

Barbara K. Wilk (barbara.k.wilk@gmail.com)

Department of Water and Wastewater technology, Faculty of Civil and Environmental Engineering, Gdańsk University of Technology

Małgorzata Cimochowicz-Rybicka

Institute of Water Supply and Environmental Protection, Cracow University of Technology

BIOVAC® WASTEWATER TREATMENT PLANTS IN THE MOUNTAIN NATIONAL PARKS

OCZYSZCZALNIE ŚCIEKÓW TYPU BIOVAC® NA TERENACH GÓRSKICH PARKÓW NARODOWYCH

Abstract

This paper presents characteristics of the Biovac® wastewater treatment plants operating in the mountain areas of the Polish national parks (NP): Tatrzański NP and Babiogórski NP as well as in the West Spitsbergen NP. On the basis of the laboratory tests performed on raw sewage and the final effluent the efficiency of the wastewater treatment plants was evaluated. It was found that high COD values and rather high COD / BODS ratios were observed in the raw sewage during an off-peak tourist season. The research has also shown that the Biovac® treatment plants (SBR technology) showed a high level of removal of pollutants from sewage discharged from mountain hostels.

Keywords: sewage treatment, SBR, mountain hostels

Streszczenie

W pracy dokonano charakterystyki wybranych oczyszczalni ścieków typu Biovac®, pracujących na terenach górskich parków narodowych: Tatrzańskiego, Babiogórskiego oraz Zachodniego Spitsbergenu. Na podstawie wykonanych oznaczeń analitycznych ścieków surowych oraz oczyszczonych dokonano oceny efektywności pracy oczyszczalni. Na podstawie wyników badań stwierdzono, że w okresie niskiego ruchu turystycznego w ściekach surowych występują: wysokie wartości wskaźnika ChZT oraz niekorzystny stosunek wartości ChZT/BZT5. Badania wykazały ponadto, że oczyszczalnie typu Biovac®, pracujące w oparciu o technologię SBR, wykazują dużą efektywność usuwania zanieczyszczeń ze ścieków pochodzących ze schronisk górskich.

Słowa kluczowe: oczyszczanie ścieków, SBR, schroniska górskie

1. Introduction

In the mountain national parks, a rapid development of tourism has been observed accompanied by the expansion of the tourist infrastructure [1]. As a result, the mountain hostels generate many different types of waste, including domestic sewage. The sewage generated at national park hostels usually has high concentrations of pollutants due to the rather strict water saving policy enforced in such buildings. The sewage, if not discharged to a wastewater treatment plant, is dumped into the mountain streams or disposed into the ground by a drainage system [2]. It is obvious that poorly treated sewage can be harmful for water [3-4] and land ecosystems in the neighbouring area.

Sewage volumes and pollution loads discharged from such hostels change seasonally, and the specific mountain climate can adversely affect the biological treatment processes. Therefore, wastewater treatment plants must not only work in a very efficient way, but also their operation and maintenance should be trouble free [2–5]. It should also be emphasised that such treatment facilities should have a long-term guarantee of failure-free operation due to the often difficult access to the treatment site. Moreover, the total dimensions of the equipment should be relatively small due to frequent area restrictions. Choosing the proper modern sewage treatment system that would work well both at the tourist peak season and off-season has become a challenge and a problem for engineers [5].

The Biovac® treatment plants (based on SBR technology) may be a good example of wastewater treatment plants that treat sewage from mountain hostels. These have been in operation in two Polish national parks (NP): Tatrzański NP and Babiogórski NP as well as in the West Spitsbergen NP.

Sewage characteristics

The volume and quality of sewage generated in the mountain hostels show a substantial variability on an annual and daily basis [4–8]. The greatest hydraulic stresses for the treatment plant occur during the peak tourist seasons – summer and winter holidays. According to the research conducted by Świerczok and others in 1994 [5], the Samotnia wastewater treatment plant in Karpacz received twelve times more sewage during the peak tourist season than during the off-peak period (1.2 m³/d compared to 15.1 m³/d). The above relationship has been also confirmed by Kaczor and others [4], who analysed the sewage volume discharged from the Chochołowska mountain hostel in 2009–2011 (9.0 m³/d – 58.5 m³/d, respectively).

The pollution load discharged with sewage from mountain hostels changes due to the seasonal nature of the tourism. According to the literature reports [4–10], the values of BOD₅, COD and pH during the peak tourist season in mountain trails are very close to those found in typical household sewage. By contrast, the values of the total suspended solids (TSS) and total nitrogen (TN) are slightly higher than typical levels, while the values of the total phosphorus (TP) are lower.

Of course, the off-season values of COD, BOD₅, TN and TP are significantly lower than those observed in the peak season. It should be noted that a significant decrease in the organic carbon content in sewage is observed, and consequently, an unfavourable COD/BOD₅ ratio. This negatively affects the treatment processes taking place in biological reactors and can

result in, for example, high COD values in the effluent; it may also disturb other treatment processes, such as phosphorus removal and biological denitrification. An unfavourable COD / BOD₅ ratio in sewage is due to a low water consumption in mountain hostels and a large amount of fats discharged from different restaurants located there [9-14]. It should also be mentioned that daily fluctuations in the sewage volume and the daily changes of pollutant concentrations in raw sewage are more diverse than during the peak tourist season.

Biovac® wastewater treatment plant description

Biovac® technology is based on the activated sludge process taking place in sequencing batch reactors (SBR). SBR technology [9], as an activated sludge option, is used mainly at small municipal wastewater treatment plants and at small domestic applications. The flow chart of the Biovac® wastewater treatment plant is presented below:

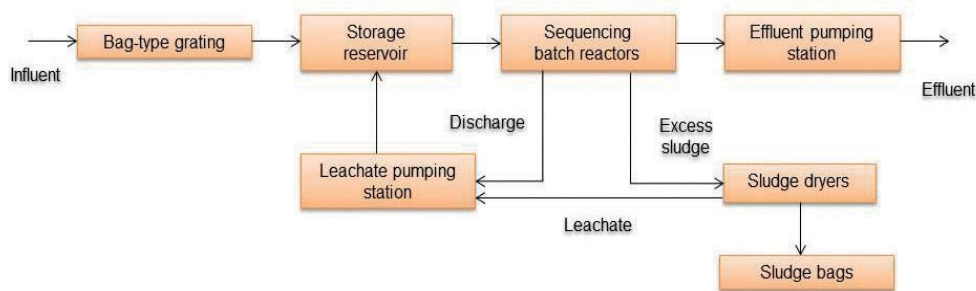


Fig. 1. Flow chart of the Biovac® wastewater treatment plant [10]

Primary treatment

The mechanical (primary) sewage treatment is a stage where solids are removed from sewage. Biovac® plants usually employ basket screens and bag screens, although occasionally fine screens, sieves or screenings and grit separators (combined in a single unit) are used for larger wastewater treatment plants. The basket screen is a coarse screen made of stainless steel. This device is placed directly by the inlet in manholes or pumping stations to which wastewater is carried by pipe. It is guided by rails and has electric or hand hoist. Floating solids of a particular size are caught in the filtering compartment. The basket moves along the rails in vertical direction [10]. After being pulled out of the tank, the basket turns to a position that guarantees automatic unloading of screenings. The separated solids/screenings are transported to a storage tank or to a filter press via a gutter. The bag screen (Fig. 2) is mounted in front of the retention tank. The bag is made of plastic fibres and removes solids of a particular diameter. Similar bags can also be found in agriculture as a packing material for agricultural crops.

The vertical retention tank (Fig. 2) equalises the sewage flow/composition and serves as a buffer during large flow fluctuations. The tank houses submersible pumps that pump sewage to the SBRs.

The pumps transport sewage from the retention tank to the SBR reactors where the cyclic treatment process is carried out. The SBR cycle is comprised of the following phases: filling



Fig. 2. Biovac® wastewater treatment plant at West Spitsbergen a) bag screen , b) retention tank [10]

the reactor with sewage; biological treatment; separation of activated sludge from the effluent; partial effluent discharge; removal of excess sludge; finally, an idle phase. During the treatment process, organic substances and nitrogen and phosphorus compounds are removed from the sewage. The typical durations of the phases in the SBR cycle used in the Biovac® wastewater treatment plants are shown in Table 1. These can be changed by the plant operator.

Table 1. Biovac® treatment process parameters [10]

Phase	1. Fill	2. Nitrification	3. Mixing	4. Idle
Time (min.)	5	180	0.17	4
Phase	5. Denitrification	6. Settling	7. Sludge removal	8. Effluent discharge
Time (min.)	40	100	0.5	25

The reactors are equipped with aeration systems that ensure the simultaneous aeration and mixing of the reactor volume (provided by disc diffusers). Compressed air is supplied using blowers. Two independent reactors are connected by a drainage system and a valve system; in this way, it is possible to transfer the activated sludge from one reactor that has finished its operation to another one that is starting.

Sludge processing

Excess sludge is directed to an aerobic stabilisation tank in which a cyclic aeration takes place via disc diffusers and a blower. After aerobic stabilisation, sludge becomes a stable product that can be stored without risk of odour. The stabilisation process also results in the partial or complete removal of pathogenic microorganisms [10–13]. The stabilised sludge is discharged to the dewatering units and subsequently dried in sludge dryers (Fig. 3).

Sludge presses or centrifuges are used for the mechanical dewatering of sludge at larger wastewater treatment plants. Centrifuges (working in a batch or in continuous mode) separate the solids from the liquid with gravitational and centrifugal forces while filter presses, squeeze water out of the sludge [14–16].





Fig. 3. Sludge processing at the Biovac® wastewater treatment plant [10]

The wastewater treatment plant at West Spitsbergen (Polish Polar Station)

In August 2001, the Biovac® wastewater treatment plant with a capacity of $10 \text{ m}^3/\text{d}$ was launched at Spitsbergen. The new wastewater treatment plant replaced the rotating biological contactors (RBC), which had been in operation there since 1985 [10]. The following diagram shows the current sewage treatment technology.

The SBR-type treatment plant at Spitsbergen treats mostly domestic sewage comprising toilet waste, food waste, surfactants, toilet paper, fats and detergents. The sewage composition shows high levels of phosphorus, nitrogen, and the presence of coliforms. The sewage composition is also influenced by the chemical laboratory located at the station where various types of chemical analyses are carried out over the year (mainly chemical analyzes of surface waters and rainwater) [10].

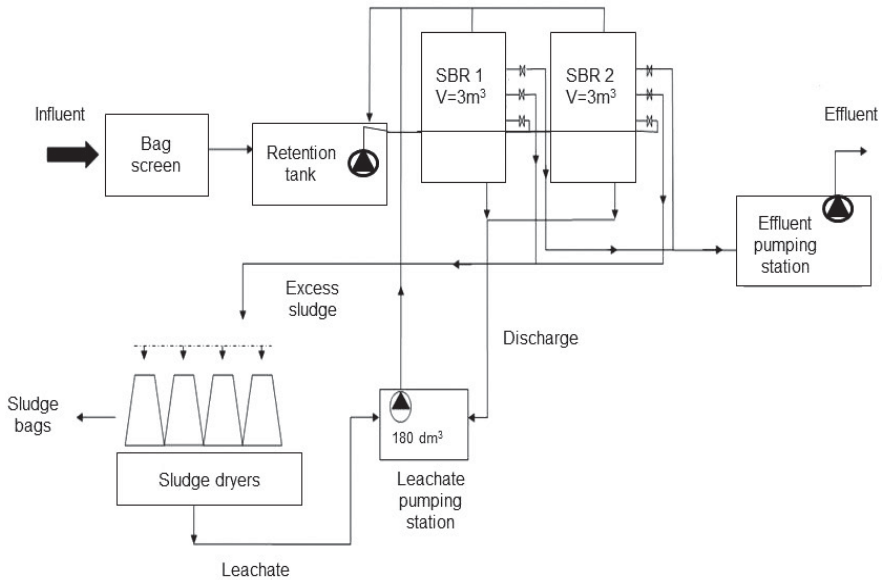


Fig. 4. Flow chart of the West Spitsbergen wastewater treatment plant [10]

Wastewater treatment plant at the Murowaniec mountain refuge

According to the work of Siwek J. et al. [2], the Murowaniec hostel discharged large amounts of NH_4^+ and PO_4^- to the Sucha Woda creek in the years 2008-2009 (the highest concentrations were reported during the summer holidays). Since a new wastewater treatment plant started its operation in 2011, the situation has significantly improved [2]. Figure 5 shows a flow chart of the new Murowaniec wastewater treatment plant.

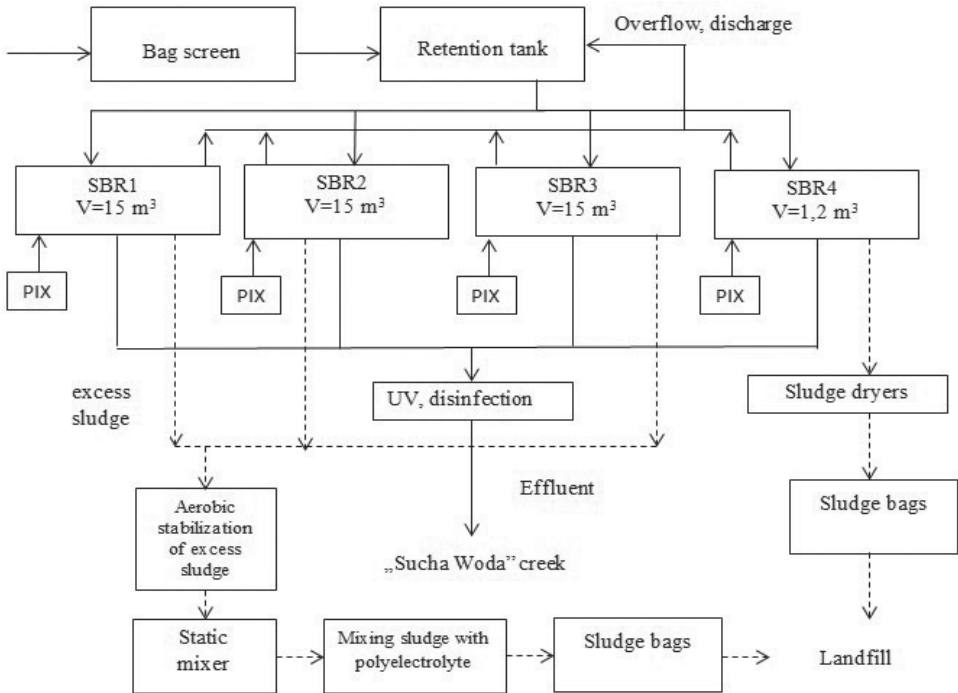


Fig. 5. Flow chart of the Murowaniec wastewater treatment plant [10]

The plant treats domestic sewage. The hostel has 116 beds and a restaurant. The wastewater treatment plant effluent is discharged into the Sucha Woda creek (13 + 800 km of the Cicha Woda creek).

Wastewater treatment plant at the Dolina 5 Stawów mountain refuge

Until 2010, the Dolina 5 Stawow hostel did not have a wastewater treatment plant. Raw sewage was discharged to the Litwor's gully and then to the Roztoka creek [2]. According to Siwek J. et al., the pollution accumulated over many years in crust of the Litwor's gully will continue to affect surrounding water ecosystems for a long time. Since 2010, the sewage from the Dolina 5 Stawów hostel has been treated by the Biovac® wastewater treatment plant. The process flow of the plant is shown below.

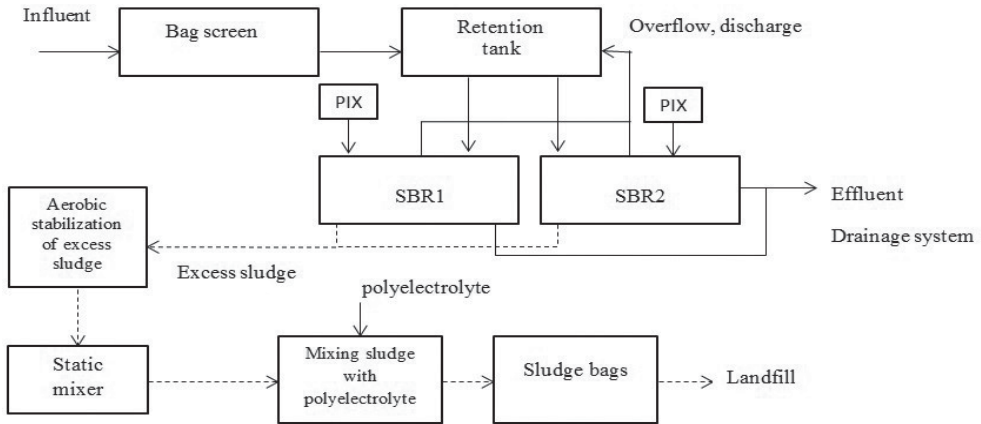


Fig. 6. Flow chart of the Dolina 5 Stawów wastewater treatment plant [10]

The plant treats domestic sewage. The mountain refuge has 67 beds and a restaurant.

Wastewater treatment plant at the Markowe Szczawiny

The Biovac® wastewater treatment plant has been treating sewage from the hostel at Markowe Szczawiny since 1995. Figure 7 shows a flow chart of the current treatment process.

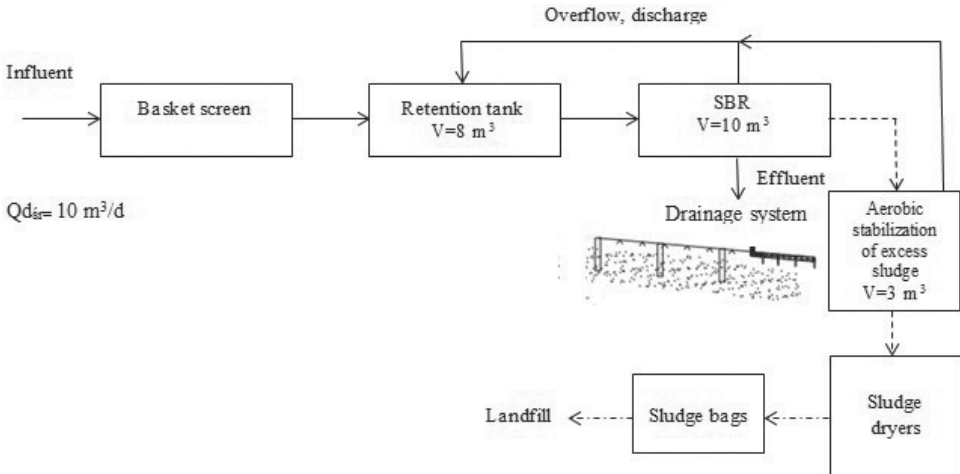


Fig. 7. Flow chart of the Markowe Szczawiny wastewater treatment plant [10]

The plant treats domestic sewage. The hostel has 72 beds and a restaurant.

2. Materials and Methods

The main goal of the research was to determine the efficiency of the Biovac® wastewater treatment plants located in the mountainous areas of national parks at: West Spitsbergen with

a capacity of 10 m³/d (Spitsbergen NP); the Murowaniec hostel with a capacity of 35 m³/d (Tatra NP); the Dolina 5 Stawów hostel of a capacity of 10 m³ /d (Tatra NP); the Markowe Szczawiny hostel (Babiogórski NP). Two sewage quality parameters were analysed – BOD₅ and COD. Based on their values, the efficiency of the biological treatment process was determined. All samples were taken in an off-season period.

Wastewater treatment plants located at the Murowaniec mountain refuge, the Dolina 5 Stawów mountain refuge and the Markowe Szczawiny mountain refuge

The characteristics of the raw sewage and the plant effluent were determined on the basis of time-proportional composite samples collected daily. The analyses were carried out by the certified laboratory in October 2016 (Murowaniec and Markowe Szczawiny hostels) and in November 2016 (Dolina 5 Stawów hostel). The raw sewage samples were collected from raw sewage sampling tanks, while the effluent samples were taken from the effluent sampling tanks. COD tests were carried out according to PN-ISO 6060:2006, while BOD₅ were performed according to PN EN 1899-1:2002 and PN-EN ISO 5814:2013 – 04E.

Wastewater treatment plant at West Spitsbergen

All samples were taken in the end of September. Raw sewage samples were collected downstream from the bag screen while the effluent samples were collected at the point of the effluent discharge from the treatment plant. The sewage samples were kept frozen for a week at the polar station. The samples were then transferred to a freezer located on a ship where they were kept in the dark for seven days. The BOD₅ measurements for raw sewage and the effluent (made in 2009) remained in the range of 0–400 mg O₂/dm³ and 0–40 mg O₂/dm³, respectively. The samples were stored and stirred for five days at 20°C in a thermostat cabinet. After this period, the BOD₅ value was read using the Oxi Top Control; this method provides a manometric, mercury-free BOD₅ measurement. COD was analysed using the bichromatic method with cuvettes. The measuring range for both raw sewage and the effluent was 100–1500 mg/dm³, the reaction time was 2 h and the process temperature in thermostat was 148°C.

3. Results and analysis

According to the studies, the average COD values in raw sewage at the wastewater treatment plants were as follows: Markowe Szczawiny, 3790 mg/dm³; Murowaniec, 920 mg/dm³; Dolina 5 Stawów, 1298 mg/dm³; West Spitsbergen, 2301 mg/dm³. The values were much higher than those found in typical domestic sewage.

The following average values of COD were observed in the effluent: Markowe Szczawiny, 106 mg/dm³; Murowaniec, 77 mg/dm³; Dolina 5 Stawów, 58 mg/dm³; West Spitsbergen, 1288 mg/dm³. The average COD removal efficiency was as follows: Markowe Szczawiny, 97%; Murowaniec, 92%; Dolina 5 Stawów, 95%; West Spitsbergen, 44%.

The average BOD₅ concentrations in raw sewage at mountain hostels were as follows: Markowe Szczawiny, 1500 mg/dm³; Murowaniec, 310 mg/dm³; Dolina 5 Stawów, 337 mg/dm³;

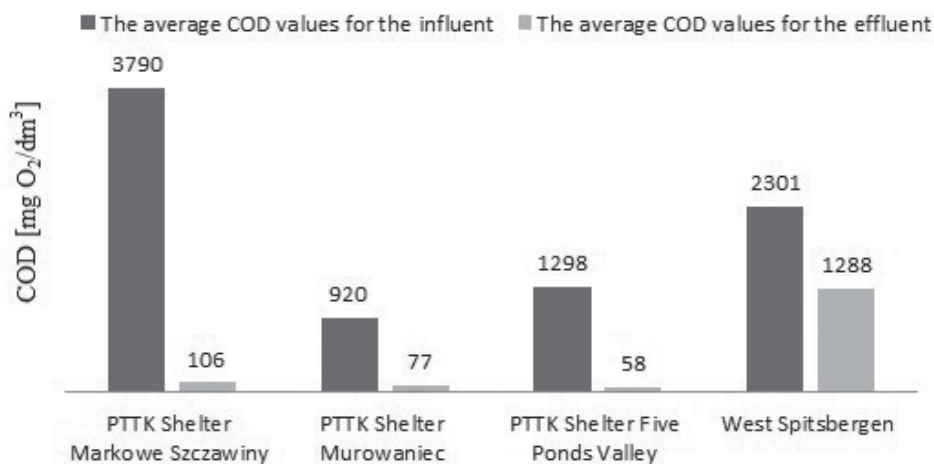


Fig. 8. COD in raw sewage and the effluent from the wastewater treatment plants located in the mountain hostels

the BOD concentrations in raw sewage from the Spitsbergen Polar Station were not determined since the samples were diluted before the BOD₅ analysis to match the expected content of organic compounds subject to biochemical oxidation. However, the dilution ratio turned out to be wrong since the BOD values were significantly higher than expected. Due to the fact that only a limited amount of the raw sewage was available, the BOD₅ analysis could not be repeated.

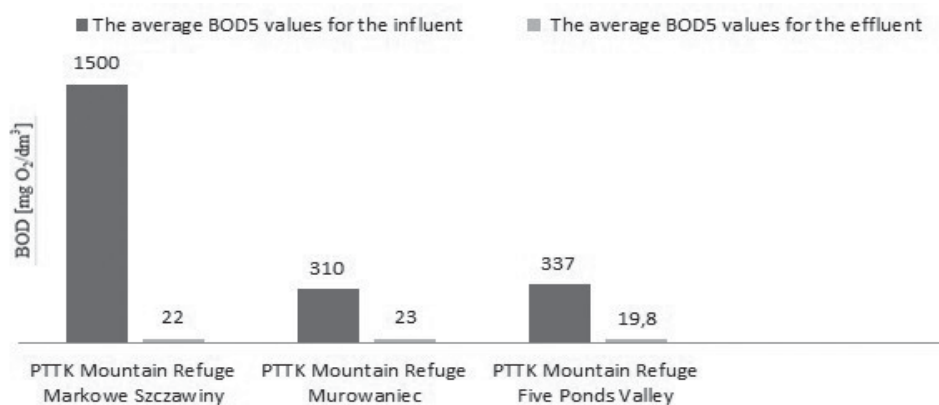


Fig. 9. BOD₅ in the raw sewage and in the effluent from the mountain hostels

The average BOD₅ concentrations in the effluent from the wastewater treatment plants were as follows: Markowe Szczawiny, 22 mg/dm³; Murowaniec, 23 mg/dm³; Dolina 5 Stawów, 19.8 mg/dm³; a Polish polar station at West Spitsbergen, 500 mg/dm³.

The average BOD₅ removal was: Markowe Szczawiny, 79%; Murowaniec, 92%; Dolina 5 Stawów, 96%.

Both raw sewage and the effluent samples were collected during an off-season period. Rather high values of the COD/BOD₅ ratio were observed in raw sewage – these were: 2.5 for Markowe Szczawiny; 2.9 for Murowaniec; 3.5 for Dolina 5 Stawów; 4.6 for West Spitsbergen. According to the literature, sewage may be successfully treated with activated sludge when the COD/BOD₅ values are less than or equal to 2.2 [4]. Such high values of COD as those observed during the research study are mostly due to the fact that the hostels impose a strict water-saving regime. The value of this parameter is also influenced by the restaurant's activity (high fat content) and the kitchen sink grinders used in most hostels.

4. Conclusion

On the basis of the study, the following conclusions have been made:

- ▶ the average BOD₅ reduction observed at sewage treatment plants located in the Polish national parks was very high and ranged from 94 % to 99 %;
- ▶ the average COD_{Cr} reduction observed at sewage treatment plants located in the Polish national parks ranged from 92% to 97%, and confirmed a very high level of efficiency of the tested sewage treatment plants;
- ▶ unfortunately, the lack of the accurate BOD₅ values in the effluent from the Spitsbergen sewage treatment plant makes it impossible to assess the efficiency of the biological treatment process. It is possible, however, to determine that the sewage treatment plan is not working correctly. This is because effluent BOD₅ average values were 500 mgO₂/dm³. The average COD removal at this plant was low and reached only 44%. The reasons behind such a poor performance of the sewage treatment plant included the specific climate of West Spitsbergen, and incorrect procedures of sampling and sample storage before analysis;
- ▶ raw sewage samples collected off-season showed high COD/BOD₅ ratios, this can seriously disrupt the biological treatment of sewage using activated sludge.

References

- [1] Myga-Piątek U., Jankowski G., *Tourism impact on the national environment and cultural landscape. Analysis of chosen examples of highlands*, Problemy Ekologii Krajobrazu, XXV/2009, 27–38.
- [2] Siwek J. P., Biernacki W., *Wpływ ścieków odprowadzanych ze schronisk turystycznych na stężenie związków biogenych w potokach – odbiornikach tych ścieków na terenie Tatrzańskiego Parku Narodowego (lata 2008–2009)*, Gospodarka Wodna, 7/2016, 201–209.
- [3] Wilk B., *Ultrafiltration membranes made of: polyaniline, ionic liquid and cellulose*, Technical Transactions, 1-Ś/2016, 171–187.

- [4] Kaczor G., Bergel T., Bugajski P., Pijanowski J., *Aspects of Sewage Disposal from Tourist Facilities in National Parks and Other Protected Areas*, Polish Journal of Environmental Studies, 24(1)/2015, 107–114.
- [5] Świerczok R., Łukawska R., Włodyga J., *Oczyszczanie ścieków z obiektów turystycznych na przykładzie schroniska „Samotnia” w Karpaczu*, Ochrona Środowiska, 1(56)/1995, 41–43.
- [6] Mucha Z., Mucha M., *Zastosowanie reaktorów z osadem czynnym o działaniu cyklicznym w gminnych oczyszczalniach ścieków*, Rynek Instalacyjny, 12/2016, 75–78.
- [7] Weissenbacher N., Mayr E., Niederberger T., Aschauer C., Lebersorger S., Steinbacher G., Haberl R., *Alpine infrastructure in Central Europe: integral evaluation of wastewater treatment systems at mountain refuges*, Water Science & Technology – WST, 57.12/2008, 2017–2022.
- [8] Maunoir S., Philip H., Rambaud A., *Small wastewater treatment plants in mountain areas: combination of septic tank and biological filter*, Water Science & Technology, 56(10)/2007, 65–71.
- [9] Mucha Z., Wójcik W., *Investment costs of small wastewater treatment plants with SBR reactors in Poland*, Ekonomia i Środowisko, 1(52)/2015, 124–130.
- [10] “Bionor” informational materials, Kielce 2017, <http://www.bionor.pl> (access: 07.2017).
- [11] Al-Rekabi W.S., Qiang H., Qiang W.W., *Review on sequencing batch reactors*, Pakistan Journal of Nutrition RG Impact & Description, 6(1)/2007, 11–9
- [12] Govindassamy V., Raman S., Sundararajan T., *Influence of Nitrogen Residue on the Performance of Sequencing Batch Reactor (SBR) in Wastewater Treatment – A Review*, International Journal of Environmental Monitoring and Protection, 1(3)/2016, 1–16.
- [13] Anielak A. M., *Unconventional methods of biogenic substance removal in sequencing batch reactors*, Gaz, woda i technika sanitarna, 2/2006, 23–27.
- [14] Dionisi D., Rashed A.A., Majumder A., *A new method to calculate the periodic steady state of sequencing batch reactors for biological wastewater treatment: Model development and applications*, Journal of Environmental Chemical Engineering, 4 (3)/2016, 3665–3680.
- [15] Marzec M., Józwiakowski K., Gizińska M., Pytka A. *Problems of operation and effects of pollution removal in wastewater treatment plants such Biovac®*, Gaz, Woda i Technika Sanitarna, 2/2012, 85–87.
- [16] Fudala-Ksiazek S., Luczkiewicz A., Kulbat E., Jankowska K., Czerwionka K., Quant B., Olanczuk-Neyman K., *Combined treatment of landfill leachates with wastewater in a sequencing batch reactor (SBR)*, In: Gidarakos E., Cossu R., Stegmann R. (Eds.), Crete 2010 – 2nd International Conference on “Hazardous and Industrial Waste Management”, 5–8 October, 457–459.