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Case study on the dairy processing industries and their wastewater generation in Latvia

Basanti Ekka, Sandis Dejus and Talis Juhna

Water Research and Environmental Biotechnology Laboratory, Riga Technical University, Riga, Latvia

Research Article

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Author for correspondence:
Basanti Ekka, Email: basanti.ekka_1@rtu.lv

Abstract

The objective of the research presented in this Research Communication was to access the environmental impact of the Latvian dairy industries. Site visits and interviews at Latvian dairy processing companies were done in order to collect site-specific data. This includes the turnover of the dairy industries, production, quality of water in various industrial processes, the flow and capacity of the sewage including their characteristic, existing practices and measures for wastewater management. The results showed that dairy industries in Latvia generated in total approximately 2263×10^3 m^3 wastewater in the year 2019. The Latvian dairy effluents were characterized with high chemical oxygen demand (COD), biological oxygen demand (BOD) and total solids (TS). Few dairy plants had pre-treatment facilities for removal of contaminants, and many lacked onsite treatment technologies. Most facilities discharged dairy wastewater to municipal wastewater treatment plants. The current study gives insight into the Latvian dairy industries, their effluent management and pollution at Gulf of Riga due to wastewater discharge.

Billions of people around the world consume dairy products each day as part of their daily nutrition. The global demand for milk and its products is produced by approximately 270 million cows. Not only are milk and dairy products an active source of nutrition, but also present income opportunities for millions of farmers, processors, shopkeepers and other stakeholders around the world. Specifically, the European dairy sector holds higher position in terms of pioneering markets in the food sector to consume around 45 million metric tons of fresh milk products annually (Burrell, 2000). Dairy production materializes in all EU member countries and represents a noteworthy proportion of the value of EU agricultural output. Total milk production in EU is estimated to be 155 million tons per year. Although Germany, France, Poland, the Netherlands, Italy and Spain are the leading producers of milk, the Baltic states account for a major share in the rest of the European region. The contribution of the dairy sector to the GDP of the Baltic states is considerable.

With population of 1.91 million, Latvia is characterized by extensive rural and coastal areas where agriculture is an important economic activity. Milk production is one of the most important sectors, and it is the second-biggest sub-sector of agriculture in Latvia. Presently, the number of dairy cows is one-fourth of the number back in 1938 and one-third of it in 1990. In 2014 there were 21 800 dairy farms with the average herd size of 7.6 cows and 40 competing milk processors (Thomassen and Boer, 2005). Despite the decreasing cow number, milk production in Latvia continues to increase, due to larger farms that choose genetically improved breeds for high milk production. The current case-study brings in the total of 58 registered milk processing industries in Latvia. These dairy industries produce a different kind of dairy products for both local consumption and export to other countries. Although the industry provides protein rich food, it generates a huge amount of wastewater as the processing of milk and dairy products demands a large quantity of water. Subsequently, the industry may create a lot of water contamination with suspended and dissolved solids, soluble organic and inorganic matter, etc. in the wastewater effluents (Tamminga, 2003; Chandra *et al.*, 2018). Protein, fat, and carbohydrate accounts for a significant organic load in dairy wastewater. Additionally, dairy wastewater contains acid, alkali, detergents, disinfectants (e.g., chlorine, hydrogen peroxide, and quaternary compounds of ammonia) along with a significant microbiological load (potentially including pathogenic viruses and bacteria) (Bortoluzzi *et al.*, 2017). The dairy industry, on an average, generates 2.5–10.0 l of wastewater per liter of milk processed (Bharati and Shinkar, 2013; Ashekuzzaman *et al.*, 2019). Typically, dairy wastewater is characterized by a high biological oxygen demand (BOD: 40–8240 mg/l), chemical oxygen demand (COD: 430–18 045 mg/l), suspended solids (SS: 24–4500 mg/l) and nutrients such as total nitrogen (TN: 14–830 mg/l), and total phosphorus (TP: 9–280 mg/l) (Danalewich *et al.*, 1998; Sarkar *et al.*, 2006; Andrade *et al.*, 2015). Dairy effluent decomposes quickly and reduces the dissolved oxygen level in water streams, resulting in anaerobic conditions that are a breeding place for disease-carrying flies and mosquitoes. Studies found that higher concentration of dairy effluents are toxic to many aquatic lives including fish and algae.

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Latvian dairy industries are spread across the country and produce many products. However, the impact on environment due to the dairy companies has not been studied in any detail. Therefore, the current study aims to analyze the size of the industry, kind of contamination and pre-treatment methods adopted in the Latvian dairy industries.

Materials and methods

The aim of the current study comprises a portrayal of each of the analyzed Latvian dairy companies: the study of their turnover, production and current practices and procedures for water management. This includes the volume and quality of water in the various industrial processes as well as the flow, load and characteristics of the sewage. Literature review and structured questionnaire were the two different sources for the collection of data from dairy industries. Face-to-face interviews with organized questionnaires were done, and samples of wastewater were obtained for analysis of chemical oxygen demand (COD), biological oxygen demand (BOD), total nitrogen (TN) and total solids (TS) of the dairy wastewater using standard spectrophotometric methodologies.

Results

The Latvian dairy industry contributes the nation's demand for milk and provides livelihood for a major portion of people. Besides the local demand, Latvia exports dairy products to the neighboring countries and elsewhere viz., Israel and the USA. The dairy products that are either consumed in the country or exported are skimmed-milk, ice-cream, cheese, yogurt, and marshmallow. Despite providing products for local consumption and export, the industry seems to be detrimental in terms of water pollution. Keeping the demand and tendency to increase the intensity of the dairy industry around the world, it is observed to have adverse effects on the environment. This case study brings in the statistics of dairy industries and the state-of-the-technologies used to curb the water pollution in Latvia.

In 2019 when the study was conducted, there were approximately 58 small- and large-scale dairy industries spread across Latvia. To assess the correct information from each dairy companies, they were divided into three scales: small, with annual turnover of EUR < 100 000; medium, with annual turnover of EUR 100 000–500 000; and large, with annual turnover of EUR > 500 000. Out of the 58 dairy industries, 29 companies are of large scale whereas others are small and medium scale. The present study conducted face-to-face interviews with many dairy companies. It was found that the Latvian dairy industries consume excessive amounts of water and generate enormous quantities of wastewater. Data revealed that the Latvian dairy industries use water for different processes such as cleaning system, cooling systems, steam generators, fire protection systems, etc. Most of the wastewater generated from these industries at the cleaning systems in which different steps such as physical cleaning (removal of all visible dirt), chemical cleaning (microscopic residues), bacteriological cleaning and finally sterile cleaning (destruction of all microorganisms) were implemented to clean the dairy equipment.

The conduction of the interviews was not so smooth at every company. Some companies provided the information generously and genuinely, and others were either provided partially or reluctant to share. Major number of companies but mostly small-turnover ones (~50%) did not provide the information on their processes and wastewater treatment systems. Therefore, we can say that the data used in this study was on half of the Latvian dairy industries. Two thirds of these had adequate pre-treatment systems before discharging the dairy wastewater to municipal wastewater treatment plants (MWWTPs) whilst the remaining third did not treat their wastewater prior to discharge. The small scale industries pose less impact on environment than the larger counterparts. Therefore, in the current study we focused more on the large scale industries whose turnover is above 1 million euro. Table 1 shows the turnover, products, wastewater flow and the treatment facility available at the 24 Latvian dairy companies that came into this category. The total wastewater flow/year for all 58 Latvian dairy industries was 2263×10^3 m^3 for the year 2019, and of this around 2203×10^3 m^3 (97%) was from 15 companies whose turnover was more than 5 million euro.

From Table 1 it could be seen that many larger dairy companies do treat their wastewater on-site, and the pre-treatment method includes dissolved air floatation, gravity settling separation, biological treatment, etc. However, some companies did not have any pre-treatment facilities and they depend on the MWWTPs. The preferred methods that were adopted at municipal sewage systems are dissolved air floatation and biological treatment systems. Table 2 shows the wastewater physicochemical parameters of the dairy industries that don't have pre-treatment possibilities. The COD and BOD levels of the dairy wastewater are beyond the permissible limits for discharge to the environment in general and to the Gulf of Riga in particular.

Discussion

Face-to-face interview with organized questionnaires bring a lot of information regarding the dairy wastewater generation, composition of dairy effluents and treatment facilities at different dairy industries. The results show that the Latvian dairy industries are widely distributed in terms of turnover. Turnover plays a crucial role in countries economy and GDP. Many Latvian industries export their products to other countries. One of them, situated in Smiltenes town, is the third largest producer of cheese in terms of volume, and sixth largest dairy company in Latvia. It supplies more than 150 quality Latvian dairy products. The company exports its products to Russia, Estonia, Germany, Israel and USA. Another dairy processing enterprise with an average manufacture volume of 250 tons of milk per day is situated at Jelgava, and its main products are semi-hard cheeses, fresh cheeses, cream and sweet whey concentrate (liquid). It exports these products to Germany, Netherlands, Italy, Finland, Estonia and Lithuania.

The dairy industries create a major contamination of water, however, the current study focuses more on the environmental impact of the contamination. The Latvian dairy sector generates 2263×10^3 m^3 of wastewater per year, and many individual companies do not treat their effluent prior to discharge to municipal water treatment. However, some have invested in effluent treatments. The dairy effluents discharged by Latvian dairy industries are composed of several organic and inorganic contaminants that are the sole reason behind elevated BOD_5, COD, and TSS.

Baltic sea eutrophication is an important issue in the European Union, and played a major role in deteriorating the quality of the Gulf of Riga (Yurkovskis, 2004). To address this, several Directives have been made. According to the European Union Council Directive 91/271/EEC (21 May 1991), Latvia along with other member states should ensure pre-treatment of industrial wastewater before discharging into municipal wastewater treatment

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Table 1. Product and wastewater characteristics of the Latvian dairy companies with turnover greater than 1 m euro per year

	Turnover (Million EUR)	Products	Wastewater production (m^3/year)	Pre-treatment (Technology)
1	81.12	Skimmed milk, cheese, ice- cream	399.86×10^3	Yes (GSS + OS)
2	59.91	Cheese, dry milk	400.78×10^3	No
3	53.18	Yoghurt, curd, cream, butter and curd snacks	119.47×10^3	Yes (GSS)
4	33.53	Skimmed milk, curd, butter, sour cream, cheeses, yoghurts, aseptic drinks, UHT cream	251.63×10^3	Yes (GSS)
5	33.02	Skimmed milk, ice-creams, cheese	246.99×10^3	Yes (GSS + OS)
6	19.45	Pasteurized milk	99.17×10^3	No
7	19.37	Milk, cheese, drinks	166.24×10^3	Yes (GSS + SS)
8	17.86	Butter, cheese, cream, curd; desserts, syrup, Kefir	42.31×10^3	Yes (GSS + OS)
9	11.54	Sour cream, curdled milk, cheese, dessert	67.47×10^3	Yes (GSS)
10	11.51	Cheese	79.39×10^3	No
11	11.07	Skimmed milk, Kefir, cheese	16.26×10^3	Yes (GSS)
12	9.970	Skimmed milk, cheese	37.63×10^3	Yes (GSS)
13	9.244	Cheese, cream, butter, skimmed milk, Kefir, yoghurt	45.52×10^3	Yes (GSS)
14	6.589	Pasteurized and skimmed milks, sour cream, Kefir, butter, yoghurt	5.77×10^3	No
15	6.455	Sour cream, Kefir, butter, yoghurt	18.89×10^3	Yes (GSS + OS)
16	4.947	Skimmed milk, edible oil and fats	no data	Yes
17	4.626	Pasteurized milk, cheese, butter	36.02×10^3	Yes (BIO)
18	4.387	Skimmed milk, cheese	67.30×10^3	Yes (GSS + SS)
19	4.328	Pasteurized milk, cheese	17.19×10^3	No
20	3.761	Kefir, cheese, cream, yogurts	21.25×10^3	Yes (GSS)
21	3.579	Pasteurized milk, cheese, yogurt	32.36×10^3	No
22	2.418	Ice-cream, cheese, Skimmed milk	no data	no data
23	2.122	Cheese, pasteurized milk	5.89×10^3	Yes (GSS)
24	1.301	Pasteurized milk, cheese, ice- cream	5×10^3	Yes (GSS)

GSS, gravity settling separation; SS, settling separation; OS, BIO, biological treatment

Table 2. Wastewater physicochemical parameters of the dairy industries that lack pre-treatment facilities

	Untreated dairy wastewater				
Dairy Industries	COD (mg l^{-1})	BOD-5 (mg l^{-1})	Total Nitrogen (mg l^{-1})	Total Phosphorus (mg l^{-1})	Suspended Solid (mg l^{-1})
2	310	600	41	13.9	310
6	1640	1150	58	16.7	340
10	3738	1120	319	30.8	1350
14	13 955	8501	226	24.1	900
19	804	653	3	5.96	235
21	1060	880	–	5.20	360

COD, chemical oxygen demand; BOD5, 5 d biological oxygen demand

plants. However, the current survey shows many dairy industries have been postponing the implementation of this Directive. Because of either lack of awareness of environmental degradation or intentionally escaping from the pre-treatment of the wastewater, nearly 50% Latvian dairy industries did not reveal their data regarding wastewater generation and treatment facilities. Around one third of the companies who did respond directly discharge dairy effluent into municipal water treatment without

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Table 3. Comparative dairy wastewater parameters for different countries

Country	COD (mg l^{-1})	BOD-5 (mg l^{-1})	TSS (mg l^{-1})
Brazil	3133	2350	10
India	8960	442	253
Ireland	3360	2335	840
Poland	3385	1523	707
Latvia	3584	2150	582

COD, chemical oxygen demand; BOD5, 5 d biological oxygen demand; TSS, total suspended solids.

pre-treatment at the site. This may be due to the easy accessibility of the municipal facilities and cost-effective treatment of dairy effluents. The legislation on dairy industrial wastewater discharge into municipal wastewater systems is in place in Latvia, however, the implementation of such laws are quite challenging. Inadequate knowledge by dairy industry organizations and treatment plants on wastewater characteristics and its effect on the municipal wastewater system and receiving water bodies (Gulf of Riga) leads to damage to the environment. Studies revealed the potential sediment toxicity in Gulf of Riga by using acute toxicity bioassay (survival test) for many aquatic lives (Strode *et al.*, 2017; Butrimavičienė *et al.*, 2018). The presence of unmeasured contaminants discharged from municipal water treatment plants could be responsible for toxicity to aquatic animals in Gulf of Riga sediments, which may be detrimental to human health.

About two thirds of the responding companies treat their effluent before discharge. Several studies show that the wastewater pre-treatment at dairy industries are beneficial to the environment (Qasim and Mane, 2013). Several methods, such as membrane filtration, reverse osmosis, coagulation and air-flotation are implemented worldwide for the treatment of dairy effluents (Vourch *et al.*, 2008; Pramanik *et al.*, 2019; Pereira *et al.*, 2020), but only a few of the Latvian dairies adopted such advanced treatment technology to treat their wastewater. The presence of fats, oils, and solid components in dairy wastewater can create several problems in wastewater treatment plants, thus it is advisable for industries to employ onsite treatment to separate these compounds prior either further treatment or discharge.

The characterization and analysis of the contaminants present in dairy wastewater plays a vital role in determining the steps to remove them. Therefore, it is important to monitor the effluent loads within a set time period. Table 3 provides a comparison of physicochemical parameters of the dairy effluents from different countries. The Latvian situation is not dissimilar to other European countries, despite the fact that some of these do use advanced pre-treatment facilities such as gravity traps, air flotation and dissolved air flotation, electro-coagulation and membrane filtration to minimize the contaminants in wastewater.

In conclusion, the current study demonstrates that many Latvian dairy companies have poor wastewater characteristics and lack pre-treatment technologies, such that they have a significant impact on municipal wastewater systems and could be regarded as a threat to the environment. In most cases investments in pre-treatment facilities at dairy industries are motivated by a fining system, and companies are only ready to invest in pre-treatment when they are obliged to do so by legislation.

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