State of Wisconsin \ DEPARTMENT OF NATURAL RESOURCES

WISCONSIN DEPT. OF NATURAL RESOURCES

Tommy G. Thompson, Governor
George E. Meyer, Secretary

101 S. Webster St.
Box 7921
Madison, Wisconsin 53707-7921
Telephone 608-266-2621
FAX 608-267-3579
TDD 608-267-6897

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WASTE MANAGEMENT ISSUES FOR DAIRY PROCESSORS

A. Introduction

As it would be expected in "Americas Dairyland" the dairy industry is a significant factor in this Department's regulatory activities in terms of numbers of facilities and wastewater volumes. Although the total number of dairies in Wisconsin has steadily declined over the years, the dairies that have disappeared were generally smaller dairies that were often consolidated with larger dairies. Often the farmer patron supplying the milk simply diverted their supply to other dairies. A recent market trend has been for small cheese makers to produce a specialty cheese for a niche market. There are 2 main types of dairies that DNR regulates and they are cheese making and whey processing. There are a few dairies that churn butter, bottle milk, produce ice cream and other dairy products, such as yogurt, but except for 2 butter manufactures these dairies tend to discharge their wastewater to publicly owned treatment works (POTW) and are not directly regulated by DNR. In the 1997 issue “Wisconsin Agricultural Statistics” it was reported that the Department of Agriculture Trade and Consumer Protection (DATCP) has 222 licensed dairies of which approximately 140 produce cheese. The DNR regulates approximately 150 of the dairies with a specific Wisconsin Pollutant Discharge Elimination system (WPDES) permit.

B. Cheese Making

Although there are many varieties of cheese being produced, the cheese making process generally starts with whole pasteurized milk. The milk is warmed in vats and a lactic acid forming bacteria is added (starter bacteria). The cheese maker tracks the progress of the batch by checking the acidity which is read as pH. At the correct time an enzyme called rennet (from the stomach of calves) is added which causes the protein to form a curd on top of the milk. The curd is then cut into cubes and the mixture is stirred slowly to collect as much protein as possible into the curd. The cheese yield is approximately 10% with the remaining 90% a liquid by-product called whey. Some cheeses are salted by spreading salt grains on the curds, which then draws out more whey. This additional liquid waste is called "salt whey." While the above statements are a general description for making cheddar cheese there are many process variations to produce just the right taste and texture for each variety of cheese, and the quality of the final product depends on the skill of the cheese maker. Some varieties of cheese are salted by soaking the blocks in a 21% salt solution. Wastewater generated during cheese making comes from washing of the cheese vats, the pipelines, milk separator, milk pasteurizer, the inside of the milk trucks, and other equipment. Most dairies use a "clean in place" (CIP) system which pumps cleaning solutions through all equipment in this order: water rinse, caustic solution (sodium hydroxide) wash, water rinse, acid solution (phosphoric or nitric acid) wash, water rinse, and sodium hypo-chlorite disinfectant. These spent chemicals eventually become waste also.

The 5 day biochemical oxygen demand(BOD_5) is a measure of the organic pollutant concentration in the wastewater, and is proportional to the amount of milk or whey lost to the sewer. Normal dairy production plant wastewater is in the range of 2000 to 3000 mg/l which is 10 times the strength of domestic sewage. The BOD_5 can go much higher if a milk spill occurs and the pH can fluctuate widely if spent CIP chemicals are carelessly discharged. It is important for dairies to manage their wastewater discharge to avoid upsetting their biological treatment process or a POTW system.

C. Whey Condensing

Whey has generally been considered an unwanted by-product by cheese makers and in addition, a problem to get rid of. Hence, before it was regulated by the DNR it was often dumped in fields and into earthen seepage pits and sometimes fed to hogs. Currently there is a good market for whey due to the development of technological processes that can produce useful products from whey.

1. Shell and Tube Condensers.

Whey processing starts by evaporating off some of the water thus "condensing" the total volume. Raw whey has a 6% dissolved solids concentration and the solids concentration has to be raised to 40% to 50% before a dry powder can be produced by spray drying. There are various types of whey condensers. One type of condenser is to use several evaporative stages or effects that operate under negative pressure so that the whey boils at temperatures much less than 212° Fahrenheit. The vapors from the first effect become the heat source for the second effect (and so on down the line) by giving up their latent heat of vaporization thus making the process energy efficient. The whey being evaporated moves through a tube surrounded by the vapors in the outer shell thus the term shell and tube condenser.

2. Mechanical Vapor Recompression (MVR)

A second type of process is called a mechanical vapor recompression evaporator in which the liquid is recycled in tubes surrounded by hot vapor. At each pass through the tubes some liquid evaporates and is sucked into a large electric powered air compressor. The compressor heats the vapor by compression and forces the hot vapors into contact with the evaporation tubes. The vapors, being hotter than the whey liquid in the tubes, give up their latent heat of vaporization thus making the process more energy efficient. Both condensation processes generate a wastewater called condensate of whey (COW water). The process also generates wastewater from cleaning the processing equipment.

3. Ultra Filtration (U.F.)

The wide spread use of ultra filtration has opened up new markets for whey products. The purpose of ultra filtration is to separate the protein molecule from the lactose sugar and other molecules in the whey. This is done by using a high pressure pump to force the smaller molecules through a molecular membrane thus leaving the large protein molecules in a concentrated stream. The protein stream is then condensed and dried by the same equipment used to process raw whey. Edible protein has found a good market as a food additive or protein supplement.

The lactose sugar fraction (permeate) can also be condensed and dried for use as baking sugar, baby food and in pharmaceuticals as a carrier for medicine. But because of a limited market and fluctuating prices, large volumes of permeate are landspread on crop land for the nitrogen, phosphorus and potassium fertilizer value. There is technology to create products such as ethyl alcohol, methane gas, or to grow yeast cells and harvest protein from lactose but this is not currently in full scale production.

4. Reverse Osmosis (R.O.)

By selecting specific molecular membranes only water molecules will be forced through thus concentrating the whey solids. Whey can be concentrated from 6% solids to about 12% solids by reverse osmosis thus saving trucking costs and evaporator capacity. The water stream from this reverse osmosis process still has enough sugar molecules to cause a BOD_5 high enough (100 to 300 mg/l) to require treatment as a process wastewater.

D. Wastewater Treatment Options

Dairies not served by a POTW have 2 basic choices for wastewater disposal; surface water discharge and/or land application. Dairies with larger flow volumes (over 25,000 gallons per day) tend to prefer treatment and discharge to surface water if there is a receiving stream available. However, this may not be an option if the stream has no additional assimilative capacity, has a high use classification (outstanding or exceptional), or if there are other site restrictions and discharge requirements that the cost of treatment increases to the point of being unaffordable.

The remaining option is land application of wastewater. The choices for land application are between spray irrigation, ridge and furrow, absorption pond or hauling and application by truck. A discussion of each treatment option follows:

1. Aerated Lagoons

Aerated lagoons are have been a commonly used method of wastewater treatment for dairies that directly discharge to surface water. Generally these systems are several large ponds connected in series with floating surface aerators or submerged air diffusers. The advantages of these treatment systems are as follows:

a. The long retention times of 30 days or more provide enough wastewater volume to absorb shock loads.

b. Lagoons are economical to construct and easy to operate.

c. Lagoons generate small volumes of sludge, and therefore can allow sludge to accumulate for years before it has to be dredged out.

The disadvantages of the system are as follows:

a. Because of their large surface area, and cold Wisconsin winters, the wastewater in the lagoons may have a low temperature which causes a decrease in biological activity and treatment efficiency.

b. Algae grow readily in these large lagoons, and algae growth in summer causes violation of effluent suspended solids limits.

c. Earthen lagoons are required to be constructed and maintained in accordance with NR 213, Wis. Adm. Code to prevent leakage and possible contamination of groundwater.

d. It's difficult to meet the effluent phosphorus limitations with phosphorus removal processes available in a lagoon.

2. Activated Sludge

The conventional activated sludge process is effective for dairy wastewater, but it does require more capital and higher operator skills. A sludge management system is also required. The activated sludge process does overcome some of the primary disadvantages of the aerated lagoons such as low waste temperatures and algae growth.

3. Sequencing Batch Reactors (SBR)

A relatively new technology that is used in a few dairies is sequencing batch reactors. This is essentially an activated sludge batch process which operates in cycles. One cycle involves shutting off aeration to the wastewater treatment vessel long enough for the sludge to settle. The clean treated effluent is then decanted off and if necessary, sludge is wasted before the aeration system is restarted.

4. Biological Tower

This could be considered a modern trickling filter in that wastewater is trickled down over a wood or plastic media covered with biological growth. The biological growth uses the organic waste of the wastewater as food and eventually sloughs off for collection in a clarifier. A biological tower is generally used as an initial treatment unit in a full treatment process and it may be used for pretreatment prior to discharging to a POTW. Significant wastewater cooling and a corresponding decrease in efficiency can occur in winter.

5. Spray Irrigation

For large dairies that rely on land application a spray irrigation system is common. Since spray irrigation is generally not practical in winter, a large storage lagoon is required. WPDES permits require that the wastewater be pretreated to approximately 100 mg/l BOD_5 prior to storage in a lagoon. This is necessary to control odors that would develop from storing an unaerated, untreated waste.

During the growing season the wastewater is applied to the fields using some type of irrigation equipment. One type of equipment is a center pivot system in which the wastewater is pumped to the pivot point of the center pivot system. The spray nozzles rotate around the field in a circular pattern, evenly distributing the wastewater. Other methods are a traveling gun system where a wheel mounted sprayer is pulled down a lane trailing a flexible rubber hose and the waste is irrigated over approximately a 100 foot wide strip. Other types of systems are temporary piping laid out in a grid pattern which is moved periodically or the nozzles are relocated such that the different areas of the field can be rested and loaded. The operation of these systems requires that there be suitable soils and at least 5 feet of separation to ground water and bedrock.

6. Ridge and Furrow Systems

The ridge and furrow system originated in the 1950's as a way to irrigate wastewater all year long. The system consists of a series of parallel, shallow furrows about 1 foot deep and located about 8 feet apart. A header ditch connects all the furrows and feeds the wastewater evenly into each furrow. A cover crop is planted on the ridges to take up water and nutrients. A properly designed system will have more than one cell such that the system can be rested and loaded thus allowing the aerobic bacteria in the soil to degrade the waste. Although the systems were popular in the '60's and '70's (there were 80 in 1984) new systems are not constructed as much today because many of these systems could not achieve compliance with the strict ground water standards for nitrates and chlorides. However, there are dozens of systems still being used by smaller dairies which are regulated and permitted by the Department. A scaled down furrow absorption system may be suitable for wash water from dairy farm milking centers.

7. Absorption Ponds

Absorption ponds were popular for dairy wastewater disposal about 25 years ago (there were 58 in 1984) but as with the ridge and furrow systems they are not constructed as much today because of concern about compliance with the new ground water standards. Typically absorption ponds were used by the smaller dairies where the wastewater volume was less than 10,000 gpd. As these smaller dairy plants have closed, many of these absorption ponds have been taken out of service, however, there are still a few of them being used and regulated by this Department. If a new absorption pond system were to be approved today by the Department there would have to be substantial pretreatment ahead of it so that the system could meet the groundwater standards for nitrate and chlorides.

8. Hauling and Land Application

When other options are not available or the strength of the wastewater is very high, then hauling and land application is generally the only viable option. In this type of operation a truck is used to transport the waste from the factory to a suitable land spreading site. All sites must be approved by the Department prior to use and must meet specific criteria to provide groundwater and surface water protection (NR 214 criteria). The trucks used to spread the wastewater may simply have a spreader bar on the back where the waste is dribbled out as the truck drives along. In some of the more advanced systems a high pressure spray nozzle allows the truck to spray it out 100 feet or more to avoid running over crops. Some systems even set up a small temporary irrigation nozzle so that they can pump the wastewater from a large truck out into a field for distribution. For some types of waste such as permeate, salt whey, and separator desludge the pollutant concentrations are so high that land application is the only practical alternative.

E. WPDES Permit Issuance

WPDES Permits regulate the discharge of treated process wastewater, cooling water or condensate of whey to surface waters and the land application of liquid waste or sludge. Dairies that discharge to POTW's are not regulated by DNR unless they also land apply sludge or high strength wastewater. The DNR also issues general permits to regulate the discharge of noncontact cooling water to surface water or the land application of small volumes of process wastewater, high strength wastewater, or sludge where these discharges are considered to have low environmental risk.

There are approximately 45 dairies that hold a WPDES permit to discharge process wastewater to surface water not counting those discharging only non contact cooling water. Of those 45, twenty dairies treat and discharge all their process wastewater and the remaining 25 discharge only condensate from whey processing. Since many dairies discharge to both surface water and land application, or to a POTW and land application, the total number of dairy permits is around 150.

1. Surface Water Effluent Limits

For cheese making and whey processing, categorical limits for BOD_5, suspended solids and pH are promulgated in NR 240 Wis. Adm. Code, Dairy Products Processing. The first step is to calculate the BOD_5 input to each dairy process using multiplication factors in the code (Table 1). Then the allowable pounds of BOD_5 and suspended solids that can be discharged are calculated from factors in the second table (Table 2). These production based limits are based on the maximum month of production in the year. The pH is limited to a range of 6 to 9. Permit categorical limits for BOD_5 and suspended solids are also the annual mass limits for purposes of determining compliance with NR 207 (antidegradation).

The dairy products processing categorical limitations were promulgated by EPA in the early 1970's and the processes used in the dairy industry have changed since then. For new technologies such as shell and tube and mechanical vapor recompression evaporators or for membrane separation technology the drafter has to rely on best professional judgement (BPJ) to establish an appropriate categorical limit. The EPA categorical limit for whey processing equipment was based on a piece of equipment called a barometric condenser which was popular in the 1970’s. However, due to higher energy costs and tighter pollution rules these are being phased out.

For the discharge of COW water from shell and tube or mechanical vapor recompression condensers, a BPJ limit has been determined by industrial wastewater engineering staff after analyzing data from a number of installations. The average BOD_5 limit calculation is based on the permittee achieving a 35 mg/l concentration limit in the COW water. The Department has determined that this limit can be achieved with good management and some COW water recycle. The quantity limit is based on the 35 mg/l concentration limit times the total volume of COW water removed (in millions of gallons per day) from the whey times 8.34 (a conversion factor). To calculate the volume of COW water removed requires a material balance using the beginning and ending solids concentration.

After calculating the categorical effluent limits, the permit drafter's or the effluent limit calculator's will next check the water quality conditions in the receiving stream to be sure that the mass limits will not exceed the water quality limits. For fish and aquatic life streams the BOD_5 assimilative capacity is determined from a model or by using the standard water quality model which predicts that 26 lbs of BOD_5 will be assimilated by each 1 cubic foot per second (CFS) of stream flow (the 26 lb rule). Maximum BOD_5 mass limits will be cut back, if necessary, to match the BOD_5 assimilative capacity of the stream at the lowest flow that occurs 7 consecutive days in 10 years ($Q_{7, 10}$).

Dairy wastewater often has significant concentrations of chlorides. Chloride concentration in excess of 395 mg/l for a long time exposure (chronic criteria) and 757 mg/l for short time exposure (acute criteria) are toxic to aquatic life. The DNR has formed a technical advisory committee to develop a chloride discharge policy. When this policy is finalized existing dischargers will be required to implement source reduction measures to reduce chloride concentrations to levels that are not toxic to aquatic life. For new dischargers WPDES permit effluent limits for chloride will be calculated by applying the chronic criteria concentration to the receiving stream. The effluent flow volume and the stream $Q_{7,10}$ are needed to calculate a dilution ratio and the effluent chloride limits, such that when the effluent is discharged into the receiving stream, the mixture will not exceed 395 mg/l chloride. The maximum end of pipe chloride concentration will be twice the acute criteria which is equal to 1514 mg/l.

The DNR also has an advisory committee to review the ammonia discharge policy. When the policy is finalized effluent ammonia limits will be recalculated taken into account the receiving streams flow, effluent discharge volume, and established ammonia criteria. Since ammonia is more toxic at higher pH's, the pH of the receiving stream and characteristics, after mixing with the effluent, is an important factor.

For marginal and intermediate streams the concentration limits for BOD_5, suspended solids, ammonia and dissolved oxygen are taken directly from NR 104. In those situations the mass limits for BOD_5 and suspended solids are still the categorical limits which are calculated from NR 240.

Dairies that discharge more than 60 lbs of phosphorus per month are subject to a 1 mg/l phosphorus limitation in accordance with NR 217 which became effective in December 1992. This limit is currently being implemented and is discussed later in this paper.

2. Land Application of Wastewater

The regulation of the land application of wastewater began in 1976 with promulgation of the first version of NR 214. In 1983 a second version of 214 included the regulation of whey which had caused groundwater pollution problems at some sites due to mismanagement. The most recent version of 214, that became effective July 1, 1990, entitled "Land Treatment of Industrial Liquid Waste, Byproduct Solids and Sludge" tightened the regulations on the dairy industry by limiting the quantities of chloride and nitrogen applied to the land. These additional design and operational criteria were necessary to comply with the groundwater standards adopted in NR 140. Another new requirement is that all land application systems must have a management plan to achieve optimal environmental operation.

a. Groundwater Monitoring Wells

For fixed location land application systems such as spray irrigation, ridge and furrow, and adsorption pond, groundwater monitoring wells are required for discharges with volumes in excess of 15,000 gallons per day. The permit requires the permittee to sample groundwater from the top of the groundwater table approximately four times per year for parameters such as nitrate, ammonia, organic nitrogen, BOD_5, COD, chloride and pH. Each parameter has a limit from NR 140 or a preventative action limit (PAL) calculated from background well analysis. If exceedances of the groundwater limits are detected the permittee will be required to improve their land application systems. For example, if nitrate is high, then the nitrogen application should be reduced by applying the waste on more acres or by maximizing cover crop growth and removal to take up more nitrogen.

b. Regulation for Each Type of System

Permits for spray irrigation systems require the permittee to collect a representative wastewater sample and analyze for Kjeldahl nitrogen, chloride, BOD_5 and other parameters on a periodic basis. The volume discharged in one application to each irrigated section is limited to what can be absorbed in the root zone so that water and nutrients are taken up by the cover crop. A rest period between applications is necessary and no runoff or ponding is allowed. Harvesting the cover crop is required to remove nitrogen from the system.

Ridge and furrow systems are managed by loading one cell for several days while the other cells rest so that aerobic organisms can degrade the organic matter in the wastewater. Sampling and analysis of the wastewater and flow measurement is required as with spray irrigation. Cover crop harvesting is encouraged but is often not practical due to the narrow ridges.

Discharge to an absorption pond also requires wastewater sampling and analysis and flow monitoring. The best designed absorption pond systems receive pretreated wastewater that is alternately loaded to multiple cells. However, there are dozens of older ponds that are still being used, generally by small dairies, that have only one cell and receive untreated wastewater. As these permits are reissued the system is evaluated to determine the potential for groundwater pollution and if deemed too high the permittee will get a schedule of compliance to develop an alternative wastewater treatment system.

The management plan for hauling and land application requires the permittee to maintain a log book showing the wastewater hauled to each site and requires them to collect a representative sample to be analyzed for nitrogen and chloride. An annual report showing the total quantities waste and the calculated pounds of nitrogen and chlorides applied to each approved field site is required. All landspreading sites must be approved by this department prior to spreading any waste. Wastewater analysis, all approved sites and the annual loading to each site are permanently recorded in a computerized system called the Land Application Management Program (LAMP). The application rate for chlorides cannot exceed 170 lbs per acre per year. Nitrogen application rates must be equal to crop nitrogen uptake. Dairies are allowed to deposit wastewater, whey or permeate in a farm manure storage structure, up to a maximum of 10% of the volume, if the structure meets Natural Resource Conservation Service designs standards and its use is approved by DNR field staff. The farmer is exempt from 214 regulations when the mixture of wastewater and animal waste is spread onto their cropland.

F. Special Problem Areas

3. Phosphorus Limitations

Dairies which discharge treated process wastewater to surface water are required to meet a 1 mg/l phosphorus limit or an alternative concentration limit, if appropriate. Some dairies have upgraded or modified their treatment facilities to facilitate phosphorus removal by biological uptake or chemical precipitation. Dairies discharging to POTW's that have effluent phosphorus limits may have to provide pretreatment facilities or contribute to the cost of upgrading the POTW.

Discharge data collected during the promulgation of the phosphorus standard showed that dairy wastewater had a range of 10 to 80 mg/l of total P, with an average of 30 to 40 mg/l. Forty to fifty percent of the load was due to phosphorus based cleaners (primarily phosphoric acid). The remainder was from product loss to the sewer. DNR has been working with dairies, through seminars and individually, to encourage use of nonphosphorus based substitutes. Nitric acid appears to be an acceptable (and cost competitive) alternative. A number of dairies have switched over to nitric acid. Through cleaning chemical substitution and controlling product losses most facilities should be able to reduce the phosphorus to a level of 15 to 20 mg/l in the untreated effluent..

Even if a dairy reduces phosphorus to a level of to 15 to 20 mg/l (which is 3 to 4 times the level in domestic wastewater), it may be difficult to achieve 1 mg/l in the effluent using typical treatment technologies. Facilities may be able to justify an alternative concentration limit, as provided for in NR 217.04, in the 3 to 4 mg/l range as being "practically achievable."

4. Chloride Limitations

Large quantities of salt are used in the dairy to salt the cheese. Chloride limitations for surface water and groundwater discharges will require careful management of the salting process to minimize loss of chloride to the wastewater stream. Another source of chloride is from backwashing of water softeners. Experience to date indicates that it will be difficult to reduce the chloride concentration to 125 mg/l which is the desired goal to assure the groundwater standards will not be exceeded. If the dairy does everything technically and economically feasible they would be allowed to increase the groundwater chloride concentration to the enforcement standard (250 mg/l) in accordance with NR 140. Landspreading of high chloride waste at a rate of 170 lbs/acre/year may be the only alternative for some dairies to comply with these chloride limits.

5. Aerated Lagoon Treatment Systems

The use of aerated lagoons may be limited because of the difficulty to remove phosphorus and problems with algae growth. There has been limited experimentation with phosphorus removal so the seriousness of this problem is not yet known. The marginal and intermediate stream suspended solids limits of 20 and 15 mg/l, respectively, are often exceeded when algae blooms occur in these ponds. In the past these algae blooms were controlled by using chemicals, such as copper sulfate, but with the low limits now required for copper there seems to be no effective method for algae control.

6. Winterspreading of Waste

Currently NR 214 allows wastewater, whey, permeate and industrial wastewater treatment sludge to be landspread year around but with more restrictive spreading site limitations for winter. However the municipal wastewater treatment sludge land application rule (NR 204) prohibits all winter application of municipal sludge. Although there are currently no EPA regulations for industrial sludge and no activities ongoing to change NR 214 to ban winter application of industrial sludge, there is concern that industries and cities should be treated alike. While banning the winter application of sludge could be achieved by building large storage structures, the banning of all liquid waste application would be hard for the dairy industry to implement. This is because dairies are land applying large volumes of high strength waste, such as whey permeate, that would create odor problems if stored. It is important that the dairy's waste manager select the best fields and use the best management practices when winterspreading to minimize the runoff potential.

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Prepared by Jerry Rodenberg
Business Sector Specialist for the food processing industry
Bureau of Cooperative Environmental Assistance
Wis. Department of Natural Resources
Box 7921
Madison, WI 53707
608- 266-7715
E-mail: rodenj@mail01.dnr.state.wi.us