid and 50% hydrogen peroxide, their TKN was determined using an ammonia sensitive probe connected to an Orion pH meter, and their TP and TK were determined colorimetrically. Ammonium and nitrites/nitrates were determined on undigested samples using specific ion sensitive probes connected to an Orion pH meter. COD was determined colorimetrically after oxidization with potassium chromate at 140°C. The pH of all samples was determined using a pH probe connected to an Orion meter.

The standard deviation of all collected data was computed using Excel (Microsoft Office 2003). Because of the nature of the project and the individual farm management practices, the installation on each farm could not be considered a repetition. The quality of the drainage waters collected from the control and seepage field drainage systems, on individual farms, was compared using the student-t test (Steel and Torrie 1980).

RESULTS and DISCUSSION

The nutrient load

The monthly volumes of wastewater produced on each farm are presented in Table 3. Farm MH-1 produced more wastewater than Farm MH-2, ranging from 12 to 22 L/cow per day and averaging 13.1 L/cow per day as compared to Farm MH-2, ranging from 13 to 19 L/cow per day and averaging 12.5 L/cow

Table 4a. Monthly characteristics of milk house wastewaters on Farm MH-1.

Month	Characteristics of milk house wastewaters						
	TS* (%)	DS (%)	SS (%)	pH	TN (mg/L)	TP (mg/L)	TK (mg/L)
2003							
June**	0.19	0.16	0.03	6.0	518	21	667
July**	0.52	0.27	0.25	6.0	101	17	174
August	0.19	0.14	0.05	5.9	154	146	350
September	0.35	0.27	0.08	7.1	117	48	245
October	0.36	0.25	0.11	6.7	111	97	96
November	0.42	0.28	0.12	6.4	46	99	200
December	NA***	NA	NA	NA	NA	NA	NA
2004							
January	NA	NA	NA	NA	NA	NA	NA
February	NA	NA	NA	NA	NA	NA	NA
March	0.85	0.45	0.40	6.0	107	96	204
April	0.29	0.28	0.01	5.7	107	103	177
May	0.43	0.30	0.13	5.7	82	96	177
June	0.24	0.13	0.11	5.4	39	81	121
July	0.34	0.30	0.04	5.8	12	155	219
August	0.25	0.12	0.13	5.9	125	68	408
September	0.24	0.14	0.10	5.8	112	79	474
October	0.27	0.11	0.16	6.1	95	77	404
November	0.22	0.12	0.10	6.5	204	82	96
December	0.20	0.11	0.09	5.8	268	88	42
2005							
January	0.22	0.12	0.10	5.8	208	111	60
February	NA	NA	NA	NA	NA	NA	NA
March	NA	NA	NA	NA	NA	NA	NA
April	0.61	0.47	0.14	6.6	98	72	156
May	0.32	0.26	0.06	6.4	29	142	134
Average	0.38 (0.36)#	0.26 (0.19)	0.16 (0.13)	6.1 (0.34	117 (70)	98 (32)	210 (135)

* TS = total solids; DS = dissolved solids: SS = suspended solids
** Values for 2003 June and July are higher because samples were collected from septic tank before cleaning rather than sediment and milk fat trap.
***NA = not available because wastewaters could not be sampled
\# Values in parentheses are standard deviations.

per day. Farm MH-1 may not have produced higher volumes of wastewaters. Its monthly average wastewater production was consistently higher during the winter as compared to other months, because the milk house water line also supplied drinking water to a group of heifers housed during this period. For both Farms MH-1 and MH-2, and when using the amount produced per pipeline connection point rather than per total number of cows in the herd, these volumes fall within the range of 15 to 20 L/cow per day as reported by Urgel Delisle et Ass. (1994). For the crop growing over the seepage field, this volume of wastewater production represented a monthly water application of 16 and 19 mm, for Farms MH-1 and MH-2, respectively, which was not likely to have an impact on crop yield but expected to reduce risks of soil gleyzation and clogging.

The monthly nutrient load generated by the milk house wastewaters is presented in Tables 4a and 4b, for Farms MH-1 and MH-2, respectively. In general, the total solids were relatively low, at less than 0.5%. The milk house wastewater pH on Farm MH-1 ranged between 5.9 and 6.5 while that on Farm MH-2, ranged between 7.6 and 8.1, likely because of the water softener. For Farm MH-1, the TKN, TP, and TK loads ranged from 12 to 268, 17 to 155, and 42 to 350 mg/L, while those of Farm MH-2, ranged from 12 to 118, 26 to 213, and 31 to 828 mg/L, respectively.

The annual nutrient load generated by the milk house wastewaters is presented in Table 5. The annual load for Farm MH-1 was higher than that for Farm MH-2, likely because of the wasted milk discharged into the septic system. On Farm MH-2, this wasted milk was sent to the manure storage facility to prevent the overloading of the septic system. The TP and TK loads, of 40 to 60 and 75 to 85 kg ha^{-1} y^{-1}, corresponded to the nutrient uptake of a high yielding forage crop, such as corn silage or alfalfa (10 dry tons ha^{-1} y^{-1}). The TN load of 50 to 65 kg ha^{-1} y^{-1} was proportionally lower than that required by a corn silage crop and higher than that recommended for an alfalfa crop.

On Farm MH-1 and for the modified system, the disposal of wasted milk had an impact on the accumulation of milk fat in the trap (Figs. 3a and 3b), as compared to Farm MH-2. On Farm MH-1, a layer of solidified milk fat, 250-mm thick, accumulated inside the trap during the first year and, not being removed, started to flow into the septic tank, as observed during its cleaning in 2004 after one year of operation. In the trap on Farm MH-2, this layer of milk fat never accumulated, likely because all wasted milk was sent to the manure storage system instead and the use of a water softener which improves soap performance and milk fat solubility.

The milk fat collected inside the trap on Farm MH-1 was sampled and analyzed (Table 6a). This fat was relatively high in TS content, ranging from 13 to 21%, nutrient load ranging from 600 to 5500 mg/L for TN, 93 to 130 mg/L for TP, and 190 to 340 mg/L for TK, and in COD ranging from 460 to 644 g/kg dry matter. Exceeding 250 mm during the first year, its yearly accumulation rate was in the range of 150 mm during the second year. Interestingly enough, the rate of milk fat accumulation and its nutrient load decreased from year 1 to year 2, likely as a result of some microbial activity developing inside the trap.

Sediments accumulated at the bottom of the trap installed on Farm MH-2 (Table 6b). The sediments collected on Farm MH-2 had a TS content ranging from 3.7 to 11.4, depending upon their density and collection period, with a nutrient content averaging 1700, 870, and 880 mg/L of TN, TP, and TK, respectively. Almost no sediments were collected from the trap on Farm MH-1 because of a primary sediment trap inside the milk house.

Table 4b. Monthly characteristics of milk house wastewaters on Farm MH-2.

Month	Characteristics of milk house wastewaters						
	TS* (%)	DS (%)	SS (%)	pH	TN (mg/L)	TP (mg/L)	TK (mg/L)
2003							
June**	0.26	0.19	0.07	7.8	55	26	828
July**	0.24	0.22	0.02	7.9	48	116	246
August	0.24	0.22	0.02	7.6	85	213	187
September	0.27	0.26	0.01	7.3	29	136	443
October	0.30	0.14	0.16	7.3	12	42	152
November	0.42	0.28	0.14	7.6	46	48	246
December	NA***	NA	NA	NA	NA	NA	NA
2004							
January	NA	NA	NA	NA	NA	NA	NA
February	NA	NA	NA	NA	NA	NA	NA
March	0.39	0.30	0.09	7.1	40	50	257
April	0.16	0.16	0.00	7.4	42	41	359
May	0.27	0.21	0.06	9.5	37	81	57
June	0.19	0.19	0.00	9.6	17	78	75
July	0.36	0.31	0.05	9.5	21	84	81
August	0.44	0.39	0.05	7.6	20	85	208
September	0.24	0.21	0.03	7.5	68	83	61
October	0.21	0.19	0.02	7.3	50	95	71
November	0.17	0.16	0.01	7.5	81	133	79
December	0.19	0.17	0.02	7.6	95	91	31
2005							
January	NA	NA	NA	NA	NA	NA	NA
February	NA	NA	NA	NA	NA	NA	NA
March	NA	NA	NA	NA	NA	NA	NA
April	0.28	0.25	0.03	8.5	28	45	66
May	0.32	0.27	0.07	7.6	118	109	69
Average	0.26 (0.08)#	0.22 (0.06)	0.04 (0.06)	7.8 (0.75)	50 (29)	109 (90)	142 (129)

* TS = total solids; DS = dissolved solids: SS = suspended solids
** Values for 2003 June and July are higher because samples were collected from septic tank before cleaning rather than sediment and milk fat trap
***NA = not available because wastewaters could not be sampled
\# Values in parentheses are standard deviations.

This is reflected by the whiter colour of the milk house wastewaters in the trap of Farm MH-1, also containing more wasted milk, as compared to the darker stirred wastewaters in the trap of Farm MH-2 (Figs. 3a and 3b, respectively). As with the milk fat on Farm MH-1, the sediment nutrient load accumulating in the trap of Farm MH-2 also dropped from year 1 to year 2, likely as a result of the development of some microbial activity (results not shown).

Table 5. Annual wastewater nutrient loading.

Parameter	Farm MH-1				Farm MH-2			
	TS	TN	TP	TK	TS	TN	TP	TK
Average load (mg/L)	2600	118	109	142	3800	117	98	210
L/cow per day	13.1	13.1	13.1	13.1	12.5	12.5	12.5	12.5
kg/cow per year	12.4	0.57	0.52	0.68	17.3	0.53	0.45	0.96
kg per year	622	28.5	26.0	33.9	692	21.2	18.0	38.0
kg/ha per year	1400	65	60	75	1540	50	40	85

Note: Loading rates do not consider impact of sediments and milk fat which normally would be removed from the trap and disposed of along with manures.

Clogging of seepage system

The sections of sewer pipe excavated after two years of operation are illustrated in Figs. 4 and 5. The colour of the soil around the sewer pipe had not changed, indicating no gleyzation both for Farms MH-1 and MH-2, likely as a result of the soil moisture level staying well below saturation (Fig. 4). The absence of crushed stone had no impact on soil water absorption, likely as a result of the dryness of the soil, its capillary action, and the limited amount of wastewater produced compared to the size of the seepage field.

The accumulation of solids, especially milk fat, inside the sewer pipes was quite obvious on Farm MH-1 and as compared to those of Farm MH-2 (Figs. 5a and 5b, respectively). This likely resulted from the excessive amount of milk fat which accumulated inside the trap and overflowed into the septic tank and seepage field. The high BOD_5 level of the milk fat likely overloaded the septic tank, especially considering its limited 4-d hydraulic retention time.

The sewer pipes excavated on Farm MH-2 did not show any substantial accumulation of solids (Figure 5b). The modified system on Farm MH-2 was performing as expected, mainly because of the limited amount of milk fat conveyed by the system and the trapping of sediments before the septic tank. On Farm MH-2, sediments were removed once a year. Cleaning the trap proved to be a simple manual operation which the producer could perform by himself, as compared to cleaning the septic tank which required a vacuum pump.

Water contamination by the modified seepage field

The samples of drainage water collected on both farms (Table 7) did not indicate any significant contamination from the modified seepage fields ($P<0.05$). On Farm MH-1, and despite the fact that the seepage field was contaminated by the runoff from the nearby manure pile, the control drainage waters were more heavily loaded in TN likely because this drain was much shorter and produced water only under very wet conditions which

Table 6a. Characteristics of the milk fat collected in the trap on Farm MH-1.

Parameter	Year 1	Year 2	Year 3
TS (%)	19.7	20.6	12.8
TKN (mg/L)	5463	1062	598
TP (mg/L)	101	130	93
TK (mg/L)	187	219	341
COD (g/kg)	460	611	644

Fig. 3a. Content of sediment and milk fat trap on Farm MH-1 showing fat accumulation. Wastewaters are white in colour because of their low sediment content.

Fig. 3b. Content of sediment and milk fat trap on Farm MH-2 showing no fat accumulation. Wastewaters were stirred before taking the picture indicating the level of accumulated sediment.

resulted in the flushing of nitrogen. Its nutrient load averaged 22, 0.4, and 127 mg/L of TN, TP, and TK, respectively, as compared to the seepage system drainage system with an average nutrient load of 10, 0.4, and 171 mg/L. On Farm MH-2, both the control and seepage field drainage waters could be collected at the same time. The seepage field pollution load of 13, 0.7, and 30 mg/L of TN, TP, and TK, respectively, was consistently but not statistically higher than that of the control, with 9, 0.6, and 25 mg/L of TN, TP, and TK, respectively. This

Table 6b. Characteristics of the sediments collected in the trap on Farm MH-2.

Parameter	Year 2	Year 3
TS (%)	3.7	11.4
TKN (mg/kg dry matter)	1943	1448
TP (mg/kg dry matter)	1227	504
TK (mg/kg dry matter)	1366	395

Note: Data from first year are excluded.

Fig. 4. No soil discolouration (gley formation) was observed around the sewer pipes.

slight difference may have resulted from the pasturing of animals over the area occupied by the modified seepage field, which resulted in a soil phosphorous loading of 200 kg/ha, which was higher than a normal load ranging from 100 to 15 kg/ha.

The cost of modifying the septic tank-seepage system

Table 8 summarizes the operations and materials required to modify the septic system on both farms. The sewer drains were installed directly on the soil, rather than in a bed of crushed stone, to minimize installation costs. Nevertheless, the installation of a geotextile around the sewer pipes required some additional labour, which added to the cost.

Over all, each system required an investment of $4400 Can, if the farm operators accounted for the use of their own labour and equipment and if the septic tank cost was excluded. This investment cost was considered quite acceptable by the two farm operators, as other solutions would have required an investment of at least $15,000 Can, besides the septic tank.

SUMMARY

A modified septic tank – seepage field system was designed to allow small dairy farms to economically but efficiently treat their milk house wastewaters. As compared to the conventional system, the modified system consisted of a sediment and milk fat trap installed before and an enlarged drained seepage field built in a cropped area after the septic tank. The size of the seepage field was based on the crop's yearly nutrient uptake.

Fig. 5a. Considerable amount of milk fat accumulated inside the sewer pipes after two years of operation on Farm MH-1.

Fig. 5b. Limited amount of matter accumulated inside the sewer pipes after two years of operation on Farm MH-2.

Table 7. Quality of the drainage waters.

Parameter	Farm MH-1		Farm MH-2	
	Seepage field	Control system	Seepage field	Control system
pH	6.8 (0.5)*	6.9 (0.4)	6.8 (0.5)	7.0 (0.5)
TN (mg/L)	10.0 (8.8)	21.9 (11.3)	13.4 (10.0)	8.6 (3.7)
TP (mg/L)	0.4 (0.7)	0.4 (0.5)	0.7 (0.8)	0.6 (0.9)
TK (mg/L)	171 (129)	127 (134)	28.9 (20.4)	24.8 (35.6)
Conductivity (mS/cm)	0.6 (0.3)	0.4 (0/05)	0.8 (0.3)	0.6 (0.2)
Sample number	25	9	33	33
Soil extractable:				
P**(mg/kg)	40 (5)		202 (26)	
K**(mg/kg)	140 (8)		400 (47)	

* Values in parentheses are standard deviations.
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Table 8. Cost of modifying septic tank-seepage field system.

Item	Unit cost	Total cost
Backhoe	$55/h	1050
Sewer pipe, filter, agricultural drain		1200
Milk fat and sediment trap		460
Sediment spoon*		150
Farm tractor and truck	18 h	730
Farm labour	$90/d x 3 person-days	810
Total cost excluding farm share		$2870
Total cost with farm share		$4400

* To remove sediments from trap

Although the 100-m criteria used in this project worked very well, more research is needed to determine the optimum sewer pipe length, especially for systems covering over 0.5 ha.

The modified system worked well and lead to no clogging as long as the sediments and milk fat were removed once a year and once every three months, respectively, from the trap. A more preventive way of limiting the accumulation of milk fat inside the trap is to use a water softener and dispose of all wasted milk through the manure storage system, as this volume is quite small. The system modification required an investment of $4400 Can, including the cost of the farm labour and equipment but excluding the cost of the septic tank. The two farm operations produced 12.5 and 13.1 L of milk house wastewater/cow per day, accounting for an annual TN, TP, and TK load of 50 to 65, 40 to 60, and 75 to 85 kg ha^{-1} y^{-1}, distributed over a surface of 0.45 ha. Finally, the monitoring operation conducted on the water drained from the modified seepage fields showed no major sign of contamination, indicating that the soil was able to adsorb the milk house wastewater nutrient load.

The present project demonstrated that it was critical to remove the milk fat accumulating inside the trap to prevent the clogging of the septic tank – seepage field. As a preventive measure and where the farm has a manure storage facility, the wasted milk should not be sent to the septic system, and a water softener should be used as practiced on Farm MH-2.

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REFERENCES

APHA. 1998. *Standard Methods for the Analysis of Water and Wastewater*, 20th edition. Washington, DC: American Public Health Association, American Water Works Association and Water Pollution Control Federation.

Craggs, R.J., C.C. Tanner, J.P.S. Sukias and R.J. Davis-Colley. 2003. Dairy farm wastewater treatment by an advance pond system. *Water Science Technology* 48 (2): 291-297.

Jamieson, R.C., R.J. Gordon, L.M. Cochrane, A. Madani and J.R. Burney. 2002. Land application of milking centre wastewater. *Canadian Biosystems Engineering* 44: 6.1-6.10.

Li, X. and R.H. Zhang. 2004. Integrated anaerobic and aerobic treatment of dairy wastewater with sequencing batch reactors. *Transactions of the ASAE* 47 (1): 235-241.

Loerh, R. 1983. *Pollution Control for Agriculture*, 2nd edition. Orlando, FL: Academic Press (Harcourt Brace Jovanovich, Publishers).

Luostarinen, S.A. and J.A. Rintala. 2005. Anaerobic on-site treatment of black water and dairy parlour wastewater in UASB-septic tanks at low temperatures. *Water Research* 39 436-448.

Mason, I.G. and J. Mulcahy. 2003. Volatile fatty acid production from dairy wastewater. *Transactions of the ASAE* 46 (3): 819-824.

Metcalf and Eddy. 1991. *Wastewater Engineering, Treatment, Disposal, Reuse*, 3rd edition. New York, NY: McGraw Hill Publishers Inc.

Morin, S., S. Lemay, A. Ali and S. Barrington. 2004. A modified septic tank system to effectively manage agricultural wastewaters. Paper 229. Winnipeg, MB: CSBE.

Newman J. M., J.C. Clausen and J. A.Neafsey. 2000. Seasonal performance of a wetland constructed to process dairy milk house wastewater in Connecticut. *Ecological Engineering* 14: 181-198.

Reimann, W. 1997. Influence of organic matter from wastewater on the permeability of membranes. *Desalination* 109: 51-55.

Rusell, E.W. 1961. *Soil Conditions and Plant Growth*. Norwich, England: Longmans, Green and Co. Ltd.

Schaafsman, J.A., A.H. Baldwin and C.A. Steb. 2000. An evaluation of a constructed wetland to treat wastewater from a dairy farm in Maryland, USA. *Ecological Engineering* 14: 199-206.

Steel, R.G.D. and J.H. Torrie. 1980. *Principles and Procedures of Statistics: A Biometrical Approach*. New York, NY: McGraw Hill Publishers.

Urgel Delisle et Ass. Inc. 1994. Évaluation de systèmes de fosse septique- champ d'épuration pour l'épuration des eaux usées de laiterie de ferme. Document produit pour le Ministère de l'Environnement du Québec sous le programme PARDE-PAAGF. Envirodoq EN 940584. Québec, Canada.