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INNOVATIVE WASTE PROCESSING METHODS IN THE AGRICULTURAL AND FOOD INDUSTRY

Abstract
This article provides the comprehensive characteristics of wastewater, including both its classification as well as a description of how the pollutant load is determined, with regard to agro-food industry wastewater. Treatment methods for wastewater from this industry have also been proposed in relation to the main disadvantages and benefits of different technologies.

Key words
wastewater, wastewater characteristics, agri-food industry, wastewater treatment methods

Introduction

Wastewater is generated during virtually all production processes in the agri-food industry [1, 2]. According to the Water Resources Law from July 18, 2001, there are various sources of wastewater. Household wastewater originates from human metabolism or is produced by households and comes from buildings inhabited by people or civic facilities. Rain or thaw water, runoff water from landfills, water from mining drainage, and industrial effluents, including those produced by the agri-food industry are other sources. Wastewater volumes are increased by infiltration and drainage water resulting from the seepage of groundwater into the sewage system.

Characterization of the pollutant load in agri-food industry wastewater

Regardless of the above classification, we often use the concept of municipal wastewater, referring to household wastewater or a mixture of household wastewater with industrial wastewater, or precipitation or melt water discharged by municipal or urban sewage systems [3]. To determine the pollutant load in wastewater, we use the so-called oxygen pollution indicators [4]. They express the amount of pollutants indirectly, determining the mass of oxygen to be supplied to oxidize them. Depending on the oxidation method, we can distinguish chemical indicators, called the Chemical Oxygen Demand (COD), or the Biochemical Oxygen Demand (BOD). Similar indicators include Total Organic Carbon (TOC), denoting the mass of carbon bound in organic compounds.

Comparing the amount of pollution expressed by COD or BOD and TOC, one should remember to convert the units: 1 mg $[O_2]/dm^3$ corresponds to 0.375 mg $[C]/dm^3$, while 1 mg $[C]/dm^3$ corresponds to 2.667 mg $[O_2]/dm^3$. The TOC designation requires the use of a special apparatus, in which the sample is evaporated and subsequently all organic compounds are completely oxidized with the use of a platinum catalyst in an oxygen atmosphere. Such a procedure accurately determines their content in the wastewater. When determining the chemical oxygen demand, we usually carry out the mineralization of the sample with $K_2Cr_2O_7$ potassium dichromate in a sulfuric acid (VI) environment, containing silver ions as a catalyst. Under these conditions, most organic compounds are oxidized, but some organic acids, aromatic ring compounds, and pyridine and its derivatives may not be completely decomposed.

Biochemical Oxygen Demand determines the mass of the oxygen used for the mineralization of pollutants in water or wastewater samples in a biochemical manner, using microorganisms, at a temperature of 20°C. This decomposition is quite slow, and its kinetics are strongly dependent on the type of pollution. Regarding typical municipal wastewater, it is assumed that it has the characteristics of a first order chemical reaction, and the daily mineralization of carbon compounds is approximately 20%. This means that after a three-day incubation, about 50% of the pollutants are oxidized, but after five days the mineralization covers nearly 70%. Currently, only the oxidation of organic carbon occurs, whereas the oxidation of nitrogen compounds to nitrate (V) ions requires longer incubation. It should therefore be borne in mind that BOD_5 (bottom index 5 denotes the mineralization time in days) corresponds to approximately only 0.7 (COD), provided that all carbon compounds have been oxidized during the determination of the chemical oxygen demand. If BOD_5 is significantly lower than 0.7 (COD), then it means that there are significant amounts of non-biodegradable chemical compounds in the wastewater, or the BOD_5 determination has not been performed properly. In general, we can assume that the BOD_5/COD quotient close to 0.7 means that the wastewater is biodegradable and that biological treatment should not be a problem. Low values of the BOD_5/COD quotient often suggest the presence of substances that impede the proper operation of the wastewater treatment plant.

One should keep in mind that a lot of impurities are present in the wastewater in undissolved form. They take the form of slurries of an organic or mineral (inorganic) nature. One determines the general, mineral or organic slurries, the results are given in mg/dm^3. The high content of slurries makes it difficult for light to access the water depths, it causes pollution to drop down to the bottom of the tank and has a negative effect on the quality of the water to which the wastewater is discharged.

An important role is played by the nitrogen and phosphorus compounds present in the wastewater, which, if discharged into surface waters, can cause rapid growth of algae (so-called frog spit), leading to a rapid deterioration of water quality [5].

To determine the balance amount of pollution generated by a single statistical resident, we use the term of "equivalent resident" as defined in the Water Resources Law. It represents a load of biologically degradable organic substances expressed as an indicator of a five-day biochemical oxygen demand in the amount of 60g [O_2] per day. In the case of biodegradable industrial wastewater, the amount of pollutants contained in them can be expressed by the equivalent number of inhabitants (ENI) by dividing the total pollutant load expressed with the five-day biochemical oxygen demand by the equivalent load per inhabitant, such as 60 g [O_2] per day.

Methods of agri-food industry wastewater treatment

An important role in the process of wastewater treatment is played by the sewage system to which the wastewater is discharged [3]. In the case of combined sewerage, all wastewater, including rainwater, is introduced into common sewers, which should be equipped with storm water overflows to allow the discharge of excess water during heavy precipitation. In the separate sewage system, there are separate networks for domestic and industrial sewage, and an independent system for precipitation waters. Half-distribution systems are also used to provide partial separation of wastewater. In practice, only the distribution system makes it possible to significantly reduce the variation in the composition of the wastewater directed to the treatment plant and to ensure the proper functioning of its biological part.

It should be emphasized that very often the technological problems associated with improper work of the treatment plant result from the variable composition of the wastewater, which is caused by their dilution by precipitation or infiltration water. The wastewater treatment plant is the final element of the sewerage network and its correct functioning depends very much on the type and technical condition of the sewerage network. A modernization limited only to the wastewater treatment plant without the renovation of the sewerage network rarely yields the expected results. A particularly significant influence on the work of the wastewater treatment plant is due to the changes in volume and composition of the wastewater. In the case of industrial wastewater, this is related to the nature of the production processes and is practically impossible to eliminate. Large urban sewerage networks with large volumes show a considerable ability to equalize the wastewater and often can directly receive wastewater with an unstable composition and volume. However, it should be borne in mind that many agri-food industry facilities operate in small towns equipped with small sewage networks. In this case, it may be necessary to use equalization tanks to stabilize the composition and volume of the wastewater produced. Such tanks should be equipped with an efficient aeration system to ensure adequate oxygen concentration throughout the entire volume of the wastewater collected. Depending on the type of the wastewater treated, the share of electricity consumed during aeration can reach up to 70% of the plant's operating costs. Therefore, modernization coupled with optimization of the aeration process usually generates very significant savings. For this reason, it is recommended to use modern membrane aerators equipped with a direct oxygen measurement control system for the tank, which is much more economical than the older type of mechanical aerators.

Before being directed to a biological reactor or sewerage network, the wastewater should be mechanically cleaned. For this purpose, one utilizes grates, sieves, primary settlement tanks, and in the case of oily substances or liquid fuels, grease traps [6]. We can distinguish dense grates, with bars offsets below 20 mm and medium grates (20-40 mm) or scarce, with a clearance greater than 40 mm. At present, very dense grates with a clearance of up to 10 mm or even sieves with a clearance of less than 6 mm are used more often. Proper selection and operation of grates allows for a significant reduction of the pollutants that accumulate in the form of screenings, and after drainage they can be processed together with other solid waste generated in the company. Increasing the efficiency of oil substance removal can be achieved by using aerated grease traps, in which the air bubbles form an emulsion with fats and facilitate its separation from the aqueous phase. In the case of a tendency of the wastewater to rot, the efficiency of the primary settlement tanks may be significantly improved using pre-aeration. This technique also reduces the emission of malodorous substances from the plant area.

In agri-food facilities, wastewater is usually purified using oxygen. It favors a relatively quick reduction of pollutants compared to the fermentation (anaerobic) methods. In practice, the two types of flow reactors most commonly used are biological deposits or activated sludge systems [5, 7].

The biological deposit [3, 6, 7] consists of a filling. For many years, stones, coarse gravel, or coke were used for this purpose. The filling is located on a scaffold in a cylindrical tank equipped with a sprinkler system for the top surface and a drainage system collecting the wastewater. They are then directed to a secondary settlement tank, where the treated wastewater is separated from the excess sludge. This sludge is waste that needs further processing [11]. The lower part of the reactor is equipped with openings to provide airflow and aeration of the deposit (Fig. 1). A biological membrane (biofilm) develops on the surface of the filling, which is formed by microorganisms that break down the pollutants present in the wastewater [8, 9]. In recent years, there have been readily available polymeric fillings for biological deposits, which avoid clogging (silting up) and increase the load. The technical solutions used currently enable high reduction of biogenic compounds using nitrification deposits and dephosphorylation stages. It should be emphasized that re-launching combined with the modernization of a treatment plant equipped with biological deposits is usually a much cheaper option than building a new plant. An additional advantage is the high stability of work and the ease of exploitation of biological deposits.

Currently, the most commonly used technology for wastewater treatment is activated sludge [3, 7]. It consists of a complex of microorganisms that is formed because of the intensive aeration of sewage in a biological reactor called an aeration chamber [8, 10]. The outflow from the reactor is directed to the secondary settlement tank, which separates the treated wastewater from the activated sludge. The latter, because of sedimentation, accumulates in the bottom of the settlement tank. The sludge stream is then divided into a recirculated sludge that is mixed with incoming fresh wastewater and reintroduced into the aeration chamber, and excess sludge, which is the wastewater generated during sewage treatment (Fig. 2) [11]. This method requires a careful process control. However, it provides a very good reduction of carbon compounds, and after modification, the nitrogen and phosphorus compounds present in the wastewater are reduced as well [9, 10].

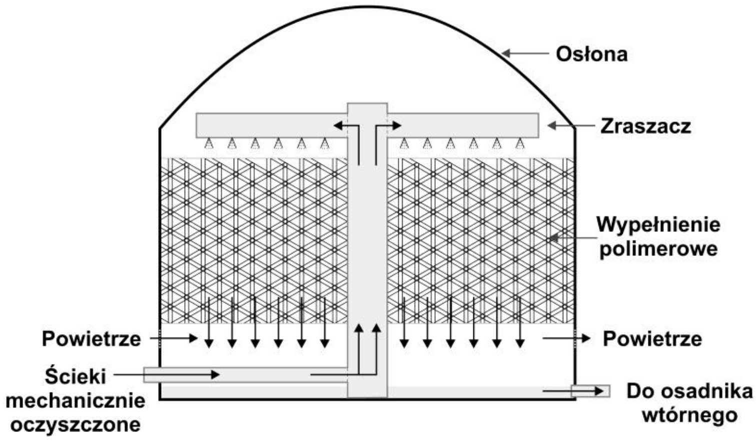

Fig. 1. A diagram of the biological deposit used for wastewater treatment

Osłona – cover; Zraszacz – sprinkler; wypełnienie polimerowe – polymer filling; powietrze – air; ścieki mechanicznie oczyszczone – mechanically trated wastewater; Do osadnika wtórnego – To the secondary settlement tank

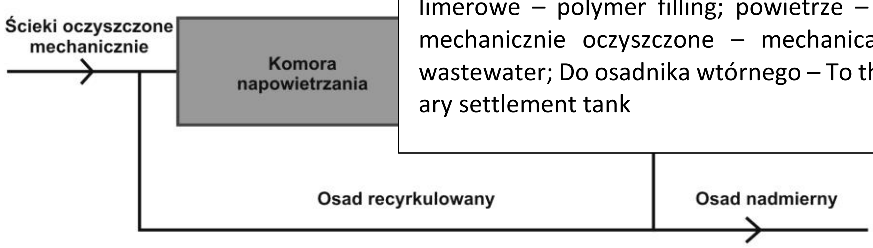

Fig. 2 A diagram of a wastewater treatment system using activated sludge

ścieki mechanicznie oczyszczone – mechanically trated wastewater; ścieki oczyszczone – treated wastewater; komora napowietrzania – aeration chamber; osadnik wtórny – secondary settlement tank; osad recyrkulowany – recirculated sludge; osad nadnierny – excess sludge

References

[1] A. Ciepielowski, *Podstawy gospodarowania wodą*, SGGW, Warszawa, 1999.
[2] H. Manteuffel Szoege, *Elementy ekonomiki gospodarowania wodą w rolnictwie*, SGGW, Warszawa, 2002.
[3] *Poradnik eksploatatora oczyszczalni ścieków*, praca zbiorowa pod red. Z. Dymaczewskiego, Polskie Zrzeszenie Inżynierów i Techników Sanitarnych, Poznań, 2011.
[4] W. Hermanowicz, J. Dojlido, W. Dożańska, B. Koziorowski i J. Zerbe, *Fizyczno-chemiczne badanie wody i ścieków*, Arkady, Warszawa, 1999.
[5] Z. Sadecka, Podstawy biologicznego oczyszczania ścieków, Seidel-Przywecki, Warszawa, 2010.
[6] Z. Heidrich i A. Witkowski, *Urządzenia do oczyszczania ścieków,* Seidel-Przywecki, Warszawa, 2010.
[7] J. Bever, A. Stein, H. Teichmann, Zaawansowane metody oczyszczania ścieków, Projprzem-EKO, Bydgoszcz, 1997.
[8] M. Błaszczyk, *Mikroorganizmy w ochronie środowiska*, PWN, Warszawa, 2009.
[9] E. Klimiuk i M. Łebkowska, *Biotechnologia w ochronie środowiska*, PWN, Warszawa, 2006.
[10] *Biotechnologia ścieków*, praca zbiorowa pod red. K. Mikscha i J. Sikory, PWN, Warszawa, 2010.
[11] *Gospodarka odpadami ściekowymi. Wybrane zagadnienia*, praca zbiorowa pod red. Ł. Fukas-Płonki, Polskie Zrzeszenie Inżynierów i Techników Samitarnych, Poznań, 2011.

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Abstract

This article presents a comprehensive characterization of wastewater types, considering both their classification as well as ways of determining the pollutant load, with emphasis on wastewater in the agri-food industry. Methods for treatment of wastewater from the industry in relation to the main advantages and disadvantages of different technologies are described.

Key words

sewage, wastewater characteristics, agro-industry, methods of wastewater treatment