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EFFECTIVENESS OF DAIRY WASTE TREATMENT IN AN INTEGRATED BIOLOGICAL REACTOR

EFEKTYWNOŚĆ OCZYSZCZANIA ŚCIEKÓW MLECZARSKICH W ZINTEGROWANYM BIOREAKTORZE

Abstract: Processes of anaerobic decomposition of sewage are used, among others, for sewage treatment in the agrarian-food sector, including dairy waste treatment. The research concerned dairy waste treatment in anaerobic conditions using original packing. The aim of the research was to determine the influence of the concentration changes of organic sewage in the sewage flowing into the anaerobic reactor on the treated waste COD value. The directions of biochemical changes being one of the factors determining the level of organic sewage in the treated sewage was evaluated on the basis of the reaction of waste, expressed as a pH. During a three-month period of research the intensity of raw sewage was gradually increased, observing lower and lower COD value of the treated sewage. At the end of the IV stage of the research the degree of reduction of organic sewage in treated sewage, in relation to raw sewage, was 81 %.

Keywords: anaerobic reactor, dairy waste, packing (molders), COD, treatment effectiveness

One of the main trends in waste management is, at present, waste recycling which means reusing worn out materials again and using them as materials for producing new, high-quality products. In this research the efficiency of treating model dairy waste in anaerobic conditions was tested in a half-technical scale. The packing of the reactor was made from waste materials. The development of an agrarian-food sector makes on-site sewage treatment facilities, which in the past treated sewage sufficiently, unable to meet the requirements today.

The fact that Poland joined the EU is connected with toughening the regulations of environmental protection, including rational water-sewage management. The European directive concerning integrated prevention and sewage limit, imposes an obligation on production plants to regulate immediately water-sewage management and to be in possession of so-called integrated permits. That is why the necessity to adjust Polish regulations to EU norms requires building new on-site sewage facilities or modern-

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ization already existing ones [1]. The second solution is chosen by many producers, enhancing the effectiveness of waste treatment.

In the dairy industry it is a very important issue because this industry uses a lot of water. The use of water in this industry is one of the biggest in all the branches of food industry. Water demand indicators for technological reasons (production processes, power industry, devices cleaning) are at the level of 3–20 $m^3 \cdot m^{-3}$ of processed milk [2]. In this context proper water-sewage management seems to be very important.

Apart from a high degree of organic components liquidation, there are a few other advantages of sewage decomposition in anaerobic conditions such as: production of sewage gas, low energy need, low increase of microorganism biomass and possibility to implement anaerobic reactors after a long exploitation break [1].

The aim of the research was to determine the influence of organic sewage concentration in the sewage flowing to the anaerobic reactor on COD value of treated sewage.

Materials and methods

The reactor, exploited during the research, is in the shape of two cylindrical pipes concentrically positioned. The diameter of the outer pipe was 88 mm, and of the inner one –188 mm (Fig. 1).

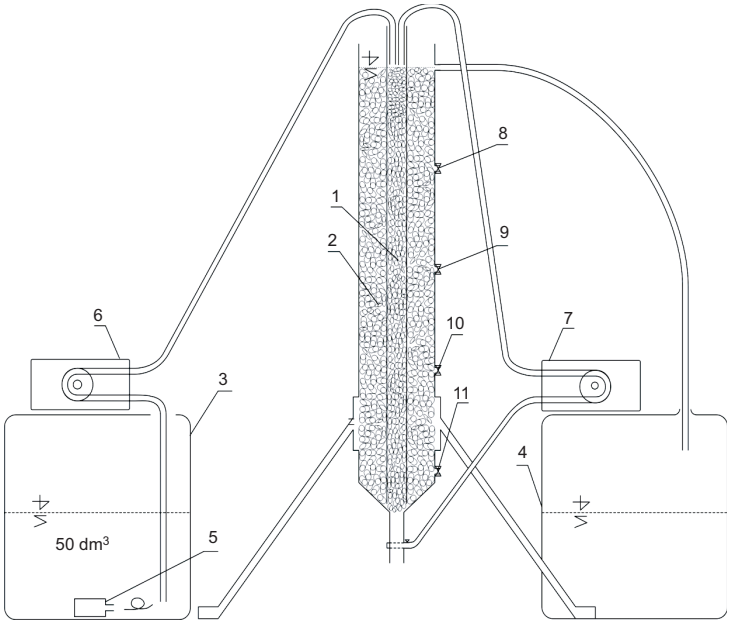

Fig. 1. Bioreactor (construction of research stand) (own study under the direction of prof. DrSc. M. Krzemieniewski in the Department of Environmental Protection Engineering: 1, 2 – reaction chambers, 3 – container of raw sewage, 4 – treated sewage tank, 5 – draught pump, 6 – pump dispensing sewage, 7 – recirculation pump, 8, 9 – sewage discharge stub pipes, 10, 11 – sewage and deposit discharge stub pipes

Space inside each of the pipes formed a reaction chamber, in which bioactive packing (moulders) have been placed. This plenum was made on the base of waste plastics with admixture of chemical substances. The moulders are in the shape of a cylinder with a hollow, non-concentric hole. An average height of the moulder is 24.4 mm, and its external diameter is 88 mm.

In order to standardize the quality composition of sewage flowing into the reactor, a draught pump was placed in the raw sewage container. From this container sewage was led to the inner pipe of the reactor. Gravitational sewage flowed downwards, next they emerged in the lower part of the reactor and flowed into the outer pipe, in which ascending floating of sewage took place. From the outer pipe the sewage floated through the discharge of treated sewage inflow placed in the upper part of the device. The bottom, conical part of the reactor was finished with a sewage and deposit discharge.

The bioreactor, which is 2.75 m high, was equipped with discharge stub pipes enabling taking waste for analysis. These discharge stub pipes are placed on the four heights of the reaction chamber: at 0.2 m, 0.8 m, 1.4 m and 2 m. About 5600 moulders were placed in the reactor, total surface of which is about 134 m^2.

25 dm^3 of digested deposit from Municipal Sewage Treatment Plant in Olsztyn, and simulated dairy waste prepared from 40 g of powdered milk solved in 45 dm^3 of water from water supply system were put into the reactor (COD = 580 mg $O_2 \cdot dm^{-3}$). From this moment a biological process of adaptation of bacterial microflora to the content of sewage began. This process required gradual adaptation of microorganisms to sewage environment and gradual growing of anaerobic bacterial microflora on the surface and inside constructed packing. With time of prolonging the adaptation of bacterial flora penetration and immobilization of bacterial flora inside the packing structure took place. During this process, every day, simulated dairy waste was put into the reactor, which was the nutrient medium for bacteria and the sewage and sludge reaction of sewage and sludge in the reactor were controlled currently.

In order to create a better immobilization of microorganisms on the surface of the packing, after 27 days from the start of the reactor exploitation, sludge and sewage which were in the reactor were flashed. Next, fresh and digested anaerobic sludge and simulated dairy sewage were placed.

The effectiveness of dairy sewage treatment in anaerobic conditions was analyzed at the four research stages, in four different concentrations of organic substances in simulated dairy waste flowing into the reactor:

– I research stage – 20 g of permeate in 50 dm^3 of waterworks water (COD = 366 mg $O_2 \cdot dm^{-3}$); this stage lasted 6 days,

– II research stage – 20 g of permeate + 20 g of powdered milk (skimmed) in 50 dm^3 of waterworks water (COD = 525 mg $O_2 \cdot dm^{-3}$); this stage lasted 7 days,

– III research stage – 50 g of permeate + 20 g of powdered milk (full-cream) in 50 dm^3 of waterworks water (COD = 1605 mg $O_2 \cdot dm^{-3}$); this stage lasted 21 days,

– IV research stage – 50 g of permeate + 40 g of powdered milk (full-cream) in 50 dm^3 of waterworks water (COD = 1719 mg $O_2 \cdot dm^{-3}$); this stage lasted 5 days.

Based on pH changes in the sewage and deposit in the reactor during its exploitation and pH changes of treated sewage, COD value of sewage flowing into the device was increased or kept at the constant level.

In winter months, in the outer pipe under the surface of sewage, an aquarium heater was placed, which kept the temperature of sewage in the reactor between 17.9 to 25 ^{o}C.

Results

The reaction of raw sewage and treated sewage at different research stages, expressed as pH was as follows:

– I research stage (COD of raw sewage was 366 mg $O_2 \cdot dm^{-3}$),
  a) raw sewage from 6.1 to 6.2,
  b) treated sewage from 6.1 to 6.2,
– II research stage (COD of raw sewage was 525 mg $O_2 \cdot dm^{-3}$),
  a) raw sewage from 5.5 to 6.1,
  b) treated sewage from 5.9 to 6.6,
– III research stage (COD of raw sewage was mg $O_2 \cdot dm^{-3}$),
  a) raw sewage from 5.6 to 7.7,
  b) treated sewage from 6.5 to 7.5,
– IV research stage (COD of raw sewage was 1719 mg $O_2 \cdot dm^{-3}$),
  a) raw sewage from 6.6 to 7.3,
  b) treated sewage from 6.9 to 7.7.

A graphic image of raw waste reaction (flowing into the reactor) and treated waste (outflow) was presented in Fig. 2.

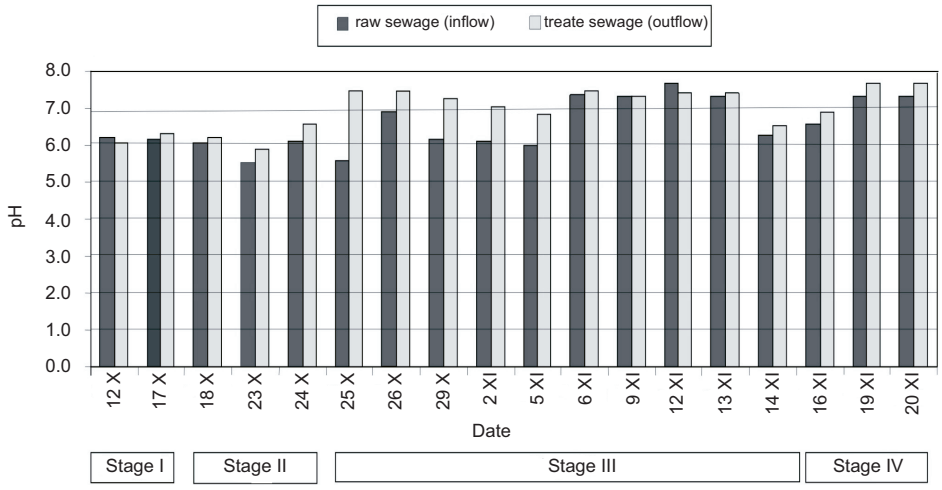

Fig. 2. Course of pH reactions in raw sewage for the inflow and treated sewage on the outflow (own research)

The second analyzed parameter was the degree of reduction of organic pollution, in the treated sewage in the ratio to raw sewage. At different research stages the following was observed:

– I research stage – organic waste concentration in the sewage on the outflow was higher than in the waste flowing into the reactor,

– II research stage – decrease of COD value in treated sewage (from 34 % to 46 %) in ratio to raw sewage,

– III research stage – from 46 % of the increase of waste concentration in the sewage flowing off the reactor to 75 % reduction,

– IV research stage – decrease of COD value in treated sewage (from 62 % to 81 %) in ratio to raw sewage.

The completion of a given research period and passing to the next one, took place only then when pH of treated sewage stayed at a similar level for a few consecutive days or was beginning to increase.

The increase of the concentration of pollution in the raw waste caused the increase of the reduction degree of COD from sewage. At the research stage, when the highest COD value of inflowing waste was used (stage IV – COD = 1719 mg $O_2 \cdot dm^{-3}$), the highest reduction of concentration of pollution – 81 % (Fig. 3) was observed.

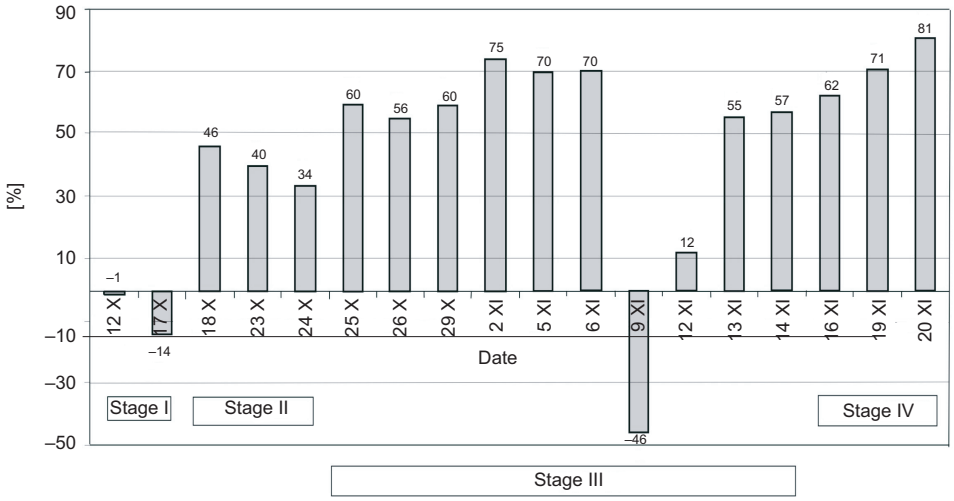

Fig. 3. Degree of COD reduction [%] (own research)

At the first stage of the experiment and after a one-month period from the start of the research the increase of the concentration of organic sewage in the treated sewage was observed in the ratio to raw sewage. It was caused by wiping of sludge introduced to the reactor, which had not been as a result of adsorption, absorption and immobilization of bacterial flora bonded on the surface and inside the plenum. With the passage of the research time at each stage (constant concentration of organic sewage in sewage flowing into the reactor) the increase of the effectiveness of treated sewage, expressed as a lower concentration of treatment in treated sewage was noticed. Possible exceptions

to the rule were caused by the changes of sewage temperature (Fig. 4), and connected with it pH changes (Fig. 2).

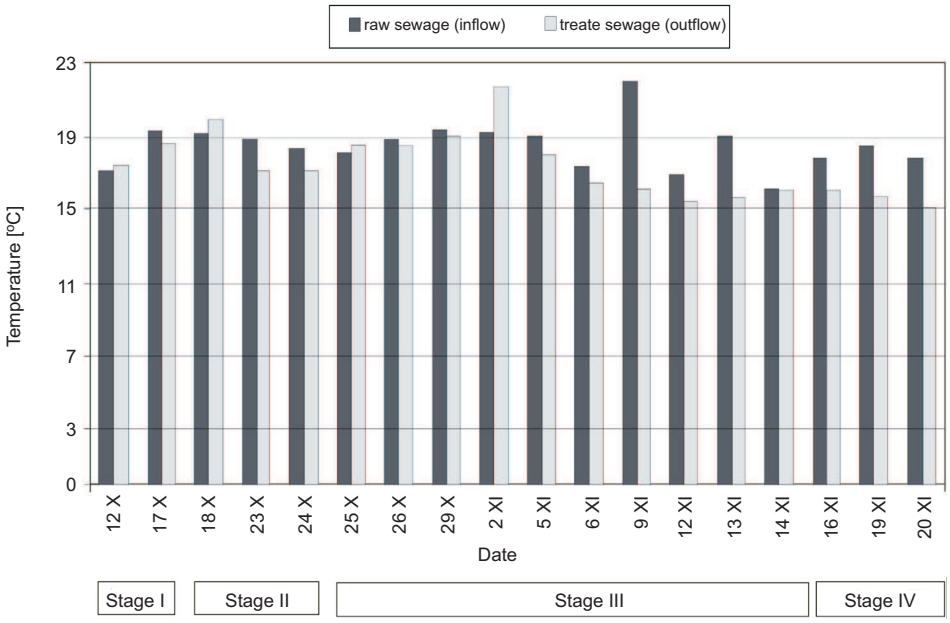

Fig. 4. Temperature [°C] changes course in raw sewage on the outflow and treated sewage on the inflow (own research)

Due to the fact that the research published in this paper has application character, for the whole research period it has been tried to keep the temperature of the surroundings, close to temperatures existing in natural conditions in on site sewage facilities of dairy plants. Outside air temperature shaped the raw sewage temperature and further also the temperature of the treated sewage.

Results and discussion

One of the factors determining the intensity of waste treatment is the intensity of biochemical processes taking place in the reactor. It was evaluated based on the changes of the values of the reaction pH of treated sewage and sewage located in the reactor [3].

At all research stages, at the beginning the decrease of the sewage pH was observed, and next its value increased. The observed reaction was the result of the fact that dairy waste has a tendency to putrefy because of the accumulation of butyric acid created by fermentation of lactose and taking place at the same time, butyric fermentation [4].

The reaction influences directly the effectiveness of waste treatment because the majority of microorganisms responsible for biological decomposition of organic substances prefer pH within the range from 6.0 to 8.0 [5, 6]. That is why, at given

research stages pH was tried to be kept at this level. The completion of a given research stage and start of a new one was connected with the increase of COD value of sewage flowing into the reactor and took place when pH was higher than 6.0 or stayed at the similar level for the few consecutive days.

The degree of reduction was within the range from 12 to 81 % reaching values over 70 % in the middle of III and at the end of IV research stages.

During the first stage a bigger concentration of organic pollution in the sewage from the reactor was noticed in the ratio to the sewage flowing into the reactor. It was caused by scouring of digested sludge from the reactor before the research period. During this period of adaptation of sludge (27^{th} September – 17^{th} October) penetration and immobilization of bacterial flora on the surface and inside the plenum structure took place. A similar situation was observed at the beginning of the second half of the third stage, when to improve immobilization of microorganisms, digested sludge and sewage in the reactor were disposed of through the discharge stub pipe, and the bioreactor was filled with fresh digested sludge again.

Conclusions

Microorganisms existing as biological membrane on the surface of a reactor plenum adopt very quickly to the increasing concentration of the organic substances in the sewage flowing off the reactor.

1. In this research it has been confirmed that treatment of dairy waste in anaerobic conditions provided positive results. At the end of the three-month research period the reduction of 81 % of the content of organic pollution in treated waste was obtained.

2. The degree of reduction of organic pollution is dependent on the concentration of pollution in the sewage flowing into the reactor. During gradual increasing of the concentration of organic sewage in raw sewage, bigger and bigger reduction of COD value in treated sewage was observed.

3. The longer the period of the given research stage was, the higher the increase of the reduction degree was observed.

4. At the beginning of each stage pH value decrease was observed which was the effect of sewage putrescibility.

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EFEKTYWNOŚĆ OCZYSZCZANIA ŚCIEKÓW MLECZARSKICH W ZINTEGROWANYM BIOREAKTORZE

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Abstrakt: Procesy beztlenowego rozkładu zanieczyszczeń są wykorzystywane m.in. do oczyszczania ścieków branży rolno-spożywczej, w tym ścieków mleczarskich. Badania dotyczyły oczyszczania ścieków mleczarskich w warunkach beztlenowych z wykorzystaniem nowatorskiego wypełnienia. Celem badań było określenie wpływu zmian stężenia zanieczyszczeń organicznych w ściekach dopływających do bioreaktora beztlenowego na wartość ChZT ścieków oczyszczonych. Kierunki przemian biochemicznych, będące jednym z czynników determinujących poziom zanieczyszczeń organicznych w ściekach oczyszczonych oceniano na podstawie odczynu ścieków, wyrażonego jako pH.

W trakcie trwających trzy miesiące badań stopniowo zwiększano stężenie zanieczyszczeń organicznych ścieków surowych, obserwując coraz mniejsze ChZT ścieków oczyszczonych. Na końcu IV etapu badań stopień redukcji zanieczyszczeń organicznych w ściekach oczyszczonych, w stosunku do ścieków surowych, wyniósł 81 %.

Słowa kluczowe: bioreaktor beztlenowy, ścieki mleczarskie, wypełnienie, ChZT, efektywność oczyszczania