Evaluation of the efficiency of removing residual pollutants from treated wastewater - third stage of wastewater treatment

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Keywords: water recovery, recycled water, fabric filtration, ion exchange resin.
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Introduction

In the face of increasing environmental challenges and changing European Union legislation, the importance of recovering water from wastewater is taking on a new dimension. Climate change and environmental pollution make saving water resources crucial. Reusing wastewater can solve the problem of droughts and water scarcity by ensuring access to this resource. The key, however, is to develop solutions to recover safe, pathogen and micropollutant-free water with sufficient nutrients.

To this end, the ReNutriWater project has been launched as part of the Interreg Baltic Sea Region program. The ReNutriWater project initiative responds to current proposals to amend the provisions of the European Union's Waste Water Directive, which for many wastewater treatment plants will mean the need to introduce tertiary treatment and the use of advanced wastewater treatment technologies. The main objective of the ReNutriWater project is to recover water from treated wastewater through the use of appropriate methods and technologies. The water recovered in the purification process will be able to be used in many sectors, from agriculture to industry and municipal services, contributing to a more complete closure of the water cycle in the city.

This paper presents the results of the first stage of research, which aimed to assess the effectiveness of the fabric filtration (FF) and ion exchange resin (IER) processes as a third stage of wastewater treatment. The tests were carried out on two independent installations, fed with the same stream of wastewater treated after a mechanical-biological process with increased nutrient removal. The quality of the wastewater discharged into the installations met the requirements of the Regulation of the Minister of Economy and Inland Navigation of July 12, 2019. (Journal of Laws 2019 item 1311) for treatment plants with an equivalent population of more than 100,000. The effectiveness of both technologies was assessed based on the analysis of the following indicators: turbidity, total suspended solids (TSS), chemical oxygen demand (COD), total phosphorus (TP) and total nitrogen (TN) in samples before and after the process. The main requirement of the tests was to achieve stable plant operation and wastewater quality expressed by a turbidity index not exceeding 1.0 NTU.

Materials and Methods

The substrate used in the study was treated wastewater (TW) from full-scale WWTP located in Mazovia Voivodeship (Poland). Characteristics of TW are summarized in Table 1 and 2.

The first system analyzed was fabric filters, which, thanks to the use of special types of fabrics, combine the features and advantages of both surface and volume filtration, which allows for a very high degree of particulate matter removal. The wastewater was fed by gravity into a steel filter chamber with a drum covered with filter fabric with an area of 2 m^2. Suspended solids and particles were removed from the wastewater during filtration through the fabric. The filtered wastewater flowed into the drum, from where it was discharged through the outlet chamber and overflow weir into the retention tank. The filter cloth was cleaned automatically at specific intervals, and the filtration process was not interrupted during the cloth cleaning cycle. The system operated at a capacity of 5-8 m^3/h.

The second system analyzed was an installation that combines several types of technologies, such as adsorption, mechanical filtration, and ion exchange filtration. Filtration takes place in seven columns, divided into two parallel streams. Each of the columns is controlled by a microprocessor controller with a display. Columns 1A and 1B filter out mechanical impurities. Columns 2A and 2B reduce organic impurities, turbidity, color and odor. Columns 3A and 3B reduce phosphorus and nitrogen. Column 4 is designed to further reduce turbidity through mechanical filtration. The columns are filled with different filter media: gravel, activated carbon, ion exchange resins, zeolite bed. The system is powered by a 1kW pump. Three reagents are dosed into the system and come into contact with the medium in the reaction tank. These reagents are intended to precipitate some of the pollutants and to support the filtration process in the filter columns. The system operated at a capacity of 1 m^3/h.

Results

The average values obtained in the studies of the fabric filtration system are shown in Table 1. The conducted research has shown that the use of fabric filters as a tertiary treatment method for wastewater allows for a reduction in the values of all analyzed indicators. The highest reduction, over 77%, was recorded in the case of turbidity.

The average value of this indicator in the treated wastewater was 3.97 NTU, while after passing through the fabric filter, it was at an average level of 0.80 NTU.

Table 1. Characterization of wastewater before and after the fabric filtration process.

Turbidity [NTU]			TSS [mg/L]			COD [mgO_2/L]			TP [mg/L]			TN [mg/L]		
TW	FF	%R	TW	FF	%R	TW	FF	%R	TW	FF	%R	TW	FF	%R
3.97	0.80	77.4	12.0	2.80	67.3	28.2	26.4	5.6	0.60	0.39	32.8	3.57	2.73	23.3

Description: TW – Treated wastewater; FF – fabric filtration; %R – reduction rate; TSS – total suspended solids; COD – chemical oxygen demand; TP – total phosphorus; TN – total nitrogen.

Table 2. Characterization of wastewater before and after the ion exchange filtration process

Turbidity [NTU]			TSS [mg/L]			COD [mgO_2/L]			TP [mg/L]			TN [mg/L]		
TW	IER	%R	TW	IER	%R	TW	IER	%R	TW	IER	%R	TW	IER	%R
3.60	0.50	84,5	13.1	3.09	68.5	29.0	15.1	47.8	0.66	0.19	69.1	3.61	2.7	24.0

Description: TW – Treated wastewater; IER – ion exchange resin; %R – reduction rate; TSS – total suspended solids; COD – chemical oxygen demand; TP – total phosphorus; TN – total nitrogen.

The average values obtained in the studies on the ion exchange resin system are presented in Table 2. The conducted research has shown that the use of ion exchange resins as a tertiary treatment method for wastewater allows for a reduction in all analyzed indicators. The highest reduction, over 84%, was recorded for turbidity. The average value of this indicator in the treated wastewater was 3.60 NTU, while after filtration through the ion exchange resin system, it was 0.50 NTU on average. The parameter that was reduced the least effectively with this technology was total nitrogen, but this was most likely due to the fact that the values of this indicator were relatively low in the treated wastewater even before the third stage of wastewater treatment was applied.

Conclusions

Comparing both methods, it can be seen that the use of the ion exchange resin system resulted in a higher efficiency of removing residual contaminants from the treated wastewater. However, in both cases, the recorded turbidity values did not exceed the limit value of 1.0 NTU. To make the final choice of technology to be applied, the investment and operating costs of both technologies should be compared.

The activities of the Warsaw Waterworks in the ReNutriWater project not only have a technological aspect, but also fit into the broader idea of sustainable development. The ReNutriWater project, is an important step towards increasing the efficiency of water resource use in Warsaw.

References

European Union. Regulation (EU) 2020/741 of the European Parliament and of the Council of 25 May 2020 on Minimum Requirements for Water Reuse. 2020. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX: 32020R0741&from=EN (accessed on 21 November 2022).

Regulation of the Minister of Maritime Economy and Inland Navigation of July 12, 2019, on substances particularly harmful to the aquatic environment and the conditions to be met when introducing sewage into water or into the ground, as well as when discharging rainwater or snowmelt into water or water facilities (Journal of Laws of 2019, item 1311).

Acknowledgements

Interreg Baltic Sea Region
Co-funded by the European Union
SUSTAINABLE WATERS ReNutriWater

The study was implemented in the scope of a project entitled "*Closing local water circuits by recirculating nutrients and water and using them in nature*" (ReNutriWater), financed in the scope of Interreg Baltic Sea Region and co-financed from the resources of the European Union.