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EVALUATION OF SUSTAINABLE DEVELOPMENT OF DAIRY INDUSTRY IN POLAND

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ABSTRACT: Dairy plants development should be based on the principle of sustainable development, which is present both in National Environmental Policy and European Union environmental protection policy. It is in compliance with Best Available Technology (BAT). Technology connected with recovering energy from sewage, sewage sludge and production waste is gaining more and more interest. The authors of this article have been cooperating with several production plants in podlaskie province for many years through conducting scientific research and preparing environmental reports or integrated permissions (IPPC). The article discusses the most crucial aspects of sustainable development of the dairy industry. Also, the results of environmental aspects (water consumption, sewage production and treatment, wastes, gas and noise emissions, energy consumption) connected with dairy plants management are presented.

KEY WORDS: sustainable development, dairy, water and sewage management, energy consumption

Introduction

Sustainable development is an multi-domain issue but nowadays it deals mainly with impact of the plants and new road infrastructure, which is growing rapidly (Boruszko et al., 2018). Dairy industry is a vital economic element of European Union countries. According to Eurostat data, dairy cattle population in the whole EU in 2015 reached 23.5 million, including 2.134 mln in Poland. Poland, along with Germany, France, Great Britain and Holland, belongs to the biggest milk producers in the EU. According to European Commission, milk production in 2016 in the EU amounted to 153.304 mln tons, including 11.130 mln tons in Poland (www.farmer.pl). According to data from 2016, Podlasie Voivodeship is the biggest milk producer in Poland, followed by Masovian Voivodeship. Development of dairy plants in Poland is, on the one hand, an opportunity for the region's development and, on the other, it creates the necessity of such activity which will minimize the plants' negative impact on the environment. The principle of sustainable development allows the functioning and development of dairy industry in such areas where large parts are under various forms of protection. Figure 1 presents the changes of the amount of milk produced in Poland between 2000 and 2015 year.

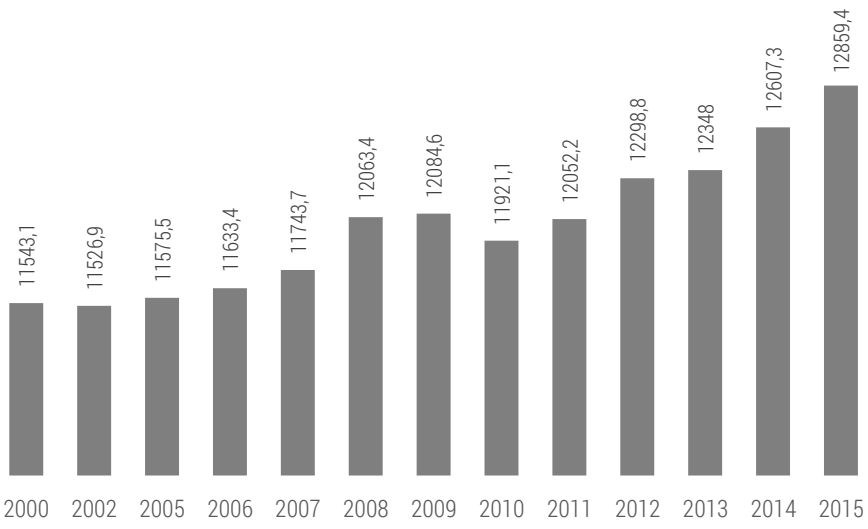


Figure 1. Milk production in Poland in the years 2000-2015 [mln dm^3]

Source: author's own work based on CSO, 2016.

Milk industry development in Poland on the example of Podlaskie Voivodeship

Podlaskie Voivodeship with the area of 20 187 km^2 and the population of 1188587 is one of the least urbanized areas of Poland. There are around 170 dairy plants functioning in Poland, 16 of which are located in Podlaskie Voivodeship. The dairy plants located within this part of Poland are responsible for over 20% of milk production in Poland. The amount of milk produced in this voivodeship has been rising systematically since the beginning of the 1990s. The changes might be observed while analyzing the investments in dairy companies. In 2015 S.M. Mlekovita and S.M. Mlekpol reached a joined income of almost 7 mld PLN. Mlekpol is the owner of 12 dairy plants, while Mlekovita 16. Beside those biggest ones, there is a number of smaller plants functioning within the region. Global milk production in the voivodeship increased from 1234.3 to 2564.8 mln dm^3 in the years 2000-2015 (CSO, 2016). Figure 2 shows the change in the amount of milk produced in Podlaskie Voivodeship in the years 2000-2015 year.

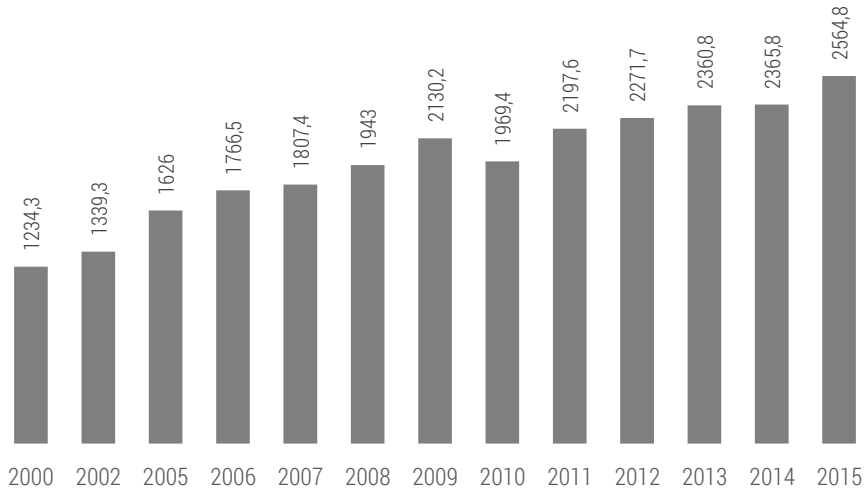


Figure 2. Milk production in Podlaskie Voivodeship in the years 2000-2015 [mln dm^3]
Source: author's own work based on CSO, 2016.

Environmental aspects connected with the functioning of dairy plants

Dairy processing plants belong to agricultural and food production branch. Their impact on the environment is not limited to the production phase only, but extends much further to milk producers themselves. Among the main environmental aspects of dairy plants, the following can be given:

- water intake and consumption during the production processes,
- sewage and sewage sludge emission,
- generating waste during production,
- emission of gas pollution from fuel combustion,
- noise emission,
- electric energy consumption.

Water utilized in dairy plants is used directly in the production process as well as in supporting processes. Depending on its purpose, the water undergoes treatment (iron and manganese removal, water softening etc.). Among the most water-consuming places within a dairy plant are water treatment stations, milk pasteurizer cooling systems and stations for cleaning devices and pipelines (Budny, Turowski, 2005a). Almost 100% of the consumed water comes from own abyssal intakes exploited by the dairy plants for many years. Only to a little extend do the dairy plants use water from municipal supply systems. Water resources are limited so the lack of a sufficient amount of water might constraint the production growth. While analyzing individual water consumption rates in dairy plants, a substantial drop of this indicator might be observed in the 1990s. Its consumption depends on the type of the final product and might vary within a very wide range (BAT, 2005; FAPA, 1998). Water consumption indicators in S.M. Mlekovita in Wysokie Mazowieckie in the previous decade amounted to 3.2 m^3 per 1 m^3 of processed milk (Boruszko et al., 2004; Boruszko, Dabrowski, 2016). For the dairy plant Bielmlek in Bielsk Podlaski the indicator was about 3.6 m^3 per 1 m^3 of treated milk according to the own research in 2015, while in 2018 the indicator decreased to 2.46 m^3 per 1 m^3 of treated milk. The lowest indicators are observed in the case of consumable milk and powdered milk production, whereas the highest are for butter and hard cheese production. An important aspect connected with water in food industry is the fact that, in view of the product safety, its consumption cannot be minimized in order to achieve, for example, reduction of production costs. Due to this, water recycling for production purposes is not applied. This type of water might be used in supporting processes, e.g. in a boiler house. The widespread use of automatic cleaning in place (CIP) stations has had a very positive effect on the water management process. The stations are installed at many production stages from milk

collection to washing pipeline installations. They are fully automatized and their application allows saving water and chemical cleaning products. The use of CIP stations has improved production safety and has shortened the time needed for washing processes within a plant. The plants are subjects to strict water quality control due to the safety of their final product. The standards describing water in dairy industry implemented in Poland after joining the European Union allow safe functioning of dairy plants.

Wastewater discharged from dairy WWTPs has significant influence for environment. Dairy sewage has similar content to municipal, with the difference of observing significantly higher values of organic compounds measured with indicators such as $BOD_{5,}$ COD or TOC (Danalewich, 1998; Gugała et al., 2015; Janczukowicz et al., 2008; Struk-Sokołowska, Ignatowicz, 2013). That is why a high load of pollutants discharged from a plant is the main problem, even though the amount of pollution is small (Struk-Sokołowska, 2016). Similar to water, the individual indicators in reference to e.g. $1m^3$ of processed milk have a very wide range connected with the type of the final product. Similar and comparable in Poland and around the world, milk processing technology has a smaller influence on the amount of sewage. According to own research conducted in Podlaskie dairy plants, since the end of the 1990s the indicator of sewage amount was on average 3.2 m^3 per 1 m^3 of treated milk and varied in the range between 1.8 m^3 and 4.1 m^3 (Dąbrowski, 2009). Own research in Bielmlek Bielsk Podlaski showed the indicator on the level of 2.6 m^3 in 2018. The drop in the amount of water used for one production unit caused a substantial increase of pollution concentration in sewage, which makes its treatment much more difficult (Danalewich, 1998; Boruszko et al., 2004; Boruszko, Dabrowski, 2016). A great part of dairy plants in Poland use their own WWTPs, while only a few smaller plants discharge their sewage to municipal treatment plants after its pre-treatment. Every treatment plant applies sludge activated system with high efficiency nitrogen and phosphorus removal, while the flotation process is a widespread method used in pre-treatment. Phosphorus is additionally removed by chemical precipitation. The biggest plant (Mlekovita company in Wysokie Mazowieckie), applies anaerobic process of sewage sludge treatment with heat and electric energy production from biogas. The rest of the plants apply aerobic stabilization, where sludge is finally used as fertilizer. Sewage sludge is a type of solid waste but its composition allows to use it as a material recycled to the environment. In a few objects in Poland the process of anaerobic dairy sewage treatment is implemented with Upflow Anaerobic Sludge Blanket (UASB) reactors (Umiejewska, 2017). Anaerobic systems have a range of advantages are commonly used in e.g. fruit and vegetable processing plants or breweries. They allow obtaining biogas during sewage treatment and reducing the

amount of sludge. The necessity of applying secondary aerobic treatment is a disadvantage (Rodriguez, 2015; Tiwary, 2015).

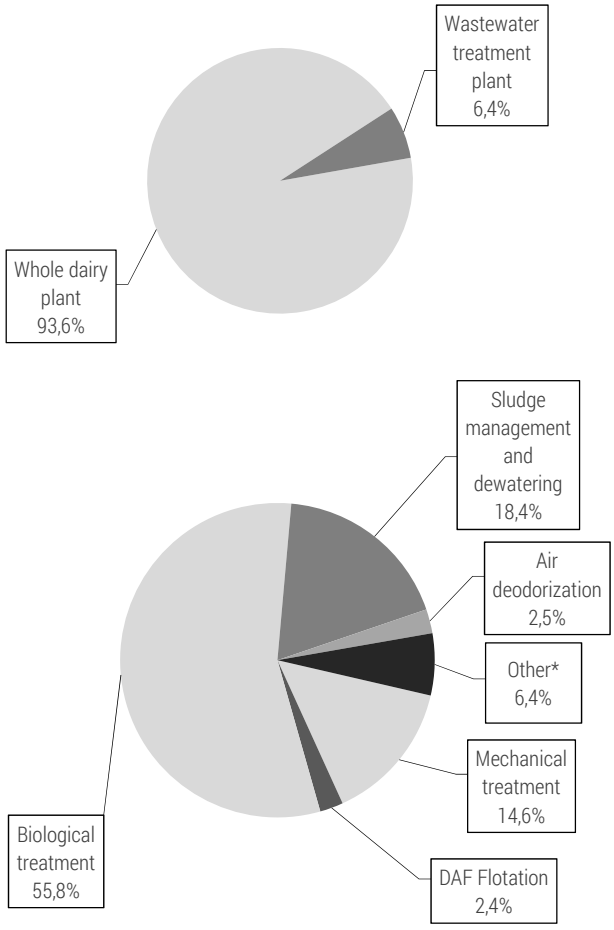
The waste in dairy industry might be closely connected with production, processing as well as with side processes, such as heat energy production in a boiler house, or water and sewage treatment. A catalogue of waste in a large dairy plant might contain several dozen entries, from container waste (paper and plastic) to industrial waste, such as slag, batteries, or lamps. Dairy plants have agreements with companies that utilize waste, recycle dangerous materials and materials other than dangerous, which are determined by a suitable regulation for waste management.

Another factor connected with environmental impact is emission of gas pollution. In dairy plants it is connected almost in 100% with the production of heat energy for the production purposes. Dairy plants produce steam in own boiler houses. The majority of them are supplied with coal and come from the 1970s. Only a few plants use gas supplies. Heat energy consumption for steam production in a dairy plant reaches 76.4% of the total energy consumption. That is why the plants use their own sources to become independent from external suppliers. The sources of gas emission, other than boiler houses, are gas heaters used in production of powdered milk, and milk powder plants, which emit dust. Among the emission indicators in dairy plants are nitrogen dioxide, sulfur dioxide, carbon monoxide and PM10 dust.

Noise emission is also a crucial element. Within the area of a dairy plant location there are several noise sources with various levels of emission and frequency characteristics (noise spectral density). These are both point sources located on an open area, on various heights above the ground level, and cubic (secondary) noise sources. The second group includes all cubic (building) production units, inside which there are technological lines, production lines, energy devices and technological safety devices, as well as other devices and machines which emit noise.

In the recent period, more attention is given to the issue of electric energy consumption in dairy plants. The problem is crucial due to the share of electric energy in the plant's functioning cost, but also due to the emission from coal power plants. In the recent years, only few dairy plants have begun electric energy production, for example from biogas obtained during anaerobic sewage and sewage sludge treatment. An example might come from S.M. Mlekovita dairy plant in Wysokie Mazowieckie, which has been producing heat energy and electric energy within its WWTP plant since 2014. Electric energy is used during the production process; however, its greatest share goes to sewage treatment (Budny, Twarowski, 2005b; Dąbrowski et al., 2017). Figure 3 presents results of energy consumption analysis conducted in Bielmlek Bielsk Podlaski in 2018. The wastewater treatment plant is responsible for

6.4% of total energy consumption of the dairy plant. During treatment of wastewater the highest amount of energy is consumed in biological reactors (sludge activated system) due to high oxygen demand. In the case of Bielmlek WWTP aeration consumes 55.8% of the total energy. Sludge management and mechanical treatment, mainly pumping, are next in the hierarchy of energy consumption. An interesting phenomenon may be observed in the case of DAF flotation which consumes 2.4% of the plant's energy while removing approximately 50% of organic pollutants load.



*as other energy consumption such factors as lightning, stuff's social needs and measurement system should be considered

Figure 3. Structure of energy consumption in Bielmek Bielsk Podlaski during research conducted in the 3rd quarter of 2018: a) distribution of energy consumption in Bielmlek dairy plant; b) distribution of energy consumption in WWTP

Source: author's own work.

Development directions and main challenges connected with sustainable development of dairy plants

Industrial plants development should be based on the principle of sustainable development, which is present both in National Environmental Policy and European Union environmental protection policy. On the one hand, industrial plants must function on the basis of economic calculation and market rules, on the other, their functioning and development must not cause excessive environment exploitation (Piasecki et al., 2016; Augusewicz et al., 2012). The rules and methods of sustainable development for agriculture and food industry plants include (Hadryjańska, 2008):

- implementing the rule of eliminating pollution at its source through the change of energy media, popularizing cleaner technology, minimizing energy and resources consumption, widespread normalization and limitation of emissions in industry,
- combining environmental costs into economical calculation, development and implementation of new economical tools for environment management,
- creating a coherent and stable legal and financial system compliant with the rule "the one who pollutes is the one who pays", ensuring effective funding of environment protection,
- implementing solutions aimed to ensure ecological safety,
- diversifying energy sources in the ecologically required direction, including increased energy production from renewable sources,
- conducting research programs aimed to increase the effectiveness of using environmental resources in production processes, especially development of alternative fuels technology allowing to replace petrochemical fuels and other based on carbohydrates,
- developing a mechanism for collecting data, controlling environment condition and obeying emission norms, as well as subjecting those processes and phenomena to monitoring and statistical analysis which have not been subjected to data collecting systems.

The abovementioned goals might be achieved, among others, through analysis and changes in environmental aspects typical for dairy plants. The technical network should allow separation of industrial sewage, meteoric and cooling water. The actions connected with water management in a dairy plant should lead to the optimization of water consumption by minimizing its usage, recycling and water cycling closing. The problem of wastewater emission is strictly connected with water consumption. Its amount and content depend directly on the amount of water used for production purposes. Production increase within a dairy plant is connected with increased water con-

sumption and wastewater generation. The amount of waste might be limited, but as a consequence there might be an increase of pollutants concentration in sewage disposed to WWTP. Such a situation was found out in dairy plants from province. In the case of dairy WWTPs, the actions must be focused on reducing the amount of biogenic substances present in sewage after treatment. According to BAT Reference Document, reduction in water consumption and the amount of wastewater in diary industry might be achieved through, among others, widespread usage of CIP, applying a closed network in cooling systems, collective heating and cooling systems, limiting raw material waste and making use of whey (BAT, 2005; IPPC, 2006). Leakages and the possibility of raw material and production waste accessing wastewater must be reduced to minimum. An even more common application of dissolved air flotation (DAF) has been observed in installations with primary treatment of sewage sludge. The DAF process allows to significantly reduce the pollution load subjected to biological treatment. In the research carried out in Bielmlek in 2017 (Żyłka et al., 2018) the average efficiency of DAF treatment was 59.3% for BOD, 49.0% for COD and 80.0% for total phosphorus while in Mlekovita in Wysokie Mazowieckie it was 62%, 65% and 51% respectively. Moreover, the waste generated in this process may undergo anaerobic stabilization, which as a consequence allows energy production. Another advantage of applying DAF process is the possibility of avoiding the extension of the biological part of WWTP in the case of raw sewage load increase. According to sustainable development rules, applying anaerobic sewage sludge digestion is advisable. Energy production and its disposal to the external network lower the costs connected with functioning of a WWTP and decrease the need for energy produced from coal. Sewage sludge typical for dairy WWTPs is characterized by low content of heavy metals and might be subjected to recycling after anaerobic or aerobic treatment. There is also no sanitary hazard due to the fact that wastewater from food industry does not contain microbiological pollutants. Sewage sludge from Podlaskie WWTPs is used in agriculture as valuable fertilizer (Dąbrowski, 2009). Sustainable development is recently also recovery of raw materials, mainly phosphorus and nitrogen, from wastewater and sewage. Main measures taken in order to reduce the amount of hazardous waste and waste other than hazardous within a dairy plant are, among others: production optimization aimed at minimizing raw material waste, reducing the amount of waste whey, using fully automatized production lines for product packaging, modernization of light and its automatized control and creating heat energy necessary for production in a gas boiler house. Because of technical issues, dairy plants must rely on coal boiler houses to a large degree; reducing the amount of waste such as slag might be achieved through boiler houses modernization and the

use of high quality fuel. It would have influence on reducing emission of air pollution. A large part of waste in a dairy plant is recycled, which is provided by specialized companies. Sewage sludge as a byproduct of sewage treatment is successfully recycled and returns to the environment as fertilizer. Reducing the emission of air pollution is one of the main problems of plants using coal boiler houses. If there is no possibility to change such fuel to gas, it is necessary to modernize boiler houses in order to reduce pollution, especially dust, sulfur, carbon dioxide and nitric oxides. Using high quality coal and effective filters is vital. Reducing emission of particular matter (PM 10 and PM 2,5) is crucial when taking into consideration the problem of air pollution in Poland. Reducing energy consumption in a dairy plant will result in reducing the emission of air pollution into the atmosphere (Dąbrowski, Żyłka, 2015). Reducing the emission of noise and odor is a separate issue. At present, as means of protection against noise in a dairy plant, the following methods, technology and techniques which minimize the impact are used: applying modern devices which emit little noise, constructing acoustic screens, limiting to the necessary minimum the movement of vehicles within a plant through appropriate planning of delivery routes, building a warehouse for completed products, and such functioning of devices in automatic cycle which reduces the possibility of simultaneous work. In the course of dairy processing, the problem of noise emission is mainly connected with the production of powdered milk. Suitable location of dairy plants and limiting the possibility of creating housing areas nearby causes only rare cases when dairy plants must apply special means to reduce noise emission. Odor emission is a similar problem which concerns only dairy WWTPs. Their location is the most important. Deodorization facilities, which reduce odor emission from primary treatment and sewage sludge stabilization, are commonly used.

Reducing electric energy consumption in dairy plants has a major influence not only on decreasing the plants' negative impact on the environment, but definitely connects sustainable development with economic industry plants effect (Graczyk, 2009; Makarewicz-Marcinkiewicz, 2015). A company's actions must result in assumed financial profit, but on the other hand it is necessary to invest in pro-ecological solutions, which increase a company's operating cost (Karolinczak, Miłaszewski, 2016). The application of cogeneration, that is connecting heat and electric energy production, is one of the development aims. In order to reduce and optimize electric energy consumption, it is necessary to apply modern monitoring systems in relation to production processes effectiveness. The research conducted by the authors at a wastewater treatment plant in Bielmlek in Bielsk Podlaski has shown a possibility of reducing energy consumption in the processes of dairy sewage and

sewage sludge treatment (Dąbrowski et al., 2017). Reducing energy consumption consequently means decreasing emissions from coal power plants and thus reducing carbon footprint. It also means lowering production cost, which will have a positive effect on the economic situation of the dairy industry.

Conclusions

In 1997 a notation on sustainable development was introduced to the Constitution of the Republic of Poland, the date being symbolic and crucial for the development of our country and society. Based on the analysis of dairy plants, it can be concluded that their sustainable development might contribute to the development of north-eastern Poland. Those regions must be protected because of their environmental value, but on the other hand it does not exclude development of specific industry branches, especially food industry. The industrial plants underwent transformation in the 1990s and their current technical condition does not differ from that of other European countries. Production growth does not have to cause an increased impact on the environment. Appropriate financial mechanisms and ecological awareness led to a compromise between development and environmental standards. The current direction for development is to reduce energy consumption and lower emissions from production processes, especially from heat energy production. Plants have transformed from energy consumers to its producers, whereas waste generated during production process might become a valuable product. Future tendency is to develop anaerobic systems for dairy sewage and sludge treatment. It will allow to produce electric and heat energy from biogas. By the moment in podlaskie province only WWTP belonging to Mlekovita is successfully utilizing anaerobic digestion of sewage and flotation sludge with energy production.

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The contribution of the authors

Józefa **Wiater** – 30% (contributed in analysis and interpretation of data and overviewing the whole text, supervised the progress of the work and coordinated tasks of each author).

Wojciech **Dąbrowski** – 20% (contributed in creating the conception of article and analysis and interpretation of data).

Dariusz **Boruszko** – 20% (involved in literature review and text correction).

Radosław **Żyłka** – 20% (responsible for acquisition and edition of data and artwork).

Sylwia **Antonowicz** – 10% (helped in data acquisition, provided valuable information about the Bielmlek plant and also overviewed the text).

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