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Suspended and immobilized biomass in individual wastewater treatment systems SBR and SBBR

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ABSTRACT

The small wastewater treatment plant is a device or group of devices which—through mechanical, biological, and chemical processes—reduces the pollution load to the values specified in the Regulation of the Minister of the Environment. The aim of this research is to show the relationship between the growth of the biomass and the effectiveness of removing contaminants from wastewater in individual wastewater treatment systems. The results of activated sludge volume after 30 min settling, microscopic analysis, and quantitative and qualitative parameters of biomass in the aeration chambers were analyzed in this article. During the research, one of the reactors was converted into a hybrid reactor (SBR filled with plastic carriers, which support the process of nitrification). A microscopic analysis of the biomass was conducted to evaluate the operation of activated sludge and biofilm. Flocs of activated sludge in the SBR were characterized by irregular shape and high biodiversity. The appearance of rotifers testified about the good condition of the sludge. The microscopic analysis of biomass of the hybrid reactor showed a negative effect of the applied biopreparation. Microorganisms such as bacteria and ciliates were observed in the biomass. In summary, the structure of the biofilm and activated sludge floc is very sensitive to the system parameters and external factors. Biofilm develops more slowly than the activated sludge. Introduction of the moving bed into the reactor of activated sludge should be made in the summertime.

Keywords: Small wastewater treatment plant; Sequencing biological reactor; Hybrid reactor; Biofilm; Moving bed; Activated sludge; Microscopic analysis; Ciliates; Rotifers; Indicators of contamination

1. Introduction

Wastewater from built-up areas not constituting an agglomeration as understood by the European Union regulations affects the environment and, in particular, the purity of surface and groundwater. Therefore, an individual wastewater treatment in the place of its formation is vital.

A small wastewater treatment plant is a device or group of devices which—through mechanical, biological, and chemical processes—reduces the pollution load to the values specified in the Regulation of the Minister of the Environment [1].

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Many investors must make a choice concerning wastewater treatment technologies. Increasingly, the decisive criterion is the effectiveness of the treatment, not the price. Producers of wastewater treatment plants offer their customers a wide range of treatment plants. Currently, the sequencing batch reactor (SBR) wastewater treatment plant is very popular. SBR is extremely flexible for biological nitrification and denitrification processes because it allows the use of sequencing anaerobic, anoxic, and aerobic zones. These kinds of reactors are inexpensive and very effective in treating systems for small wastewater treatment plants [2–4].

A critical factor for nitrification process is the oxygen concentration. One advantage of an immobilized biomass system (biofilm) is the reduced energy cost for aeration. The reactor becomes SBBR when a biofilm is adapted to SBR. Biological processes occur in two phases: inside the reactor and inside the biofilm after contact with its surface. Canto shows the potentiality of SBBR system for removing ammonium nitrogen from liquid effluents [5]. A solution for newly erected or modernized facilities can be a combination of the technology of activated sludge and a moving bed. The hybrid reactor (SBBR) enables the purification of sewage by the suspended biomass and the biomass immobilized on the carriers. Simultaneous nitrification and denitrification (SND) is done in aerobic reactors. Researchers described two reasons of the practical application of SND. The first is the fact that the products of the nitrification are reactants in the denitrification. Nitrification produces acid and denitrification produces alkaline [6]. The carriers float freely in the purified medium, characterized by a large surface area and a density close to the density of the liquid. For facilities that do not meet the requirements as to the quality of the treated wastewater, the introduction of an appropriate number of carriers serves the increasing of the wastewater treatment plant efficiency operation and meets the requirements of the Regulation of the Minister of the Environment [7].

Activated sludge and biofilm are characteristics of forms of biomass used in wastewater treatment. Activated sludge is a suspension consisting of microorganisms which have the ability to carry out nitrification, denitrification, oxidation of organic compounds, and a phosphorus accumulation in cells. Activated sludge primarily consists of bacteria including filamentous organisms, multicellular animal organisms (rotifers, nematodes, earthworms, arachnids), fungi, protozoa (ciliates, dinoflagellates, ameba), and a mineral suspension [8].

The diameter of a sludge floc ranges between 50 and 100 μm. It is formed by microorganisms secreting high-molecular weight compounds (Extracellular Polymeric Substance). Zooglea are the result of bacterial cells division that are embedded in a gelatinous matrix. The substances contained in the wastewater are not immediately absorbed into the interior of the flocs. Most substances are adsorbed and decomposed into simple compounds on the surface of the flocs. This form is absorbed by microorganisms (Fig. 1). Then, the substrate undergoes further biochemical transformations, which are catalyzed by the enzymes (produced by microorganisms). Macromolecular compounds (e.g. proteins, lipids) are decomposed to inorganic products (H_2O, CO_2, PO_4^{3-}, NO_3^-, SO_4^{2-}) or used in the synthesis of biomass [9].

A microscopic analysis showed a floc morphology characterization for the well-developed flocs. The nucleus of the floc is beige or brown, inorganic, and is usually 30–33% of the floc. There are particles of the ground and calcium phosphates, which form on the border of the aerobic and anaerobic zone. The organic part forms 67–70% of the floc and its boundary zones are bright [8].

Flagellates, ciliates, and rotifers can be the indicator organisms, which determine the quality of

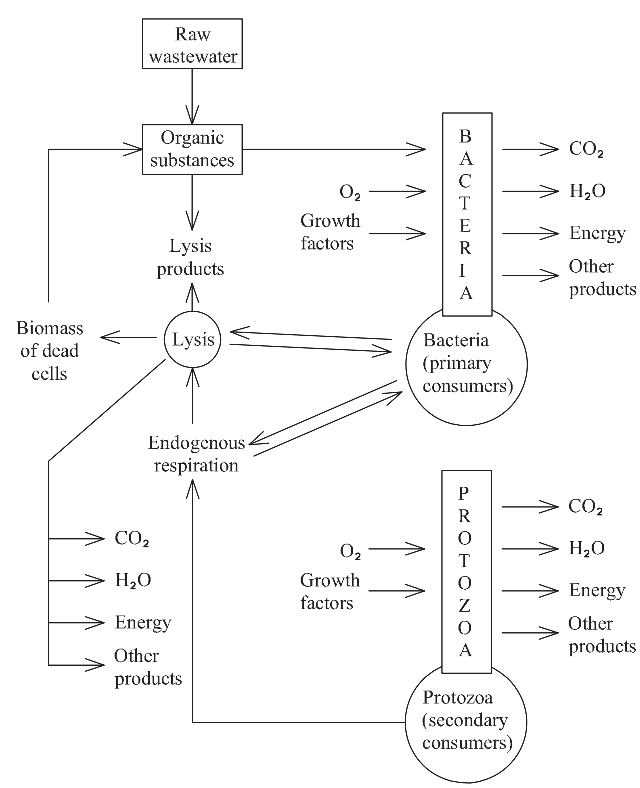

Fig. 1. Diagram of the biochemical processes of biological wastewater treatment with activated sludge [9].

the treated wastewater. The growth of microorganisms depends on the load and the age of the sludge is shown in Fig. 2.

The outflow of sludge flocs from the system occurs under conditions of high load and short sludge age. The result is a deterioration in the quality of treated sewage. Flagellates are the dominant organisms then. Chambers which operate with a low load (high sludge age) are rich in rotifers and nematodes. Their role consists in the absorption of bacteria and small protozoa. On the one hand, the presence of multicellular organisms allows the maintenance of the biological balance and promotes rejuvenation of the population; on the other hand, it proves too high a concentration of oxygen in the sludge and a deterioration in the quality of treated sewage [9]. Systems dominated by ciliates (sludge age appropriate for a given technological system) are characterized by high quality outflow. The presence of ciliates also proves the presence of the good sedimentation properties of the flocs [8].

In the natural environment, the formation of biofilm is the preferred microbial growth mode (because of the large energy benefits). The growth of biofilm occurs in any environment where the support surface, water, and nutrients are present. The appearance of the biofilm can be disadvantageous in water treatment processes because of the growth of pathogens or other undesirable microbes. Biofilm formation is advantageous in the technology of wastewater treatment. The purpose of this process is biodegradation of organic pollutants or transformation of undesirable mineral substances into harmless ones. The formation of a biofilm is an important mechanism of the interaction between the surface of carriers and the biological processes. Biofilm is an organic material composed of microorganisms, which are embedded in an extracellular polymeric substance—EPS. Microorganisms can form groups or columns, which enables the advective transportation of the substance into the biofilm. This phenomenon leads to a microbial diversity, and variability of processes depending on the location of the biofilm. The surface of carriers should not be flat. Sharp edges have an impact on the hydrodynamic flow and transportation of mass from the liquid to the biofilm [10].

The objectives of this study were to investigate and describe the basic groups of microorganisms and their concentration in SBR and SBBR systems. The results of activated sludge volume after 30 min settling and microscopic analysis of the biomass in the aeration chambers were analyzed in this article. Biodiversity in these systems was compared.

2. Materials and methods

2.1. *Characteristics of studied reactors*

Suspended and attached biomass came from small biological wastewater treatment plants of the SBR type (Fig. 3).

The wastewater treatment plants were in Rakoniewice and Dakowy Mokre (Fig. 4)—the municipality of Grodzisk Wielkopolski. Wastewater (pretreated in a septic tank) flowed into the reactor by gravity during the whole operation cycle—about 600 dm^3/d. There was only one cycle during a day. An average length of aerobic reaction phases lasted 14 h and 55 min and an average length of anaerobic phases lasted 7 h and 5 min. The sedimentation phase occurred once a day (from 2.00 to 3.45 AM). It was 1 h and 45 min. The timing of a decant phase was 15 min. The treated sewage was pumped out of the reactor by a Omnigea WQ 18.OF pump. The air was supplied by a blower (fine-bubble diffused-air aeration). Treated wastewater was discharged into the soil through an absorbing well. A low-impact activated sludge was used in the biological treatment; The bioreactor in Rakoniewice was

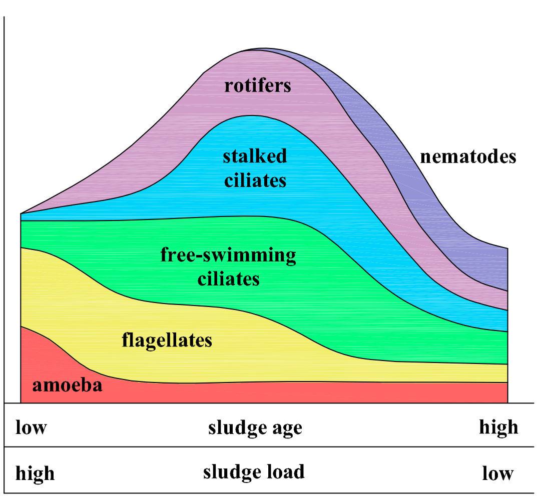

Fig. 2. Changing populations of indicator organisms in activated sludge, depending on the sludge age and sludge load [8].

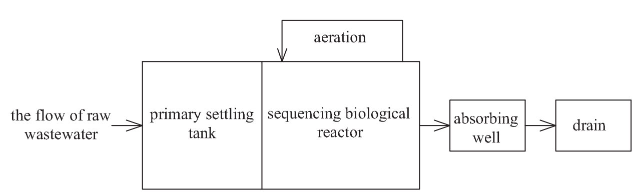

Fig. 3. Diagram of SBR wastewater treatment plant with a absorbing well [11].

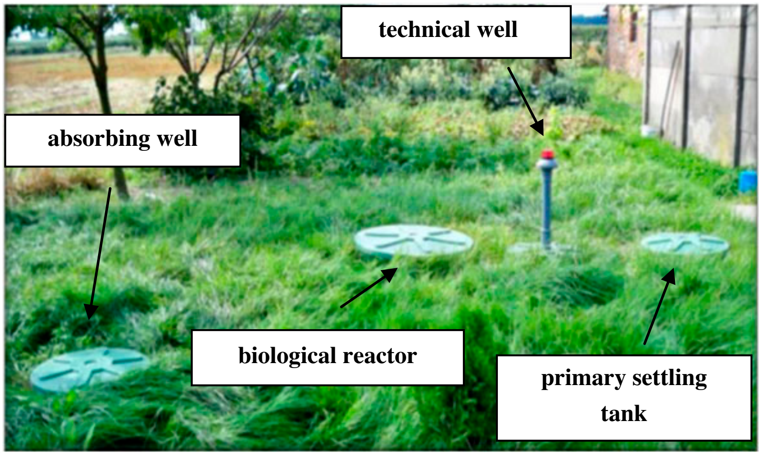

Fig. 4. Small wastewater treatment plant SBR in the village of Dakowy Mokre.

additionally filled with a moving bed (cylindrical polyethylene carriers 13 × 13 mm, the density—0.94 g/cm^3, carriers specific surface—500 m^2/m^3). Technical data of the treatment plants are shown in Table 1.

The number of carriers—13 715 pcs—was determined based on the relationship with suspended biomass loading of organic pollutions [12].

2.2. Methodology

Research was conducted from July 2012 till July 2013. The inflowing pollution indicators were the following (average values): BOD_5—301.1 g/m^3, COD—632.2 g/m^3, total suspended solids (TSS)—300.5 g/m^3 for wastewater treatment plant in Dakowy Mokre (SBR) and BOD_5—266.1 g/m^3, COD—389.1 g/m^3, total suspended solids (TSS)—1,148 g/m^3 for wastewater treatment plant in Rakoniewice (SBBR). Samples of wastewater and activated sludge were taken from the bioreactors (nine times) during the aeration phase. The carriers were taken five times.

The activated sludge volume after 30 min settling was determined immediately after sampling using a 1 dm^3 cylinder. The mass of activated sludge and biofilm as total suspended solids and organic suspended solids were determined in the laboratory of the Department of Hydraulic and Sanitary Engineering. The mass of activated sludge was determined by the weight method [13]. Each carrier was rinsed with distilled water to separate the biofilm. Carriers always were rinsed with the same volume of water—2 cm^3. The mass of biofilm on the carrier was determined by the content of organic nitrogen in the biomass [14]. The sludge volume index (after Mohlman) was calculated on the basis of the results. Microscopic analysis of biomass was also carried out. An observation of the sludge flocs and biofilm was carried out under a light microscope AXIOSTAR PLUS Zeiss, at magnification 100× and 400× in unstained preparations. Morphometric characteristics: the structure, size, shape, and color were specified. The quantity of microorganisms present in suspended biomass and immobilized biomass was also determined.

3. Results

3.1. Activated sludge volume after 30 min settling

Fig. 5 shows the results of activated sludge volume after 30 min settling, obtained for the suspended biomass. According to the literature, the result of the activated sludge volume after 30 min settling for a

Table 1
Technical data of the systems in Rakoniewice and Dakowy Mokre

Location of the system	Septic tank volume (m^3)	SBR reactor volume (m^3)	Average influent of sewage (dm^3/d)	Average load in influent (g BOD_5/d)	The number of users (M)	Moving bed
Rakoniewice	1	2	422	112.53	4	Yes
Dakowy Mokre	1	2	270	81.3	5	No

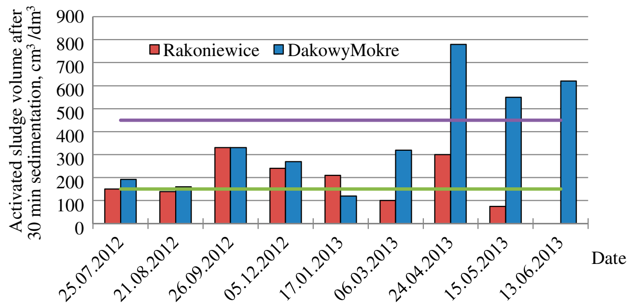

Fig. 5. Activated sludge volume after 30 min sedimentation for small wastewater treatment plants in Rakoniewice and Dakowy Mokre.

well-working activated sludge should be between 200 and 400 cm^3/dm^3 [15].

The activated sludge volume after 30 min settling should be within 150–450 cm^3/dm^3, according to the recommendations of the wastewater treatment plant manufacturer. The amount of sludge in the Rakoniewice wastewater treatment plant was lower in March and May. In June, the reactor contained a small amount of activated sludge. The reason was the damage of the time controllers. In Dakowy Mokre, the results of activated sludge volume after 30 min settling were in the required range. The result obtained in January—below the minimum value—was an exception. In April, May, and June the results of activated sludge volume after 30 min settling exceeded the upper limit of the range.

3.2. *Efficiency of organic compounds removal in the reactors*

In December, the bioreactor in Rakoniewice was additionally filled with a moving bed. Its purpose was to improve the removal of ammonium nitrogen that was observed gradually. Any abnormalities in the operation of the wastewater treatment plant causing a rapid decrease in the efficiency of wastewater treatment concluded after 24th of April 2013. The reason of this phenomenon was uncontrolled use of biopreparation by user of the wastewater treatment plant. A significant and constant increase of organic compounds content in the purified wastewater was observed. An increase of ammonium nitrogen occurred later (postponed due to the presence of nitrificants attached to the carriers).

No abnormalities were found in the operation of wastewater treatment plant in Dakowy Mokre. Efficiency of organic compounds removal in Dakowy Mokre was above 90% from September to October (Fig. 6).

Concentration of pollution indicators in raw and purified wastewater from wastewater treatment plant in Rakoniewice and Dakowy Mokre was described by Sowinska and Makowska [4].

3.3. *Quantity and quality of the biomass in the reactors*

The amount of the activated sludge in the reactors was calculated on the basis of the concentration of total suspended solids in aeration chambers in Rakoniewice and Dakowy Mokre wastewater treatment plants. The volume of the chamber was 1.5 m^3. The results are presented in Table 2.

Table 2 also contains values of the sludge volume index (after Mohlman). The sludge volume index (after Mohlman) of well-sedimenting activated sludge should be ranging from 50 to 150 cm^3/g [16].

The above data indicate that the activated sludge in the bioreactor in Dakowy Mokre was in better shape. The results of activated sludge volume after 30 min and the amount of activated sludge and sludge volume index (after Mohlman) testify to that. In Rakoniewice during autumn there, a growth of suspended and immobilized biomass was observed. The results of the efficiency and stability of the wastewater treatment plant confirmed these observations [4].

Microscopic analysis aimed to assess the operation of the activated sludge and biofilm. The research was conducted three times: in April, May, and June.

3.4. *The microscopic analysis for the small wastewater treatment plant in Rakoniewice*

The microscopic analysis for the small wastewater treatment plant in Rakoniewice included sludge flocs and biofilm. During the microscopic observation conducted in April and May, irregular shapes of activated

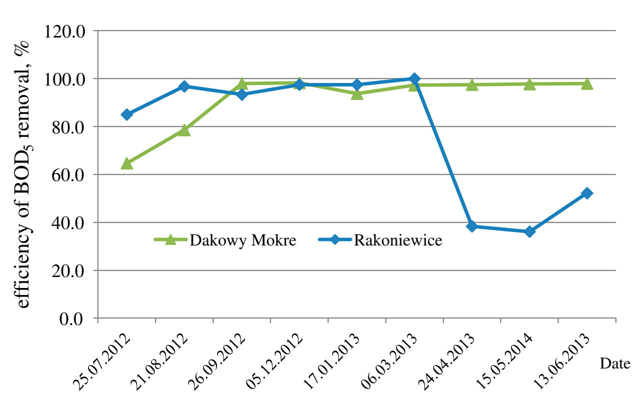

Fig. 6. Efficiency of organic compounds (BOD_5) removal in Rakoniewice and Dakowy Mokre.

Table 2
Quantitative and qualitative parameters of biomass in the aeration chambers, calculated on the basis of the concentration of total suspended solids and the volume of the aeration chamber

Date	Rakoniewice				Dakowy Mokre		
	Concentration of total suspended solids (g/m^3)	The amount of sludge (g)	Sludge volume index (after Mohlman) (cm^3/g)	The amount of biomass on the carriers (g)	Concentration of total suspended (g/m^3)	The amount of sludge (g)	Sludge volume index (after Mohlman) (cm^3/g)
21 August 2012	21.4	32.1	6542.1	–	30.2	45.3	5,298
26 September 2012	1,337	2005.5	246.8	–	3,010	4,515	109.6
05 December 2012	40	60	6,000	–	1,007	1510.5	268.1
17 January 2013	208.6	312.9	1006.7	15.54	–	–	–
06 March 2013	434.4	651.6	230.2	10.62	2732.4	4098.6	117.1
24 April 2013	1,220	1830	245.9	38.4	6,421	9631.5	121.5
15 May 2013	786.2	1179.3	99.2	28.6	3038.2	4557.3	181
13 June 2013	165.2	247.8	0	16.35	6,829	10243.5	78.7

sludge flocs were found. Filamentous organisms were the cause of the irregular forms and the loose structure of the flocs (Fig. 7). The indistinct boundary between floc and liquid phase indicated a weak coherence and structure.

Activated sludge was bacterial. There were macromolecular organic and inorganic components. There were microorganisms that feed on bacteria located in the liquid phase or occurring at the shore flocs (Table 3).

There were free-swimming ciliates (Fig. 8), but no stalked ciliates and rotifers in the sludge. Crawling ciliates—due to their thin external cell membrane—can assume any shape. The occurrence of ameba (Fig. 9) or flagellates can attest to a low concentration of oxygen in the system.

Microscopic analyses, conducted in April, show that the biofilm was bacterial and poorly developed. Small amounts of filamentous organisms were present in the biofilm (Table 4).

In May, the biofilm was characterized by a compact structure (Fig. 10). The biofilm contained primarily eukaryotic organisms belonging to the Protista e.g. free-swimming ciliates (Table 4). Stalked ciliates that occur in the biomass in systems with high efficiency of wastewater treatment did not occur in this biofilm.

The analysis carried out in June revealed the existence of an additional factor responsible for the growth of both suspended and immobilized biomass. Three types of microorganisms dominated in the sludge flocs and biofilm (Fig. 11). It was due to the

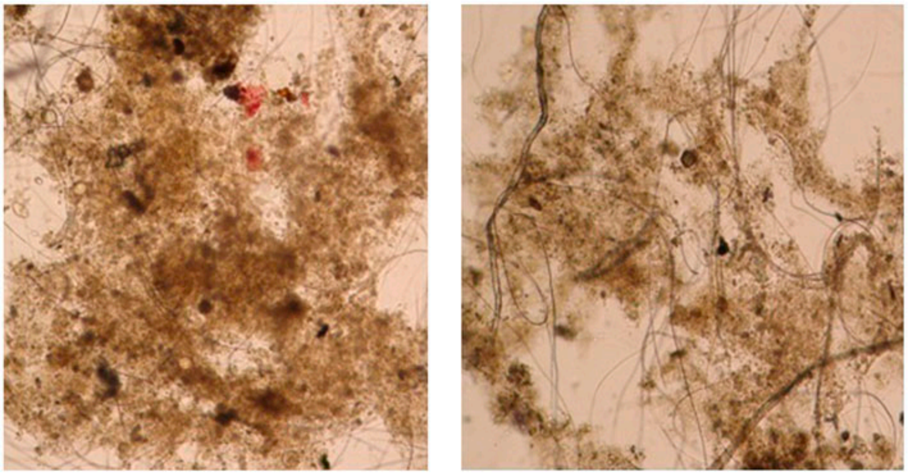

Fig. 7. The structure of activated sludge flocs in a small sewage treatment plant in Rakoniewice during microscopic analysis carried out in May—visible filamentous microorganisms.

Table 3
The frequency of microorganisms in the suspended biomass in a small wastewater treatment plant in Rakoniewice

Frequency	Rakoniewice—flocs of activated sludge (24 April 2013)				Rakoniewice—flocs of activated sludge (15 May 2013)				Rakoniewice—flocs of activated sludge (13 June 2013)			
Microorganisms	absent	rarely	often	very often	absent	rarely	often	very often	absent	rarely	often	very often
Filamentous bacteria			+				+		+			
Stalked ciliates	+				+				+			
Free-swimming ciliates		+				+				+		
Crawling ciliates		+				+			+			
Rotifers	+				+				+			

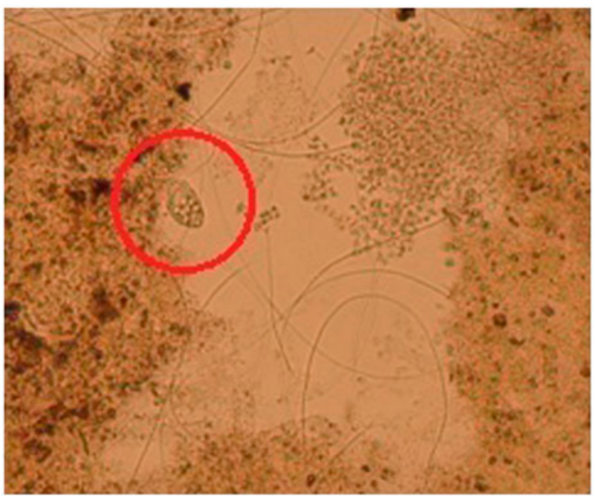

Fig. 8. Free-swimming ciliate.

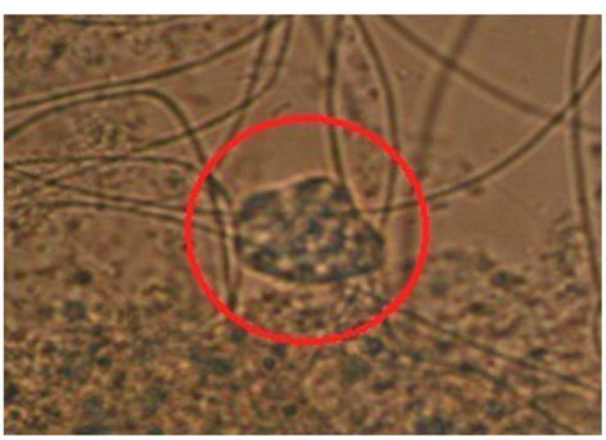

Fig. 9. Naked Amoebae.

use of a biopreparation, which was intended for the proper maintenance and exploitation of the settlers and the drainage pipes. According to the producer,

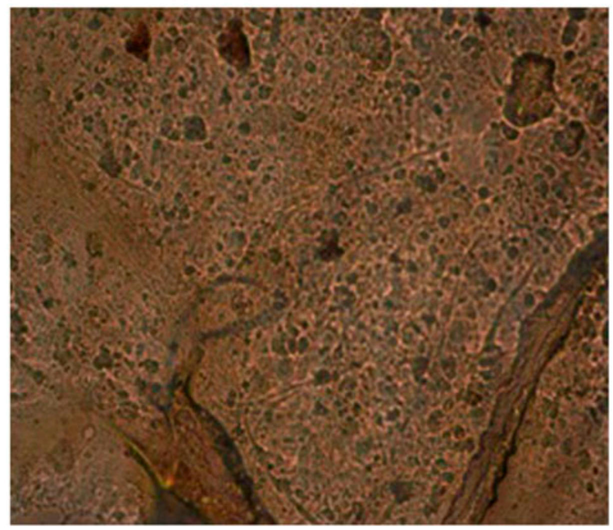

Fig. 10. The structure of the biofilm on the carriers in April.

the preparation contains three strains of organisms which mineralize the sludge to reduce its volume. The biopreparation was added twice, in April and May. In April, indicators of contamination pointed to the problem with the operation of the wastewater treatment plant. The biopreparation blocked the growth of the biomass, suspended and immobilized. The preparation probably contained organisms which are predators in relation to the activated sludge organisms or produce enzymatic proteins decomposing other cells. Another cause of the deterioration of the efficiency of the wastewater treatment could have been the absorption of the nutrients by microorganisms activated by the biopreparation. The lack of nutrients caused the extinction of the microorganisms.

Failure of the wastewater treatment plant in Rakoniewice was recorded during the sampling in June. The aeration time controller was broken. Sewage

Table 4
The frequency of the microorganisms in the immobilized biomass in the small wastewater treatment plant in Rakoniewice

Frequency	Rakoniewice—biofilm (24 April 2013)				Rakoniewice—biofilm (15 May 2013)				Rakoniewice—biofilm (13 June 2013)			
Microorganisms	absent	rarely	often	very often	absent	rarely	often	very often	absent	rarely	often	very often
Filamentous bacteria		+				+			+			
Stalked ciliates	+				+				+			
Free-swimming ciliates	+					+			+			
Crawling ciliates	+					+			+			
Rotifers	+				+				+			

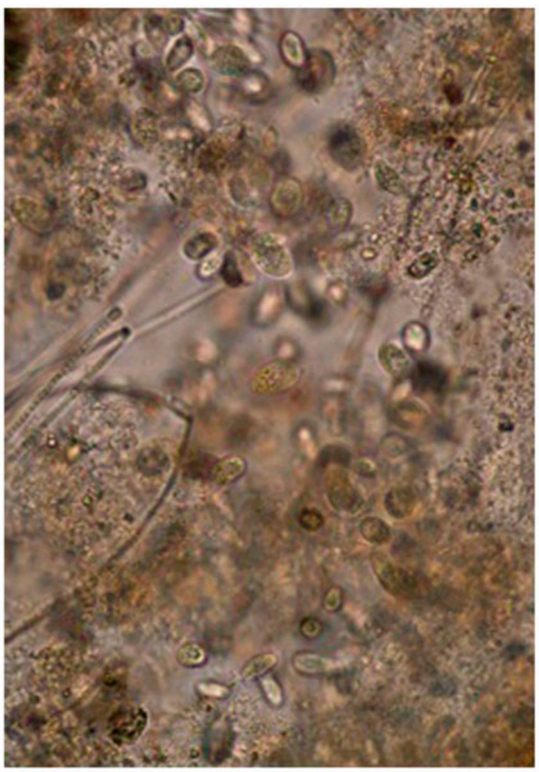

Fig. 11. Dominant microorganisms in the biofilm after addition of the biopreparation.

contained in the reactor was continuously aerated also during switching of the pump. Consequently, most of the sludge was discharged outside the treatment plant. The load of the biofilm proved to be too high to ensure an appropriate level of wastewater treatment [4].

Microorganisms such as protozoa, nematodes, or rotifers were absent in the biofilm (Table 4).

3.5. Microscopic analysis for a small wastewater treatment plant in Dakowy Mokre

The microscopic analysis for the small wastewater treatment plant in Dakowy Mokre involved the observation of sludge floc.

In April, the shape of the sludge floc was irregular. Flocs were characterized by a compact structure with a high cohesion. Low temperature was probably the cause of the low-diversity composition of the population. Trace amounts of the filamentous organisms, crawling ciliates (Fig. 12), stalked ciliates (Fig. 13), free-swimming ciliates (Fig. 14) were observed during the microscopic analysis (Table 5).

The analysis carried out in May revealed the growth of suspended biomass. The increase of temperature and the sufficient amount of nutrients flowing into the sewage explain the appearance of rotifers. Sludge flocs, medium and large in size, had a compact structure with a high cohesion. The center of the floc was clearly visible. A growth of biomass of activated sludge and many protozoa were observed (Table 5). Stalked ciliates were observed at the wastewater treatment plant in Dakowy Mokre (Figs. 15 and 16).

The research in June confirmed the very good condition of the activated sludge in the small wastewater treatment plant in Dakowy Mokre. The microscopic analysis showed the presence of microorganisms, which are characteristic of a well-working activated sludge. This testified to a high quality of wastewater treatment. Stalked ciliates such as *Vorticella* sp., *Carchesium* sp., *Opercularia* sp., dominated in the entire system. Free-swimming ciliates (Fig. 17) and crawling ciliates were also observed during the microscopic analysis. There were rotifers (Fig. 18) in the wastewater treatment plant in Dakowy Mokre, which are indicators of well-working activated sludge (Table 5).

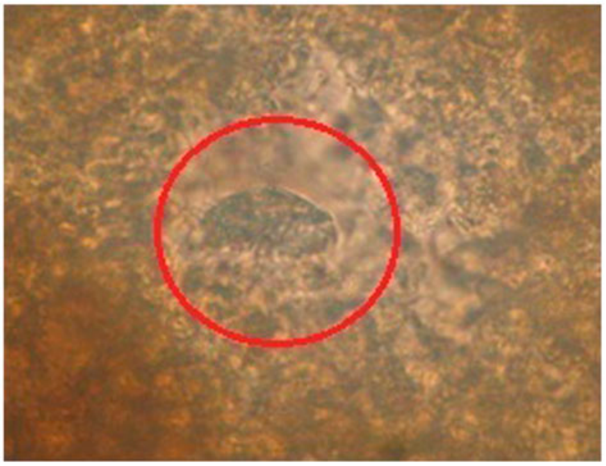

Fig. 12. Crawling ciliate.

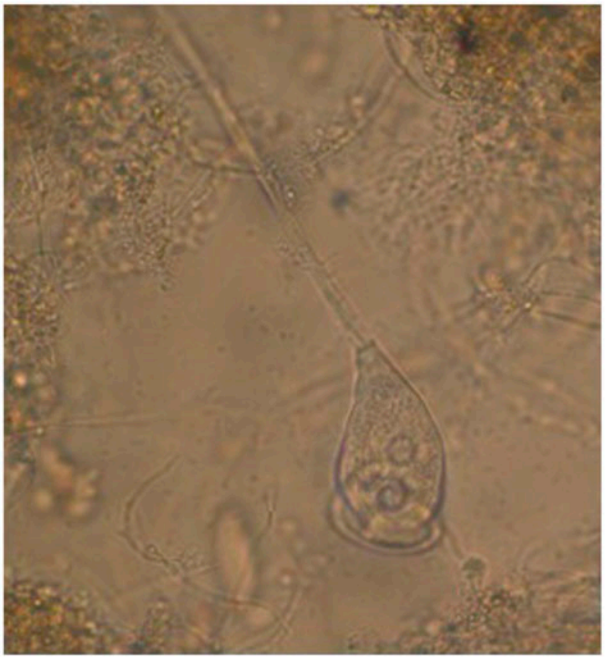

Fig. 13. Stalked ciliate*:* *Vorticella* sp.

The microorganisms observed in the research of the wastewater treatment plants are presented in Table 6.

4. Discussion

SBR reactors can be used for small wastewater treatment plants, although Straub [17] places them at a further position after the flow system and free water surface constructed a wetland. The biomass is suspended and present in the form of activated sludge

Fig. 14. Free-swimming ciliate.

in conventional reactors. Additional biomass immobilized on a carrier can improve the efficiency of sewage treatment in the wastewater treatment plants with high irregularities of quantity and quality of the wastewater influent. Such a variant was used in the wastewater treatment plant in Rakoniewice. The species composition of microorganisms present in the suspended biomass as well as in the immobilized biomass was somewhat different. Filamentous bacteria, ciliates, and rotifers occurred more frequently in the suspended biomass. Free-swimming ciliates were mainly observed in the immobilized biomass. The composition of the biomass changed in the initial period of the research despite the addition of the carriers to the reactor during the autumn-winter season. Nevertheless, microorganisms were additionally exposed to the adverse effects of a biopreparation, which was added by the user. The microorganisms from the biopreparation predominated both in the suspended and immobilized biomass. These microorganisms have not been observed in the samples since the time when its application was discontinued.

A control sample was carried out in the laboratory to confirm this thesis. The biopreparation was added to a well-working activated sludge. The activated sludge was nourished by sewage with a similar composition as studied wastewater. A decrease in the efficiency of wastewater treatment was found a few days after the start of the experiment. The number of

Table 5
The frequency of the microorganisms in the suspended biomass in the small wastewater treatment plant in Dakowy Mokre

	Dakowy Mokre—flocs of activated sludge (24 April 2013)				Dakowy Mokre—flocs of activated sludge (15 May 2013)				Dakowy Mokre—flocs of activated sludge (13 June 2013)			
Frequency Microorganisms	absent	rarely	often	very often	absent	rarely	often	very often	absent	rarely	often	very often
Filamentous bacteria		+			+				+			
Stalked ciliates		+					+					+
Free-swimming ciliates			+				+				+	
Crawling ciliates			+				+				+	
Rotifers	+				+					+		

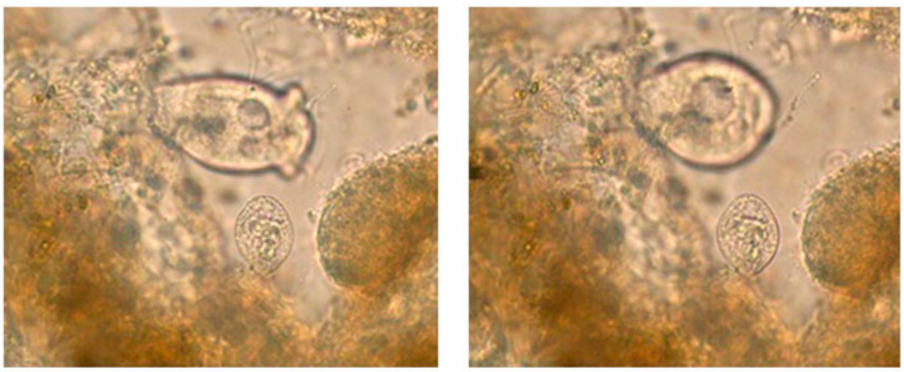

Fig. 15. Stalked ciliate (*Vorticella* sp.) during the absorption of nutrients.

Fig. 16. *Opercularia* sp.—stalked ciliates that live in the colonies.

Fig. 17. Free-swimming ciliate.

Fig. 18. Rotifer.

Table 6
Microorganisms observed in the studied biomass

Microorganisms	Rakoniewice		Dakowy Mokre
	Activated sludge	Biofilm	Activated sludge
Filamentous bacteria	+	+	+
Stalked ciliates	–	–	+
Free-swimming ciliates	+	+	+
Crawling ciliates	+	+	+
Rotifers	–	–	+

stalked ciliates decreased dramatically. Rotifers were observed less frequently. Biomass looked and behaved similarly to the one observed in the wastewater treatment plant in Rakoniewice, after the addition of the biopreparation.

Biomass in the form of the activated sludge occurred in the second wastewater treatment plant (Dakowy Mokre). The activated sludge was in a very good condition. It consisted mainly of ciliates and rotifers, which improved the oxygen conditions inside the flocs [8]. This sludge was characterized by significantly better sedimentation properties (Fig. 5 and Table 2). The small wastewater treatment plant in Dakowy Mokre operated more stably and more efficiently than the corresponding facility in Rakoniewice, due to the lack of interference from outside. Regular supervision of the elements of the system occurred only in the wastewater treatment plant in Dakowy Mokre.

5. Conclusions

(1) The structure of the biofilm and activated sludge flocs are very sensitive to system parameters and external factors.
(2) Biofilm develops more slowly than activated sludge. Immobilized biomass supports the work of the whole system. A high degree of biofilm growth guarantees the maintenance of wastewater treatment processes in the case of a failure of the facility.

(3) The introduction of the moving bed into the reactor of activated sludge should be made in the summertime. As literature describes and own research proves, the rate of biomass growth is much lower and may fall by half in the winter.
(4) The presence of ciliates, nematodes, and rotifers, determines the high efficiency of wastewater treatment and the ability to adapt to changing operating conditions.
(5) Operation, periodical control of the level of sludge in the septic tank and the reactor chamber, control of the blower and the pump are all very important in small biological wastewater treatment plants.
(6) Biopreparations should be used only when necessary (e.g. start of the wastewater treatment plant) and in accordance with their intended use.

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