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EVALUATION OF WASTEWATER TREATMENT EFFICIENCY IN WOLBROM

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Abstract

The study was conducted to assess the effectiveness of wastewater treatment at the municipal wastewater treatment plant in Wolbrom, to which predominantly domestic wastewater and industrial sewage flow. The assessment was made based on the analysis of the physical and chemical research results of raw and treated wastewater. The research was carried out in the period from January 2014 to December 2014. To perform the analysis of the treatment plant efficiency, four indicators of wastewater pollutants such as BOD_5, COD, total nitrogen and total phosphorus were selected for further investigation. For each of the indicators degrees of reduction and coefficients of treatment plant operational reliability were calculated. The calculated degrees of reduction for each of the indicators were high and amounted to 99.0% for BOD_5, 95.2% for COD, 91.0% for total nitrogen and 91.6%. for total phosphorus. These results prove the effective reduction in the amount of pollutants. The determined coefficients of treatment plant operational reliability were at a low level: BOD_5 – 0.27, COD – 0.44, total nitrogen – 0.33 and total phosphorus – 0.53. The conducted analyses prove the effective operation of the treatment plant, which was confirmed by high efficiency of pollutants removal.

Keywords: wastewater treatment plant, the efficiency of wastewater treatment

INTRODUCTION

Water plays a very important part in natural environment. It is an essential ingredient of life on our planet: it supports life functions, provides essential minerals for all living organisms, has a large impact on food production and allows for the functioning of the industry. Water purity regularly deteriorates; continuous population growth, the development of industry and agriculture result in water resources being vulnerable to pollution and excessive, irrational economy. Keeping water resources at the highest level guarantees health safety and the reduction of expenditure on the acquisition of drinking water (Skinner 1995). According to the study of the Central Statistical Office (2014) the degradation of water resources and their contamination in recent years was caused mainly by wastewater. Wastewater is water used (mainly for domestic purposes) and then discarded, as well as water used in industry, meltwater and rainwater flowing into the sewage systems (Act 2001). Domestic wastewater generally has a constant composition. It contains large amount of organic substances, detergents and cosmetics, which is associated with large amount of phosphorus and nitrogen. The composition of industrial sewage depends on the type of production activities and the materials used (Mikulski 1998). Discharging untreated sewage into water causes, for example, eutrophication, which results in the processes of decay and contaminates water with numerous germs. It is vital to improve the processes of collection and wastewater treatment, which would increase the efficiency of contaminants removal from wastewater in such a way that it would be possible to reuse water and reduce the environmental burden. The conditions that must be met when discharging sewage into water are defined in the Regulation of the Minister of the Environment of 18 November 2014 on the conditions to be met when discharging sewage into water or soil and on substances particularly harmful to the aquatic environment. The indicator that best informs about the effectiveness of wastewater treatment by a particular sewage treatment plant is called the efficiency of wastewater treatment. The research in this area was conducted by; for example, Bugajski *et al.* (2008), Ślizowski and Chmielowski (2008), Chmielowski *et al*. (2012), Chmielowski *et al.* (2015), Kaczor and Bugajski (2007).

THE AIM AND METHOD OF THE RESEARCH

The aim of the study was to evaluate the effectiveness of wastewater treatment by the municipal wastewater treatment plant in the town of Wolbrom. The evaluation was based on the results of physical and chemical analyses of raw and treated wastewater samples. The results, dating from January to December 2014, were provided by the plant. Changes in the value of the four pollution indicators that is COD, BOD_5, total nitrogen and total phosphorus were analysed. The average monthly inflows of wastewater to the wastewater treatment plant were also presented. In addition, basic descriptive statistics such as the maximum value Max and the minimum Min and mean were determined for each indicator.

The evaluation of the wastewater treatment efficiency was carried out based on the degrees of reduction which were calculated for each of the analysed pollution indicators according to the relationship:

$$\eta = \frac{S_s - S_o}{S_s} \cdot 100\ [\%] \qquad (1)$$

where,
η – the degree of reduction of the given pollution indicator in treated wastewater [%],
S_s – the value of the pollution indicator in raw wastewater [$mg \cdot dm^{-3}$],
S_o – the value of the pollution indicator in treated wastewater [$mg \cdot dm^{-3}$].
Additionally, coefficient of treatment plant operational reliability was calculated applying the following equation:

$$COR = \frac{S_m}{S_p} \quad [-] \qquad (2)$$

where,
COR – coefficient of reliability [-],
S_m – the mean value of the given pollution indicator in treated wastewater [$mg \cdot dm^{-3}$],
S_p – the permissible value of the given pollution indicator in treated wastewater [$mg \cdot dm^{-3}$].

DESCRIPTION OF THE OBJECT OF RESEARCH

Water and sewage management of the municipality of Wolbrom is run by the Department of Water Supply and Sewerage in Wolbrom. The wastewater treatment plant in Wolbrom is a mechanical-biological treatment plant and consists of the following technological and support facilities: multi-function biological reactors BIOOXYBLOK BX 18/26, a social building with a control room, workshops and a laboratory, a two-chamber plot for drying sand, a compressed air installation, an expansion chamber, sludge lagoons, energy facilities, a water catchment point, technological pipes, a main pump room, a vertical sand separator, a screenings room, a sludge landfill site, stabilization ponds and flumes. Wastewater flows into the treatment plant by the combined sewage system, and then goes into a collecting chamber, which serves as a reservoir for accumulating excessive inflow of sewage. According to the design, the average daily capacity of the wastewater treatment plant in Wolbrom is at the level of 7400 $m^3 \cdot d^{-1}$, while the maximum is 10 800 $m^3 \cdot d^{-1}$. Wastewater is also supplied to the treatment plant by sewage removal vehicles. The wastewater influent comprises domestic wastewater and industrial sewage. The Centara river at the 8 + 080 kilometre is the receiver of treated wastewater.

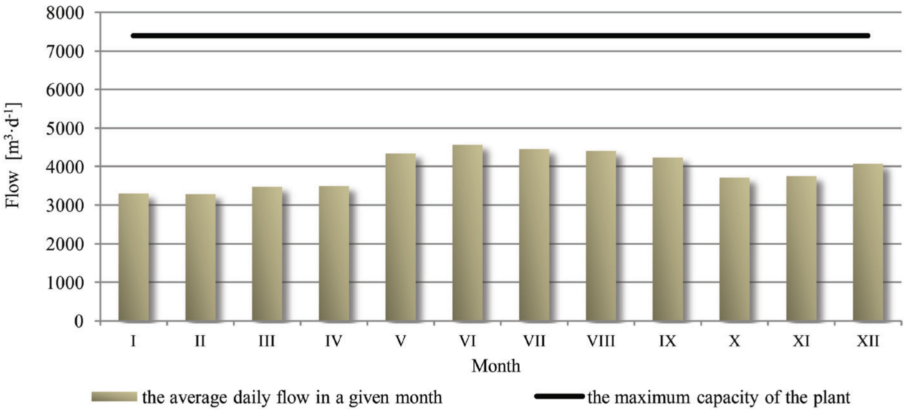
RESULTS AND DISCUSSION

The average daily volume of wastewater flowing into the sewage treatment plant in 2014 amounted to 3,932.2 $m^3 \cdot \mathbf{d}^{-1}$which represents 53.1% of its capacity. The highest inflows were recorded in the summer months (June, July, August), while the lowest in the winter months (January, February) (Figure 1). Uneven daily flow of sewage into the wastewater treatment plant during the analysed period did not constitute a threat to the purification processes, because it did not exceed the maximum capacity of the plant. The coefficients of inequality shown in Table 1 for the examined indicators in raw sewage were at similar level. The lowest coefficients of inequality occurred 1.15 for COD and the highest 1.52 for total phosphorus.

Table 1. Coefficient of inequality for raw sewage

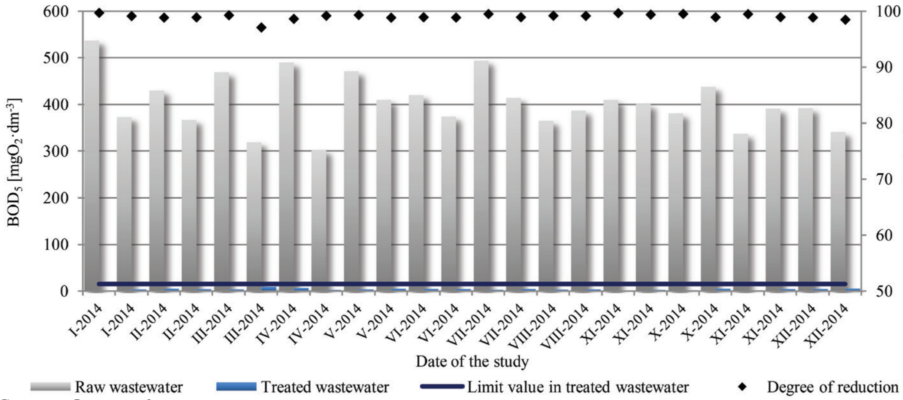
Coefficient of inequality [-]	**Flow** $[m^3 \cdot d^{-1}]$	**BOD_5** $[mg \cdot dm^{-3}]$	**COD** $[mg \cdot dm^{-3}]$	**N_t** $[mgN_t \cdot dm^{-3}]$	**P_t** $[mgP_t \cdot dm^{-3}]$
Maximum	1.16	1.33	1.15	1.23	1.52
Standard deviation	0.12	0.14	0.09	0.11	0.23
Range	0.33	0.58	0.30	0.44	0.82

Source: Own study



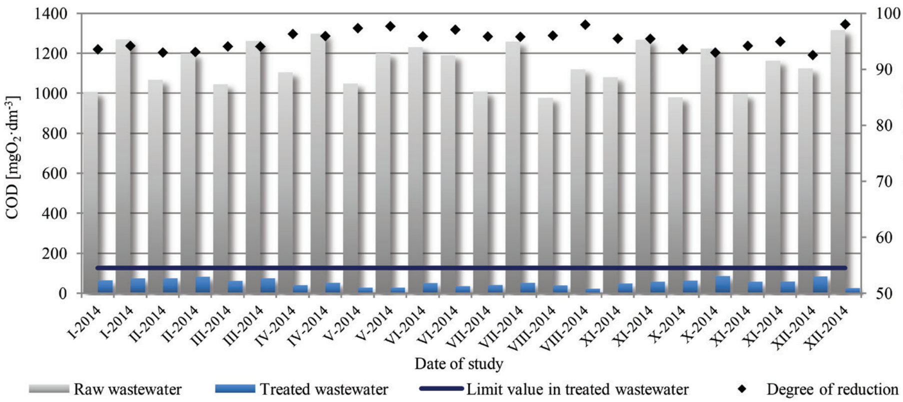
Source: Own study

Figure 1. The average flow of wastewater into the sewage treatment plant in 2014



Source: Own study

Figure 2. Changes in the concentrations of BOD$_5$ in raw and treated wastewater and the degree of BOD$_5$ reduction in the year 2014



Source: Own study

Figure 3. Changes in the concentrations of COD in raw and treated wastewater and the degree of COD reduction in the year 2014

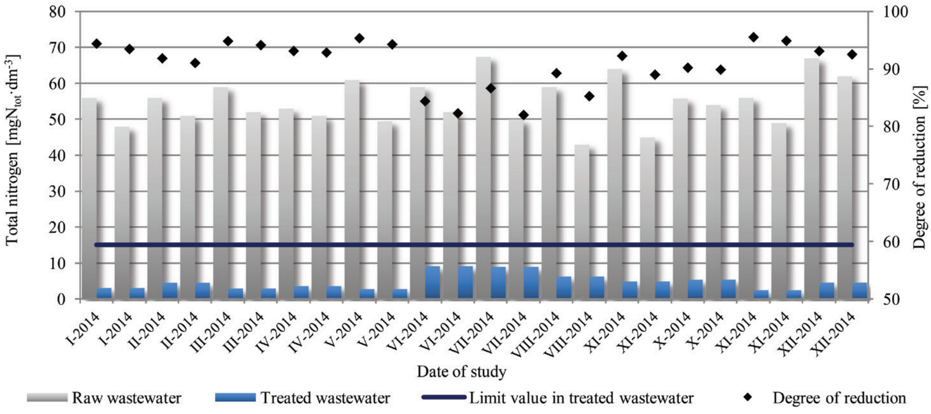
The Figures 2-5 show the changes in the value of the analysed pollution indicators of raw wastewater, flowing into the treatment plant and then treated.

The values of BOD$_5$ in raw wastewater in the analysed period ranged from 303 to 537 mgO$_2$·dm^{-3} with the mean value of 404.8 mgO$_2$·dm^{-3} (Fig. 2). In treated wastewater values of BOD$_5$ ranged from 1.6 to 9.4 mgO$_2$·dm^{-3} with the mean value at the level of 4.0 mgO$_2$·dm^{-3}. In treated wastewater no value of BOD$_5$ exceeded the permissible values regulated by the Regulation of the Minister of the Environment (2014). The degree of reduction of BOD_5 in the wastewater was high and for the tested period amounted to 99.0%.

The lowest value of COD in raw wastewater amounted to 977.0 $mgO_2 \cdot dm^{-3}$ and the highest 1316.0 $mgO_2 \cdot dm^{-3}$ (Fig. 3). The mean value of this indicator was equal to 1143.2 $mgO_2 \cdot dm^{-3}$. In the case of treated wastewater, COD values ranged from 23.0 mg $mgO_2 \cdot dm^{-3}$ to 86.0 $mgO_2 \cdot dm^{-3}$, with the mean value for the year 2014 equalling to 54.6 $mgO_2 \cdot dm^{-3}$. In none of the analysed samples of treated wastewater the limit value for the index specified by the Regulation was exceeded. As in the case of BOD_5, the degree of reduction of COD in the year 2014 was high and ranged from 97.1% to 98.0%.

The obtained degrees of reduction of BOD_5 and COD are higher than the presented by Chmielewski *et al*. (2009, 2012, 2015) and by Masłoń and Tomaszek (2013).

Total nitrogen in wastewater is the other analysed indicator of pollution. The lowest concentration in raw wastewater equalled to 43.0 $mg \cdot dm^{-3}$, and the highest amounted to 67.4 $mg \cdot dm^{-3}$ (Fig. 4). The mean concentration of total nitrogen in raw wastewater reached the level of 55.0 $mg \cdot dm^{-3}$. Given the treated wastewater, the minimum concentration of total nitrogen was observed at the level of 2.50 $mg \cdot dm^{-3}$, the mean concentration amounted to 4.94 $mg \cdot dm^{-3}$, whereas the maximum one equalled to 9.20 $mg \cdot dm^{-3}$. The permissible concentration of nitrogen described in the Regulation was not exceeded in the analysed period of time. The removal efficiency of total nitrogen from wastewater for the analysed period varied from 82.0% to 95.5% with the mean value of 91.0%.

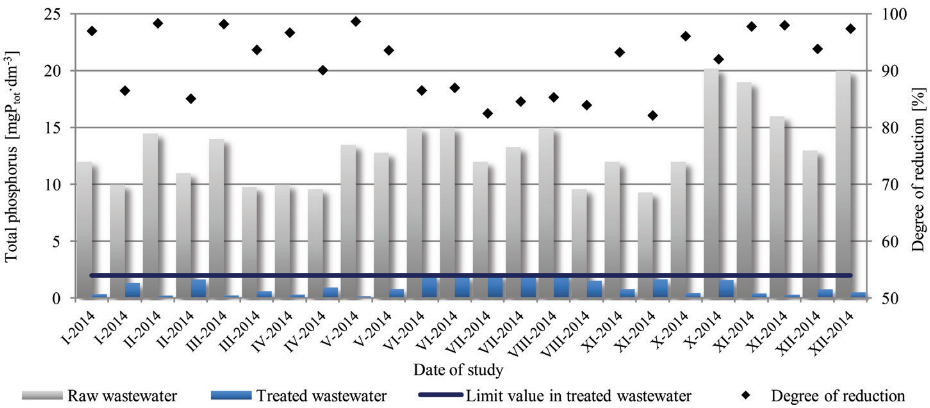


Source: Own study

Figure 4. Changes in the concentrations of total nitrogen in raw and treated wastewater and the degree of total nitrogen reduction in the year 2014

The last of the analysed pollution indicators is total phosphorus, whose concentration in raw wastewater ranged from 9.3 $mg \cdot dm^{-3}$ to 20.0 $mg \cdot dm^{-3}$, and the mean concentration amounted to 13.3 $mg \cdot dm^{-3}$ (Fig. 5). Concentration values of this indicator for treated wastewater fluctuated between 0.18 $mg \cdot dm^{-3}$ and 2.20 $mg \cdot dm^{-3}$. The mean concentration of total phosphorus in treated wastewater amounted to 1.1 $mg \cdot dm^{-3}$. The degree of reduction of total phosphorus in treated wastewater ranged from 82.2% to 98.7% with the mean value of 91.6%. The regulated by the Regulation (2014) permissible concentration of total phosphorus in treated wastewater was slightly higher for 4 out of 24 analysed samples. However, the condition of the minimum percentage of total phosphorus reduction, which was over 80%, was fulfilled.

The coefficients of reliability for the examined indicators were at a low level. The lowest amounted to 0.27 for BOD_5 and the highest 0.53 for total phosphorus. Coefficient of reliability for COD was 0,44 and for total nitrogen 0,33. The calculated coefficient of reliability for BOD_5 is lower compared to the values obtained for the wastewater treatment plants in Tuchów, Lipnica Wielka and Kołaczyce (Chmielowski *et al.* 2009, 2012, 2015). In the case of COD these values are at a similar level.



Source: Own study

Figure 5. Changes in the concentrations of total phosphorus in raw and treated wastewater and the degree of total phosphorus reduction in the year 2014

CONCLUSIONS

The analysis conducted on the results from physical and chemical tests of wastewater allows for the evaluation of the wastewater treatment plant effectiveness by putting forward the following conclusions:

1. The degrees of reduction of the indicators for the analysed period are high: BOD_5 – 99.0%, COD – 95.2%, total nitrogen – 91.0%, total phosphorus – 91.6%, which proves the high effectiveness of wastewater treatment in the wastewater treatment plant in Wolbrom.
2. The calculated values of coefficients of treatment plant operational reliability with regard to all indicators were at a low level: BOD_5 – 0.27, COD – 0.44, total nitrogen – 0.33, total phosphorus – 0.53, which proves the appropriate operation of the wastewater treatment plant in Wolbrom.

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