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Implications of Water Quality Regulations for Minnesota Dairy Processing Plants

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Station Bulletin 520-1977

Agricultural Experiment Station,
University of Minnesota,
in cooperation with the Economic
Research Service, U.S. Department of Agriculture

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The authors gratefully acknowledge the technical assistance provided to this project by Mary Paul Even and Jeffrey D. Nielsen, assistant scientists, Agricultural Engineering Department, University of Minnesota.

Implications of Water Quality Regulations for Minnesota Dairy Processing Plants

Under the National Pollution Discharge Elimination System (NPDES), limitations have been placed on the types and quantities of pollutants that may be discharged from the dairy processing industry. Dairy plants which currently do not meet the limitations imposed by the NPDES but desire to continue operations at their present location are faced with two alternatives: (1) connect to a municipal sanitary sewer system or (2) construct a private waste treatment system.

The NPDES program established a compliance schedule for dairy plants discharging directly to receiving waters. On July 1, 1977, these plants were to meet discharge limitations using the "best practicable control technology." By July 1, 1983, discharge limitations must be met using the "best available technology economically achievable."[1]

While under a slightly different compliance schedule, municipalities will also be required to meet discharge limitations on effluent from their municipal waste treatment plants. Many municipal systems were installed 20 or more years ago and will require renovation or replacement to meet discharge requirements. Others, because of design limitations and excessive treatment demands, will require expansion and/or renovation in order to comply with the NPDES limitations.

Municipalities applying for federal grants under Public Law 92-500 (Federal Water Pollution Control Act Amendments of 1972) will be required to determine the "proportionate share of the federal share of capital costs" as well as the "proportionate share of the costs of operation and maintenance" for industrial users of the municipal treatment system prior to receiving grant monies.[2] Federal grants comprise 75 percent of the allowable capital costs of the project. As a result, some dairy plants will be faced with dramatically increased sewer charges for their share of both capital and operating costs of the municipal treatment system.

This report considers the current status of waste handling, treatment, and disposal in the Minnesota dairy processing industry.[3] It identifies the destination of water discharge, estimates investment and annual costs for three alternative private waste treatment systems, and discusses the possible effect of complying with effluent limitations on consumer prices.

Number of Dairy Processing Plants in Minnesota

In 1976, Minnesota produced almost 8 percent of the nation's milk supply and ranked fourth in production among all states. About 22 percent of all butter and 11 percent of all the cheese produced in the United States was manufactured in Minnesota.

In 1965, there were 563 dairy plants operating in Minnesota. As of November 1975, there were 271 dairy plants operating in the state (table 1). Although wastewater effluent limitations were probably a factor, the rapid decline in the number of dairy plants has been greatly influenced by economies of size in plant operation, concentration of milk production within the state, and improved transportation methods for moving milk over longer distances to central processing plants. Of these 271 plants in 1975, 98 were receiving stations whose sole function was to collect milk for shipment to processing plants. Another 39 plants bottled fluid milk, leaving about 134 plants that were manufacturing butter, cheese, nonfat dry milk, and other manufactured products.

There was a marked decline in the number of plants producing each of the products from 1965 to 1975 except for cheese and dry whey. The number of cheese plants in-

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[1] Twelve subcategories within the dairy processing industry were established. Discharge limitations for 1977 and 1983 were established for each category with 1983 limitations more restrictive than those for 1977. (See Federal Register, Vol. 39, No. 103, May 28, 1974, pp. 18594-18609.)

[2] Federal Register, Vol. 38, No. 39, February 28, 1973, p. 5333.

[3] Date for this analysis was derived from several sources. The Minnesota Pollution Control Agency (MPCA) surveyed all 271 dairy plants in Minnesota and obtained responses from 121 of them. This survey combined with discharge monitoring reports and other information on file at the MPCA provided monitoring the basis for determining private processing waste treatment and discharge destinations. Municipal sewer charges and intentions for construction of new or renovation of municipal wastewater treatment plants were obtained by the authors in a survey of 148 cities receiving wastewater from dairy plants.

creased from 19 in 1965 to 25 in 1975, while plants producing dry whey increased from none in 1965 to 14 in 1975 (table 1).

The trend to fewer and larger processing plants will likely continue. However, the absolute decline is expected to decrease as the total number of plants declines.

Nearly 70 percent of the 271 dairy plants in the state in 1975 were cooperatives which processed the majority of all milk produced. About 70 to 80 percent of the manufactured dairy products are processed in plants owned and operated by three major cooperatives: Associated Milk Producers, Inc.; Land O'Lakes, Inc.; and Mid-America Dairymen, Inc.

Table 1. Number of dairy processing plants in Minnesota by type of product, 1965 and 1973-75.

Activity	1965	1973	1974	1975
Number of plants producing each product:[a]				
Receiving[b]	149	117	107	98
Butter	311	63	58	57
Cheese	19	22	25	26
Bottling	130	44	42	39
Nonfat dry milk (human use)	70	39	38	34
Nonfat dry milk (animal feed)	25	9	7	7
Dry whey	0	9	13	14
Frozen foods	55	27	25	19
TOTAL PLANTS	563	301	280	271

SOURCE: Minnesota Dairy Processing Plants, 1975, Minnesota Department of Agriculture, St. Paul, Minnesota; Minnesota Dairy Statistics, 1965-1974, Minnesota and U.S. Department of Agriculture, January 1976, p. 11.

[a] Does not sum to state totals because some plants manufactured more than one product.

[b] 1965 is not entirely comparable with figures for 1973-75 because of change in definition. Comparable number of receiving stations with 1965 is 192 for 1973, 185 for 1974, and 177 for 1975.

Characteristics and Volume of Dairy Plant Wastes

In compliance with the provisions of the Federal Water Pollution Control Act, as amended,[4] dairy plants discharging to surface waters are required to obtain a discharge permit. The permit authorizes the plant to discharge under the National Pollution Discharge Elimination System (NPDES) but specifies a time schedule under which the plant must comply with effluent limitations and outlines the discharge monitoring requirements. Effluent characteristics upon which the discharge limitations are usually based are flow, BOD_5, total suspended solids, and fecal coliform. Other characteristics including phosphorous, turbidity, pH, floating solids, oil, temperature, and odor are also subject to limitations.[5]

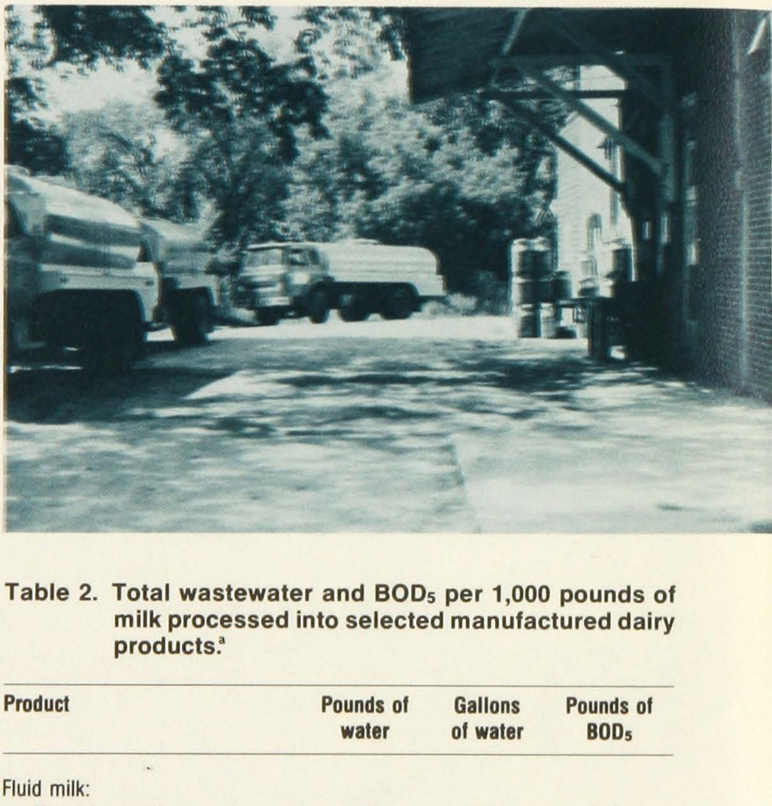
The constituents of dairy products of primary concern in water pollution are fat, protein, lactose, lactic acid, added organic ingredients, total organic solids, calcium, phosphorous, chloride, sulfur, total ash, and viscosity.

SUMMARY OF OHIO STUDY

A review of the literature by the Department of Dairy Technology at Ohio State University was summarized showing pounds of BOD_5 per 1,000 pounds of milk processed (appendix). The average total waste load generated in producing major dairy products is summarized in table 2. Of the products considered in table 2, churn process butter production was estimated to generate the highest waste load per 1,000 pounds of milk processed in terms of both gallons of waste and pounds of BOD_5. The Ohio State study also estimated that spray drying and fluid milk bottling (where rinse water was saved) generate the lowest waste volume and pounds of BOD_5 per 1,000 pounds of milk processed of all products considered.

What Happens to Dairy Plant Wastewater?

A dairy plant that does not discharge directly into receiving waters but is connected to a municipal wastewater treatment system is in compliance with waste discharge regula-



A typical small creamery utilizes milk delivered in cans and bulk trucks.

Table 2. Total wastewater and BOD_5 per 1,000 pounds of milk processed into selected manufactured dairy products.[a]

Product	Pounds of water	Gallons of water	Pounds of BOD_5
Fluid milk:			
Normal operation	1,000	120	2.48
Rinses saved	500	60	0.46
Butter:			
Churn process	1,450	175	2.60
Continuous churn	1,060	128	1.96
Cheddar cheese:			
Washed curd	770	93	1.70
Ice cream	1,150	139	2.09
Spray drying	440	53	1.25
Representative plants:			
Fluid milk	1,000	120	2.48
Butter	1,260	152	2.28
Cheese	770	93	2.23
Receiving station	573	69	0.50

[a] "Dairy Food Plant Wastes and Waste Treatment Practices," U.S. Environmental Protection Agency, 12060 EGU, March 1971.

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[4] Federal Water Pollution Control Act, as amended, 33 U.S.C. 1251.

[5] Toxic Pollutants, Sec. 307a of the Federal Water Pollution Control Act, as amended, 33 U.S.C. 1251, and Minnesota Statutes, Chapters 115 and 116, as amended. The ratio of pounds of BOD_5 to pounds of organic solids is an indication of the relative completeness of biological oxidation in 5 days for the various products. A summary of reported BOD_5 values of various dairy products is reported in the Appendix.

tions under the NPDES. However, these plants are subject to substantial changes in waste treatment costs as the costs of meeting regulations imposed on municipalities are passed on to all contributors. This has and will represent a major change in waste disposal costs for many dairy plants.

The Minnesota Pollution Control Agency conducted a mail survey in October, 1975, to determine, in part, whether dairy plants were using municipal waste treatment systems or what kinds of private treatment facilities, if any, the plants used. Of the 271 plants contacted, 121 responded to the survey.

Over 68 percent of the dairy plants discharged processing wastes to a municipal sanitary sewer system (table 3). Just over 16 percent of the plants utilized private waste treatment systems. Septic tanks were the most common private treatment systems, while stabilization ponds, aerated lagoons, and ridge and furrow systems were used by about 4 percent of the plants. Nearly 9 percent of the plants discharged processing wastes directly to receiving waters without treatment.

Table 3. Destination of waste discharge from Minnesota dairy processing plants.

	Plants	
	Number	Percent
Municipal system	186	68.6
Private treatment systems:		
Septic tank	27	9.9
Stabilization pond	4	1.5
Aerated lagoon	3	1.1
Ridge and furrow	3	1.1
Spray irrigation	1	0.4
Other	6	2.2
Total private	44	16.2
Direct to receiving waters	24	8.9
Marketing or distributor	6	2.2
Unknown[a]	11	4.1
TOTAL PLANTS	271	100.0

[a] Information on processing waste destination was obtained from MPCA survey and files. The discharge status of 11 plants was unknown as of December 1975.

Status of Plants on Municipal Waste Treatment Systems

Because nearly 70 percent of Minnesota's dairy processing plants discharge to municipal waste treatment systems, additional information was obtained on current and proposed waste treatment in these municipalities. City officials in 123 municipalities, representing 159 of the 186 plants discharging into a municipal system, were contacted to obtain information on their current waste treatment system, sewer use charges to the dairy plants, and, if new facilities were planned, the new sewer use charges to dairy plants.

MUNICIPAL WASTE TREATMENT

Most of the municipal treatment facilities were stabilization ponds, trickling filter, or activated sludge systems and were constructed between 1960 and 1969 (table 4). Only one trickling filter system was constructed after 1970. Significantly, only 20 of 123 municipalities surveyed had installed or remodeled treatment systems subsequent to enactment of P.L. 92-500 in 1972. Twenty-six systems were installed prior to 1960 while the majority were installed between 1960 and 1972.

Of the 123 city officials contacted, 44 percent indicated municipal intentions to remodel existing systems or install new treatment systems in the next few years. However, 66 percent of these municipalities with intentions to remodel or build noted that the city had not progressed beyond preliminary planning stages.

SEWER USE CHARGES

A great deal of variation in sewer use charges existed between municipalities. Results of the interviews with city officials indicated that the waste treatment cost per 1,000 pounds of milk processed varied from 0.20 to 93.6 cents (table 5). Generally, bottling plants paid more sewer use charges per 1,000 pounds of milk received than did plants producing other products. Bottling plants generally are concentrated in the metropolitan areas of the state. Sewer charges in the metropolitan areas typically are based on water consumption rather than BOD_5 or suspended solids levels in the wastewater. While bottling plants commonly discharge organic loads lower than other types of processing plants, their water demands accounted for the high per plant sewer charge. This significant variation in sewer use charges is, to a large extent, caused by variations on how the

Table 4. Type of municipal wastewater treatment systems that received dairy plant wastes by age of facility.

Type of system	Year system installed or last remodeled						Municipalities	
	1940-	1940-1949	1950-1959	1960-1969	1970-1972	1973-1976	Number	Percent
	cities							
Stabilization pond	—	—	3	28	7	11	49	39.9
Activated sludge	—	—	3	17	5	6	31	25.2
Trickling filter	3	3	11	15	—	1	33	26.8
Aerated lagoon	—	—	—	2	1	2	5	4.1
Sludge storage	—	—	1	1	—	—	2	1.6
Imhoff tank	2	—	—	—	—	—	2	1.6
Ridge and furrow	—	—	—	1	—	—	1	0.8
TOTAL RESPONDENTS	5	3	18	64	13	20	123	100.0

SOURCE: Telephone interviews with city officials in 123 municipalities representing 159 of the 186 plants discharging into a municipal system.

Table 5. Municipal sewer charges for dairy plants discharging to municipal wastewater treatment systems.

Activity	Plants*	Cents/1,000 lb of milk received	
		Range	Average
All plants	79	0.20 - 93.59	7.21
Bottling	11	2.53 - 47.78	11.38
Butter	19	0.20 - 19.58	4.97
Cheese	8	1.15 - 41.10	11.14

*This table required cross tabulation of volume of milk received with sewer use charges for each plant. Volume of milk received data were only available for 79 of the possible 159 plants located in 123 municipalities.

bill was computed including the base used and the age of the municipal treatment system.

Water consumption was used as the sewer billing basis for about 40 percent of the plants while just over 38 percent of the plants paid a flat rate for sewer use. Most of the eight plants not charged for sewer service had agreements permitting the cities to use the plants' well water during emergencies.

Nine of the 14 plants billed on waste flow and amount of BOD_5 paid over $5,000 in sewer charges, while the two dairy plants that were billed on a combined flow, BOD_5 and suspended solids basis paid over $15,000 annually. The average bill was slightly under $4,200 per year for 159 plants using the 123 municipal waste treatment systems. Bills based on flat rates and water consumption generally averaged less than $1,000 annually.

Table 6. Current and proposed sewer charges and basis for determining charges for dairy plants located in municipalities that are planning to install new systems or remodel existing treatment systems.

Current basis	Proposed basis for computing charge	Annual sewer charge		Percent change in charges
		Current	Proposed	
		----------dollars----------		
Flow-BOD_5	Flow-BOD_5	27,913	61,737	121
Flow-BOD_5	Flow-BOD_5	1,611	2,551	58
Flow-BOD_5	Flow-BOD_5	33,132	39,407	19
Flow-BOD_5	Flow-BOD_5	2,570	2,122	−17
Flow-BOD_5	Flow-BOD_5	540	[a]	—
Flow-BOD_5	Flow-BOD_5	192	[a]	—
No charge	Flow-BOD_5	0	9,920	—
Water consumption	Water consumption	3,693	19,406	425
Water consumption	Water consumption	5,567	13,375	140
Water consumption	Water consumption	1,752	3,504	100
BOD	Water consumption	600	[a]	—
Flat rate	Water consumption	540	[a]	—
No charge	Water consumption	0	[a]	—
Flat rate	Wastewater flow	420	4,102	877
Wastewater flow	Wastewater flow	11,498	17,958	56
Flat rate	Wastewater flow	[a]	262	—

[a] Not available.

Sixteen municipalities planning to install new systems or remodel existing waste treatment systems had determined the sewer billing basis for dairy plants connected to their sewer lines. Based on current intentions, seven dairy plants will be billed on a combined waste flow-BOD_5 basis, six on water consumption, and three solely on wastewater flow (table 6). Proposed sewer billing will exceed $30,000 for two of the seven dairy plants billed on a waste flow-BOD_5 basis. The new sewer charge for all except one plant will be 19 to over 800 percent higher under the new charges than under the old sewer rate structure. One plant will be charged less under the proposed billing due to an anticipated reduction in waste flow.

Generally, the older the municipal treatment facility, the lower the sewer use charge. This underscores the substantially higher waste treatment cost that plants connected to municipal waste treatment facilities will face as municipal facilities are constructed or renovated. These plants consider private treatment systems as alternatives but, in some cases, private treatment would be unfeasible because of lack of space and proximity of the plant to populated areas.

Plants Discharging Directly to Receiving Waters

Twenty-four dairy plants were identified as having direct discharge of processing wastes to receiving waters with no prior treatment. Fifteen of these plants processed over 263 million pounds of milk or about 3 percent of all milk processed in Minnesota in 1974.

Twelve of the 24 dairy plants discharging waste directly to receiving waters reported distances to the nearest municipal sewer line in the MPCA survey. None of the 12 plants were located within 4 miles, five were located 4 to 5 miles, and seven were located 6 or more miles. Therefore, it would appear that relatively few plants were located so that discharge to a municipal waste treatment facility would be feasible.

Survey respondents who reported direct discharge were asked to indicate the distance from their plants to the nearest land available for irrigation. Of the 10 plants responding, only one plant indicated there was land available for irrigation that was then owned by the plant. Nine indicated a distance of one-half mile or less to the nearest land not owned by the plant. One plant reported a distance of 2 miles to land not owned.

Dairy Plants Meeting Selected Effluent Limitations

Waste discharge limitations have been written into many of the NPDES permits issued to dairy plants. The maximum limitations vary from 5 to 100 milligrams/liter (mg/1) of BOD_5 and suspended solids depending on the specific plant and whether the limitation was applicable to the 1977 or 1983 deadline. Dairy plants with a NPDES permit are required to monitor wastewater discharge and submit monthly reports to the Minnesota Pollution Control Agency on the levels of BOD_5, pH, and suspended solids in the wastewater. In order to determine whether or not these plants were consistently achieving these effluent limitations, discharge monitoring reports for 39 Minnesota dairy plants were analyzed.[6]

Nearly 90 percent of the reporting plants would have met a limitation of 100 mg/1 for both BOD_5 and suspended solids in at least one reporting period (table 7). However, less than 24 percent met the 25 and 30 mg/1 limitations for BOD_5 and suspended solids in one or more reporting periods. Only two plants would have met a 5 mg/1 limitation for BOD_5 and suspended solids.

Less than 16 percent of the plants would have met a restriction of 100 mg/1 for both BOD_5 and suspended solids in all reporting periods. None of the plants would have met restrictions of 50 mg/1 or less in all reporting periods.

Monthly discharge monitoring reports are based on a grab sample taken at the point of discharge into receiving

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[6] These reports are based on grab samples from waste streams which fluctuate greatly in flow and strength during a processing day. Recognizing the limitations of the date, it is possible to make some comparisons of the data.

waters. Daily and seasonal fluctuations in wastewater flow and waste load, if not taken into account, can result in waste characteristics data that does not reflect the true waste load discharged to receiving waters. Additionally, the monthly discharge monitoring reports indicate the degree of waste treatment achieved from private waste treatment systems.

Table 7a. Dairy plants meeting both BOD$_5$ and suspended solids discharge limitations in at least one reporting period.

	BOD$_5$/suspended solids discharge limitation				
	5/5 mg/1	15/15 mg/1	25/30 mg/1	50/50 mg/1	100/100 mg/1
Reporting periods	2	15	39	125	297
Percentage of total periods (488)	0.4	3.1	8.0	25.6	60.9
Plants	2	4	9	26	34
Percentage of total plants (38)	5.3	10.5	23.7	68.4	89.5
Average periods per plant	1.0	3.8	4.3	4.8	8.7

Table 7b. Dairy plants meeting both BOD$_5$ and suspended solids limitations in all reporting periods.

	BOD$_5$/suspended solids discharge limitation				
	5/5 mg/1	15/15 mg/1	25/30 mg/1	50/50 mg/1	100/100 mg/1
Plants	0	0	0	0	6
Percentage of total plants (38)	0	0	0	0	15.8

Case Studies in Minnesota

Four Minnesota dairy plants using different private waste treatment systems were selected for further study (table 8). Samples of waste discharged directly from the plant (influent into the treatment system consisting of non-contaminated cooling water and contaminated cleaning water) were collected each hour with an automatic 24-hour sampler. Flow rate was also measured. Because of its uniformity over time, the effluent from the treatment system was sampled three to four times during the same 24-hour period. Samples were analyzed at a University of Minnesota laboratory for total solids, total volatile solids, chemical oxygen demand, pH, and orthophosphate.[7] Samples were taken during fall, winter, and spring months except for a large cheese plant. The sample taken at the large cheese plant during the spring was not representative because unusual cleaning of the system occurred during the sample period.

A small butter plant using a two-cell stabilization pond achieved a higher efficiency in removing COD and total solids than any of the other plants (table 8). Results showed that this plant met a 25 mg/1 COD and, because BOD$_5$ is always less than COD, a more stringent 25 mg/1 BOD$_5$ standard in all four months it was sampled. A 5 mg/1 COD was met in two of the four sample periods. A 25 mg/1 total solids was met in only two of the four sample periods.

Given the amount of waste loading from the large cheese plant and the two receiving stations, their respective treatment systems were clearly underdesigned to achieve a 25 mg/1 of COD or total solids standard during all seasons (table 8). These results suggest that many Minnesota dairy plants now having private waste treatment systems likely do not

Table 8. Laboratory analysis of influent and effluent samples from four Minnesota dairy plants.

Type of plant				Chemical oxygen demand				Total solids			
	Approximate annual milk received, 1,000 lbs.	Date of sample	Flow/ day, 1,000 gal.	Influent, kg/day	Effluent kg/day	Effluent mg/1	Efficiency percent	Influent kg/day	Effluent kg/day	Effluent mg/1	Efficiency percent
Large cheese and butter plant using a two-cell aerated lagoon	499,200	Feb 1975	190.2	3,228.0	164.10	228	95	4,354.0	1,730.0	2,403	60
		May 1976	187.0	3,131.0	668.70	945	79	3,444.0	2,061.0	2,912	40
Small butter plant using a two-cell stabilization pond	50,000	Sep 1975	22.0	61.14	0.34	4	99	137.30	2.07	25	98
		Jan 1976	27.1	37.35	2.59	25	93	49.74	8.86	86	82
		Feb 1976	22.9	32.93	1.95	22	94	55.88	6.54	75	97
		May 1976	25.8	45.89	0.49	5	99	57.19	1.58	16	97
Small receiving station using a package aeration system	16,300	Sep 1975	7.0	25.04	0.93	30	97	23.80	6.88	260	71
		Mar 1976	7.4	16.32	9.12	326	44	15.60	24.89	890	0[a]
		May 1976	8.4	17.08	6.41	202	62	16.38	29.00	935	0[a]
Receiving station using a primary settling tank, 18 ft^2 trickling filter and final settling tank	91,300	Sep 1975	18.2	35.66	14.95	217	58	92.72	53.04	770	43
		Feb 1976	16.6	69.85	65.34	1,040	65	136.50	55.79	888	59
		May 1976	19.8	68.52	8.92	119	87	92.63	52.46	700	43

[a] At the time samples were taken the concentration of total solids in the effluent exceeded the concentration in the influent. This emphasizes the variability that can occur in measures of waste concentration.

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[7] BOD$_5$ tests were also run but were considered unreliable and not reported here. The BOD$_5$ loading would be less than the COD loading but expected to be related to the COD measurements.

Stabilization ponds provide storage and treatment of plant wastewater.

meet the current pollution standards written into permits. These plants face additional costs to come into compliance.

Probably only a private waste treatment system that has no effluent but disposes of waste totally on land (such as a ridge and furrow or sprinkler irrigation system) would be able to meet the most stringent regulation of 5 mg/1 or less of both BOD_5 and total solids. However, the non-point pollution regulation of groundwater or runoff from irrigation fields may become a problem for plant management using these systems. Effluent from a properly designed stabilization pond treatment system could be expected to meet a 25 mg/1 or less of BOD_5 and total solids but not a 5 mg/1 regulation. The two-cell stabilization pond used by the small butter plant provided about 184,000 square feet of surface area.[8] Based on the highest COD loadings obtained from the influent samples (table 8), this size of lagoon provided more than 1,360 square feet per pound of COD loading per day. Therefore, the square feet per pound of BOD_5 loading would be even higher.

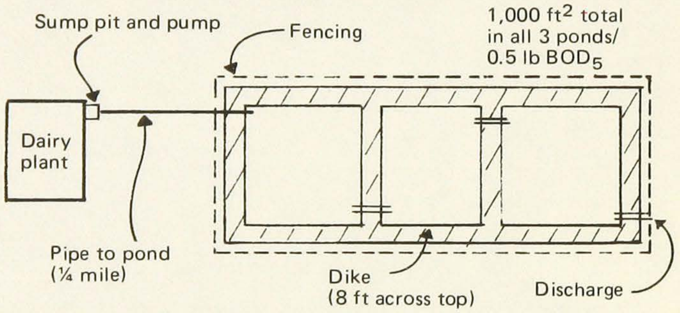
Differences in the efficiency rates and between sampling dates among the systems studied and reported in table 8 probably are explained in large part by the amount of loading relative to the design of the system, increases in amount of milk processed and, therefore, organic loading during the winter months, and cold weather reducing the efficiency of the systems analyzed.

Private Waste Treatment Alternatives

Dairy processing plants discharging waste directly or using private treatment that may not meet water quality regulations must consider alternative ways to come into compliance with possible pollution control regulations. Also, plants presently using municipal waste systems but facing substantial increases in use charges may also consider an alternative private waste treatment system. Three waste treatment systems for typical dairy plants are analyzed in this report: (1) stabilization pond, (2) aerated lagoon-irrigation, and (3) ridge and furrow irrigation. All three systems require land located no closer than one-fourth mile from the dairy plant and/or other residences. Therefore, these alternative treatment systems may not be feasible for plants located in urban areas. Most plants in urban areas would probably have the option of discharging waste to a municipal treatment system.

Eleven dairy plants, representative of the type and sizes of plants in Minnesota, were selected to evaluate initial investment and annual cost of the above alternative waste treatment systems. These included three sizes of butter plants annually receiving 14.7, 40, and 135 million pounds of milk, respectively; two sizes of cheese plants annually receiving 70.6 and 469 million pounds of milk, respectively; three sizes of fluid bottling plants annually receiving 3.3, 39, and 100 million pounds of milk, respectively, and three sizes of receiving stations annually receiving 13, 23, and 58 million pounds of milk, respectively.

Figure 1. Sketch of stabilization pond wastewater treatment system (not drawn to scale).



STABILIZATION POND

The stabilization pond is not a total disposal system, but usually will discharge effluent at least during parts of the year. The aerobic treatment of waste is achieved by designing a series of three ponds of sufficient total size to provide 1,000 square feet of surface area for each 0.5 pounds of BOD_5 discharged per day. Fewer square feet of exposed pond surface could result in odor problems. Therefore, only one treatment level could be expected. The effluent discharged from this system would not be expected to have less than 25 mg/1 BOD_5 during all seasons of the year.

The three successive ponds are designed with a 3-foot freeboard on the dikes and the bottom 1-foot set aside for solids storage.[9] The volume between 1 foot from the pond's bottom and the water level of the pond is the design storage/treatment volume (figure 1).

The major components of the system, in addition to the ponds, include sump pump lift-station and transport pipe to move the waste from the plant to the disposal area. Each area is fenced and seeded to grass.

The expected investment and annual costs, given the volume and BOD_5 content of wastes from the 11 typical types and sizes of Minnesota dairy plants, are shown in tables 9 and 10.

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[8] The waste treatment consisted of two lagoons: one 360 feet square and another 360 feet long by 150 feet wide.

[9] "Recommended Design Criteria for Sewage Stabilization Ponds," Minnesota Pollution Control Agency, Division of Water Quality, November 1, 1974.

Table 9. Estimated investment for a stabilization pond waste treatment system for representative types and sizes of Minnesota dairy plants.

	Type of plant and thousand pounds of milk received annually										
Equipment and	Butter			Cheese		Fluid bottling			Receiving station		
facilities	14,700	40,000	135,000	70,600	469,000	3,300	39,000	100,000	13,000	23,000	58,000
	dollars										
Sump pit	575	575	575	575	575	575	575	575	575	575	575
Sump pump	7,460	7,460	9,340	7,460	9,340	7,460	7,460	9,340	7,460	7,460	7,460
Pipe to pond	3,830	3,830	4,720	3,830	4,720	3,830	3,830	4,720	3,830	3,830	3,830
Pipe between ponds	340	340	340	340	340	340	340	340	340	340	340
Excavation of ponds	5,070	9,000	17,250	12,120	33,540	2,670	11,280	18,480	2,040	2,790	4,740
Fencing	2,700	4,210	6,970	5,470	13,060	1,790	5,110	7,490	1,480	1,810	2,790
Seeding grass	80	130	360	150	660	40	140	380	30	40	70
Subtotal	20,055	25,545	39,555	29,945	62,235	16,705	28,735	41,325	15,755	16,845	19,805
Land	9,240	21,700	64,400	35,000	207,200	3,780	30,520	72,800	2,520	3,920	8,260
Total	29,295	47,245	103,955	64,945	269,435	20,485	59,255	114,125	18,275	20,765	28,065
Total per 1,000 lb milk received	1.99	1.18	0.77	0.92	0.57	6.21	1.52	1.14	1.41	0.90	0.48

Investment. The estimated investment for the 11 representative dairy plants to construct a stabilization pond treatment system varied considerably (table 9). For the small fluid bottling plant, total investment was estimated at slightly over $20,000 which amounted to over $6 per 1,000 pounds of milk received. Total investment, mostly for land, was estimated to be over $250,000 for a large cheese plant receiving 469 million pounds of milk annually. However, investment per 1,000 pounds of milk received was only 57 cents for this plant. The large receiving station handling 58 million pounds of milk annually would need to invest an estimated 48 cents per 1,000 pounds of milk received, the lowest of all representative plants.

Annual cost. Total annual cost was computed based on two assumptions regarding recovery of investment. Assuming a 15-year recovery, annual cost ranged from over $30,000 for the large cheese plant to about $3,200 for the small receiving station (table 10).[10] The annual cost per 1,000 pounds of milk received was less than 30 cents for all representative plants except the small fluid bottling plant, where it exceeded $1. Annual cost almost doubled when it was assumed that investment would be recovered over a 5-year rather than the 15-year period.

AERATED LAGOON-IRRIGATION

Surface aerators were assumed impractical for winter operation in Minnesota because of the cold temperatures and freezing water. It was assumed that seven months of waste must be stored over the winter months, then irrigated onto land during the spring and fall. Aerators would operate for about 6 months in the summer, primarily to control odor.[11] The 7-month detention time is based more on the volume storage required for the winter period than on the level of treatment desired.

A two-stage disposal system includes chemical treatment equipment (top right) and a wastewater aerator (foreground).

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[10] Depreciation for equipment with a useful life of less than 15 years was based on the actual useful life.

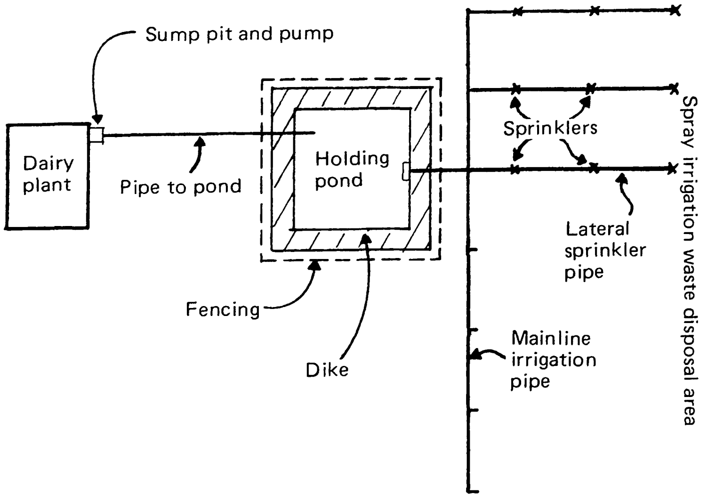
[11] Recommended Design Criteria for Aerated Stabilization Ponds, Minnesota Pollution Control Agency, Division of Water Quality, March 1971.

Table 10. Estimated annual cost for a stabilization pond waste treatment system for representative types and sizes of Minnesota dairy plants.

Equipment and facilities	Type of plant and thousand pounds of milk received annually										
	Butter			Cheese		Fluid bottling			Receiving station		
	14,700	40,000	135,000	70,600	469,000	3,300	39,000	100,000	13,000	23,000	58,000
	dollars										
15-year or useful life depreciation:											
Depreciation	1,528	2,062	3,103	2,358	4,645	1,463	2,276	3,223	1,399	1,467	1,676
Interest (non-land)	802	1,022	1,582	1,198	2,489	668	1,149	1,653	630	674	792
Repairs and maintenance	764	829	1,106	883	1,368	725	868	1,128	712	726	768
Electricity	45	90	150	90	300	40	75	125	45	45	45
Labor	189	200	235	210	347	186	207	238	186	186	189
Subtotal	3,328	4,203	6,176	4,739	9,149	3,082	4,575	6,367	2,972	3,098	3,470
Principal on land	620	1,454	4,315	2,345	13,882	253	2,045	4,878	169	263	553
Interest on land	323	760	2,254	1,225	7,252	132	1,068	2,548	88	137	289
Total	4,271	6,417	12,745	8,309	30,283	3,467	7,688	13,793	3,229	3,498	4,312
Total per 1,000 lbs. milk	0.29	0.16	0.094	0.118	0.065	1.051	0.197	0.138	0.248	0.152	0.074
5-year recovery of investment:											
Subtotal	5,811	7,250	10,984	8,181	16,951	4,960	8,046	11,409	4,724	5,000	5,755
Principal on land	1,848	4,340	12,880	7,000	41,440	756	6,104	14,560	504	784	1,652
Interest on land	323	760	2,254	1,225	7,252	132	1,068	2,548	88	137	289
Total	7,982	12,350	26,118	16,406	65,643	5,848	15,218	28,517	5,316	5,921	7,696
Total per 1,000 lb milk	0.543	0.309	0.193	0.232	0.140	1.77	0.390	0.285	0.409	0.257	0.133

Wastes are discharged from the dairy plant into a sump pump lift-station that in turn pumps the waste underground to the lagoon (figure 2). The irrigation system is used to dispose of waste on land adjacent to the lagoon and is designed so that the sprinkler pipe is moved only once a week. This disposal area is large enough to meet the Minnesota Pollution Control Agency's recommended maximum application rates of ¼ inch per hour, 2 inches per week, and the capacity to handle 12 months of waste discharge over an 18-week irrigation season.[12]

Figure 2. Sketch of a spray irrigation waste disposal system for dairy processing plant (not drawn to scale).



Investment. The estimated investment for the 11 representative dairy plants to build an aerated lagoon-irrigation waste disposal system (including land) varied from over $100,000 for the large cheese plant to about $21,000 for the small receiving station (table 11). Investment per 1,000 pounds of milk received annually was less than $1.20 for all plants except the small butter and fluid bottling plants. Investment per 1,000 pounds of milk received annually of 39 cents for the large cheese plant was lowest of all representative plants considered.

Annual costs. Assuming a 15-year recovery period for investment, the annual cost for operating the aerator lagoon-irrigation waste disposal system ranged from over $37,000 for the large representative cheese plant to about $4,300 for the small fluid bottling plant (table 12). The annual cost per 1,000 pounds of milk received was less than 50 cents for all representative plants except the small fluid bottling plant where it was about $1.30.

Annual cost was about 50 percent higher when it was assumed that investment would be recovered over a 5-year rather than a 15-year period.

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[12] **Recommended Design Criteria for Disposal of Municipal Effluents by Land Application, Minnesota Pollution Control Agency, Division of Water Quality, May 1, 1972.**

Table 11. Estimated investment for aerated lagoon-irrigation waste disposal systems for representative types and sizes of Minnesota dairy plants.

Equipment and facilities	Type of plant and thousand pounds of milk received annually Butter			Cheese		Fluid bottling			Receiving station		
	14,700	40,000	135,000	70,600	469,000	3,300	39,000	100,000	13,000	23,000	58,000
	----------dollars----------										
Sump pit	575	575	575	575	575	575	575	575	575	575	575
Sump pump	7,460	7,460	9,340	7,460	9,340	7,460	7,460	9,340	7,460	7,460	7,460
Pipe to pond[a]	3,830	3,830	4,720	3,830	4,720	3,830	3,830	4,720	3,830	3,830	3,830
Culvert	40	40	70	40	70	40	40	70	40	40	40
Holding pond const	1,210	2,640	7,320	2,880	13,800	370	2,160	4,800	490	1,170	1,920
Irrigation platform	100	100	100	100	100	1000	100	100	100	100	100
Irrigation system[b]	5,210	12,720	33,490	13,787	49,820	1,270	10,170	22,142	2,500	2,590	11,260
Fencing-holding pond	1,150	1,610	2,530	1,670	3,340	900	1,500	2,160	840	990	1,440
Aerators	5,200	5,700	12,800	6,400	21,750	5,200	5,700	7,250	5,200	5,200	5,200
Seeding grass	130	260	780	270	1,590	40	170	470	60	90	180
Subtotal	24,905	34,935	71,725	37,012	105,105	19,785	31,705	51,627	21,095	22,045	32,005
Land[c]	6,300	12,740	38,780	13,580	79,520	1,820	8,400	23,520	2,660	4,200	8,820
Total	31,205	47,675	110,505	50,592	184,625	21,605	40,105	75,147	23,755	26,245	40,825
Total per 1,000 lb milk received	2.12	1.19	0.82	0.72	0.39	6.55	1.03	0.75	1.83	1.14	0.70

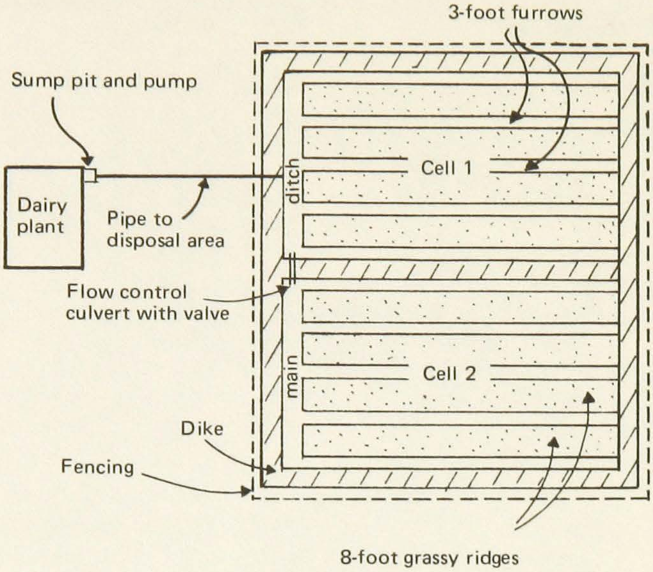
[a] Pipe and underground installation. [b] Pump and motor, main line, and lateral lines. [c] Valued at $1,400 per acre.

Table 12. Estimated annual cost for aerated lagoon-spray irrigation waste disposal system for representative types and sizes of Minnesota dairy plants.

Equipment and facilities	Type of plant and thousand pounds of milk received annually Butter			Cheese		Fluid bottling			Receiving station		
	14,700	40,000	135,000	70,600	469,000	3,300	39,000	100,000	13,000	23,000	58,000
	----------dollars----------										
15-year or useful-life depreciation:											
Depreciation	2,833	3,903	8,202	4,170	12,193	1,176	3,571	5,701	2,454	2,522	3,584
Interest	996	1,397	2,869	1,480	4,204	791	1,268	2,065	844	881	1,280
Repairs and maintenance	1,087	1,145	1,875	1,200	2,581	1,077	1,141	1,443	1,074	1,081	1,100
Electricity	883	1,613	4,196	1,949	8,068	781	1,503	3,515	840	864	1,145
Labor	340	490	1,078	511	2,009	263	427	732	284	308	410
Subtotal	6,139	8,548	18,220	9,310	29,055	4,088	7,910	13,456	5,496	5,656	7,519
Principal on land	422	854	2,598	910	5,328	122	563	1,576	178	281	591
Interest on land	221	446	1,357	475	2,783	64	294	823	93	147	309
Total	6,782	9,848	22,175	10,695	37,166	4,274	8,767	15,855	5,767	6,084	8,419
Total per 1,000 lb milk	0.461	0.246	0.164	0.151	0.079	1.295	0.225	0.159	0.444	0.265	0.145
5-year recovery of investment:											
Subtotal	8,287	11,632	24,363	12,542	37,883	6,869	10,680	18,080	7,261	7,543	10,336
Principal on land	1,260	2,548	7,756	2,716	15,904	364	1,680	4,704	532	840	1,764
Interest on land	221	446	1,357	475	2,783	64	294	823	93	147	309
Total	9,768	14,626	33,476	15,733	56,570	7,297	12,654	23,607	7,886	8,530	12,409
Total per 1,000 lb milk	0.664	0.366	0.248	0.223	0.121	2.21	0.324	0.236	0.607	0.371	0.214

Plant growth is improved by water and nutrients from the ridge and furrow treatment system.

Figure 3. Sketch of a two-cell ridge and furrow waste disposal system (not drawn to scale).



RIDGE AND FURROW

Ridge and furrow irrigation is a final land application wastewater disposal system. Wastewater is discharged into a sump pit lift-station where it is then pumped underground to a distribution canal (figure 3), The wastewater then flows into furrows which are nearly level and at a slightly higher elevation than the main ditch. For this study, furrows are assumed to be 3-feet wide and 1-foot deep with the grassy ridges 8-feet wide. When liquid rises in the furrows to about 1-foot depth, an overflow into another cell or area is provided. Control gates between cells can permit the operation of one section at a time which allows taking some sections out of service for either maintenance or resting.

The major components of the system, in addition to the disposal area, are (1) sump pump lift-station and transport pipe to move waste from the plant to the disposal area and (2) flow control culverts in the disposal area. In Minnesota, about twice as much land area is assumed for this system during the winter months as during the summer months. The costs are based on the higher winter requirements of 5,000 gallons of waste per acre per day.[13] Volume of waste discharged from the plants is based on gallons of waste reported in table 2.

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[13] F. H. Schraufnagel, Dairy Waste Disposal by Ridge and Furrow Irrigation. Proceedings of 12th Indiana Waste Conference, Purdue University, Indiana Agricultural Extension Series, May 1957.

Table 13. Estimated investment for a ridge and furrow waste disposal system for representative tapes types sizes of Minnesota dairy processing plants.

Equipment and	Type of plant and thousand pounds of milk received annually										
	Butter			Cheese		Fluid bottling			Receiving station		
facilities	14,700	40,000	135,000	70,600	469,000	3,300	39,000	100,000	13,000	23,000	58,000
	dollars										
Sump pit	575	575	575	575	575	575	575	575	575	575	575
Sump pump	7,460	7,460	9,340	7,460	9,340	7,460	7,460	9,340	7,460	7,460	7,460
Pipe to disposal area	3,830	3,830	4,720	3,830	4,720	3,830	3,830	4,720	3,830	3,830	3,830
Culverts	110	110	360	110	660	110	110	360	110	110	110
Excavation	980	1,540	2,630	1,580	3,740	550	1,380	2,070	550	710	1,110
Fencing	1,330	2,040	3,590	2,110	5,150	660	1,820	2,300	900	1,130	1,690
Seeding grass	50	120	350	130	720	20	90	210	30	40	80
Subtotal	14,335	15,675	21,565	15,795	24,905	13,205	15,265	19,575	13,455	13,855	14,855
Land	2,380	5,740	17,500	6,160	35,980	700	4,620	10,640	1,120	1,780	3,920
Total	16,715	21,415	39,065	21,955	60,885	13,905	19,885	30,215	14,575	15,635	18,775
Total per 1,000 lb milk received	1.14	0.54	0.29	0.31	0.13	4.21	0.51	0.30	1.12	0.68	0.32

Table 14. Estimated annual cost for ridge and furrow waste disposal system for representative types and sizes of Minnesota dairy plants.

Equipment and facilities	Type of plant and thousand pounds of milk received annually										
	Butter			Cheese		Fluid bottling			Receiving station		
	14,700	40,000	135,000	70,600	469,000	3,300	39,000	100,000	13,000	23,000	58,000
	dollars										
15-year or useful-life depreciation:											
Depreciation	1,304	1,399	1,897	1,409	2,149	1,226	1,370	1,753	1,244	1,272	1,341
Interest	573	627	863	632	996	528	611	783	538	554	594
Repairs and maintenance	705	736	960	739	1,027	676	726	905	687	697	721
Electricity	45	90	150	90	300	40	75	125	45	45	45
Labor	188	196	226	197	272	184	204	209	185	186	192
Subtotal	2,815	3,048	4,096	3,067	4,744	2,654	2,986	3,775	2,699	2,754	2,893
Principal on land	160	385	1,173	413	2,411	47	310	713	75	119	263
Interest on land	83	201	613	216	1,259	25	162	372	39	62	137
Total	3,058	3,634	5,882	3,696	8,414	2,726	3,458	4,860	2,813	2,935	3,293
Total per 1,000 lb milk	0.208	0.091	0.044	0.052	0.018	0.826	0.089	0.049	0.216	0.128	0.057
5-year recovery of investment:											
Subtotal	4,378	4,784	6,512	4,817	7,576	4,069	4,669	5,937	4,146	4,253	4,523
Principal on land	476	1,148	3,500	1,232	7,196	140	924	2,128	224	356	784
Interest on land	83	201	613	216	1,259	25	162	372	39	62	137
Total	4,937	6,133	10,625	6,265	16,031	4,234	5,755	8,437	4,409	4,671	5,444
Total per 1,000 lb milk	0.336	0.153	0.079	0.089	0.034	1.283	0.148	0.084	0.339	0.203	0.094

Investment. The estimated investment for the 11 representative dairy plants to construct a ridge and furrow waste disposal system varied from about $61,000 for the large cheese plant to almost $14,000 for the small fluid bottling plant (table 13.) Investment per 1,000 pounds of milk received annually was less than $1.15 for all plants except the small fluid bottling plant. Investment per 1,000 pounds of milk received annually of 13 cents for the large cheese plant was the lowest of all representative plants considered.

Annual cost. Assuming a maximum 15-year recovery period of all investments, the annual cost for operating the ridge and furrow waste disposal system ranged from about $8,400 for the large cheese plant to about $2,700 for the small fluid bottling plant (table 14). The annual cost per 1,000 pounds of milk received was less than 22 cents for all representative plants except the small fluid bottling plant where it was about 83 cents.

Annual cost was about 60 percent higher when it was assumed that investment would be recovered over a 5-year rather than a 15-year period.

INVESTMENT AND ANNUAL COST COMPARISONS

Investment and annual cost per 1,000 pounds of milk received annually were lower for the ridge and furrow than for the aerated lagoon-irrigation and stabilization pond systems for all representative dairy plants considered (table 15). The annual cost per 1,000 pounds of milk received for all sizes of butter plants and receiving stations was less for the stabilization pond than for the aerated lagoon-irrigation system. The opposite was true for cheese and fluid bottling plants.

The estimated annual cost for the three alternative private treatment or disposal systems, except the ridge and furrow system, exceeded the average sewer use charge paid by similar plants that were discharging into municipal waste treatment systems. Annual cost for the ridge and furrow system was less for both size cheese plants and the large fluid bottling plant than the average sewer use bill paid by their counterparts that were discharging into municipal waste treatment systems.

The increased cost per pound of butter and cheese produced in representative plants was less than 0.87 cents for all three waste handling systems considered (table 15). When considering only the lowest cost ridge and furrow system, the increased cost to produce a pound of butter was estimated to be about 0.36 cents for the small and 0.09 for the large butter plants. The increased cost to produce a pound of cheese was estimated to be about 0.87 cents for the small and 0.03 for the large cheese plants. The increased cost per half-gallon of milk was estimated to be about 0.55 cents for the small fluid plant and about 0.04 cents for the large bottling plant.

The increase in cost for waste treatment or disposal was considerably lower for small than for large plants of any of the four representative types of plants analyzed (table 15).

Table 15. Summary of investment and annual cost for three alternative waste treatment or disposal systems for representative types and sizes of dairy plants.

Equipment and facilities	Type of plant and thousand pounds of milk received annually										
	Butter			Cheese		Fluid bottling			Receiving station		
	14,700	40,000	135,000	70,600	469,000	3,300	39,000	100,000	13,000	23,000	58,000
	cents per 1,000 lbs of milk received										
Investment:											
Stabilization pond	199	118	77	92	57	621	152	114	141	90	48
Aerated lagoon-irrigation	212	119	82	72	39	655	103	75	183	114	70
Ridge and furrow	114	54	29	31	13	421	51	30	112	68	32
Annual cost (5-year recovery of investment):											
Stabilization pond	54.3	30.9	19.3	23.2	14.0	177.0	39.0	28.5	40.9	25.7	13.3
Aerated lagoon-irrigation	66.4	36.6	24.8	22.3	12.1	221.0	32.4	23.6	60.7	37.1	21.4
Ridge and furrow	33.6	15.3	7.9	8.9	3.4	128.3	14.8	8.4	33.9	20.3	9.4
Average sewer use charge by municipalities	4.97			11.14		11.38			7.21		
Added cost:	per pound butter[b]			per pound of cheese[c]		per half-gallon milk[d]			per 100 pounds milk		
Stabilization pond	0.589	0.335	0.209	0.242	0.146	0.756	0.167	0.122	49.0	2.57	1.33
Aerated lagoon-irrigation	0.720	0.397	0.269	0.232	0.126	0.944	0.138	0.101	6.07	3.71	2.14
Ridge and furrow	0.364	0.166	0.086	0.093	0.035	0.548	0.063	0.036	3.39	2.03	0.94

[a] See Table 10.

[b] Assumes 4.61 pounds of butter and 8.96 pounds of nonfat dry milk from 100 pounds of milk.

[c] Assumes 9.6 pounds of cheese from 100 pounds of milk.

[d] Assumes 23.25 half-gallons of milk from 100 pounds of milk.

Conclusions

Regulations designed to protect the nation's water from pollution will affect the manufacturing costs for essentially all of Minnesota's dairy processing plants. Plants that do not discharge their wastewater directly into a municipal sewer system will be required to have their own treatment or land disposal system. Information from the case studies of four Minnesota dairy plants with private treatment systems and from discharge monitoring reports filed with the Minnesota Pollution Control Agency suggest that only a final land disposal system (a system without effluent) such as the ridge and furrow or aerated lagoon-irrigation could meet the most restrictive 5 mg/1 BOD_5 and suspended solids in all months of the year. A well-designed stabilization pond could at best be expected to meet a 25 mg/1 of BOD_5 and suspended solids effluent limitation.

Sewer use charges for most dairy plants that discharge into a municipal waste treatment system have or will be expected to increase as municipalities remodel or construct new waste treatment facilities to meet high pollution control standards.

Results suggest that, generally, dairy plants that use municipal waste water treatment facilities are better-off (or as well-off) cost-wise to remain with the municipalities and pay the higher use charge than to construct their own private treatment system. For those dairy plants located without the opportunity to use municipal waste treatment systems, the ridge and furrow land disposal system would cost less than either the stabilization pond or aerated lagoon-irrigation systems. Also, because the ridge and furrow has no effluent discharge, it would obviously meet any discharge limitations as far as surface water was concerned. The implication of the ridge and furrow system for pollution of groundwater has not been considered in this study. Many factors would affect this potential pollution including soil, distance to the water table, and the topography of the land.

Results show that for typical Minnesota dairy processing plants production costs would be expected to increase about 2 percent for most manufactured dairy products. At the retail level, price would be expected to rise from 0.3 to 0.7 percent to cover increased pollution control costs.

The decision of individual plants on whether to incur higher costs and continue manufacturing is influenced by many factors. Whether the plant is an individual proprietor or part of a larger multi-plant cooperative may be important. Added costs associated with wastewater may provide additional incentive for multi-plant cooperatives to consolidate milk into fewer plants and not construct wastewater facilities for all plants. Cash flow and ability of the firm or cooperative to finance the added investment are also important considerations for individual dairy processing plants.

APPENDIX

Appendix Table 1. Pounds of wastewater and BOD generated per 1,000 pounds of milk processed in milk market and butter processing and manufacturing by plant process.[a]

Type of plant and process	Water	BOD	Water	BOD
	------------pounds		------------	
Market milk plant:	normal operation		rinse saved[b]	
Tank truck milk receiving	125	0.20	100	0.05
Clarifying and/or standardizing	15	0.08	15	0.01
Storage of raw milk	100	0.20	80	0.05
HTST pasteurization, homogenization, automatic by-product formulation	500	0.80	200	0.15
Storage	100	0.20	80	0.05
Filling (paper and plastic)	50	0.30	50	0.05
Conveying	20	0.10	20	0.10
Cold storage	10	0.10	10	0.00
Distribution	100	0.50	0	0.00
Total	1,000	2.48	500	0.46
Butter production:	batch churn		continuous churn	
Milk receiving	125	0.20	125	0.20
Separation	15	0.08	15	0.08
Skim, storage, shipped out	50	0.15	100	0.15
Cream storage	100	0.30	100	0.30
HTST pasteurization phase inversion and oil storage	—	—	500	0.80
Vat pasteurization	300	0.50	—	—
HTST pasteurization	500	0.80	—	—
Standardization	—	0.20	500	0.80
Churning	500	0.20	500	0.20
Washing butter	200	0.30	—	—
Printing and packaging	100	0.10	100	0.10
Storage and distribution	10	0.05	10	0.05
Total	1,450	2.60	1,060	1.96

[a]Source: U.S. Environmental Protection Agency, "Dairy Food Plant Waste Treatment Practices," Water Pollution Control Research Series 12060 EGU, March 1971. This report was prepared by the Department of Dairy Technology, Ohio State University.

[b]CIP sludge saved, HTST start-up, changeover, and shutdown segregated and saved; returns used as feed.

Appendix Table 2. Pounds of wastewater and BOD generated per 1,000 pounds of milk processed in cheddar cheese and ice cream manufacturing by plant process.

Type of plant and process	Water	BOD
	--------------pounds	--------------
Cheddar cheese manufacturing:		
Milk receiving	125	0.20
Milk storage and standardization	100	0.28
Cream storage	100	0.30
Starter manufacture (skim)	100	0.25
Curd making, cutting, cooking, and whey manufacture	100	0.20 (no whey)
Cheddaring, milking, salting	—	0.10
Washed curd, processing, salting	200	0.50
Hooping, forming, pressing	—	0.30
Aging	50	0.05
Grading, trimming, shipping	—	0.05
Total	775	1.25 (cheddar) (1.70 washed curd)
Ice cream manufacturing:		
Receiving and storage	125	0.10
Standardization	15	0.80
Dry ingredient blending	—	0.10
Mixing	—	0.10
HTST, pasteurization, and homogenization	500	0.80
Cooling and storage	100	0.20
Flavoring, fruits, nuts	—	0.10
Freezing	350	0.50
Filling and conveying	50	0.10
Hardening and distribution	10	0.10
Total	1,150	2.09

Source: U.S. Environmental Protection Agency, "Dairy Food Plant Waste Treatment Practices," Water Pollution Control Research Series 12060 EGU, March 1971. This report was prepared by the Department of Dairy Technology, Ohio State University.