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ORIGINAL RESEARCH PAPER

WASTEWATER GLOBAL POLLUTION INDEX AS AN INDICATOR IN ASSESSING THE QUALITY OF THE EFFLUENT FROM THE ARAD MUNICIPAL TREATMENT PLANT

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Abstract: The main aim of the present study was to characterize the quality of the sewage leaving the Arad Municipal Wastewater Treatment Plant and highlight the emergence and importance of water reclamation, recycling, and reuse as vital components in integrated aquatic resources management for further reuse. The sewer quality assessment was performed for the period 2018 - 2021. For this purpose, the Global Pollution Index (I_{GP}^{*}) was used to determine the degree of pollution of the wastewater influent and effluent from the Arad treatment plant during the mentioned period. These results on the quality of incoming and outgoing sewerage can contribute to developing a management plan for protecting and properly managing water resources.

Keywords: *performance assessment, physicochemical parameters, wastewater influent and effluent quality, water reuse, water scarcity*

INTRODUCTION

Water has two significant roles in life in general and in human activity in particular. It creates vital ecological systems, making it an important environmental factor.

Water must meet strict quality standards to be considered suitable for its intended use in human activity. Considering the mentioned aspects, implementing proper standard guidance is needed to increase the efficient usage of this vital resource [1]. Natural phenomena and anthropic activities could influence the preservation of natural water properties [2 – 4].

The need for expanding the industrial wastewater treatment sector arose from the growing global population, the development of numerous companies, and the depletion of water supplies [5 – 9]. Due to the myriad chemical and microbiological contaminants found in industrial sanitary wastewater, its release into the environment contaminates agricultural products, soil, and groundwater, adversely affecting the health of humans and other living organisms [7, 10, 11].

Recently, wastewater reuse has attracted considerable attention as an alternative water source [10, 12 – 17]. Recycling wastewater for irrigation, forestry, and agricultural purposes has become widespread. Industries have also adopted wastewater recycling as an alternative to freshwater use. Although wastewater reuse can contribute significantly to managing a nation's water resources, there are potential risks related to human exposure to pathogenic and chemical contaminants in the wastewater reuse process [13, 18].

According to the Directive of the European Parliament and the Council on Urban Wastewater Treatment [19], it is required that after the application of initial mechanical procedures, the biochemical oxygen consumption of the wastewater must be reduced by at least 20 %. In comparison, the total suspended solids content must be decreased by at least 50 % before discharge to the outfall. The primary stage of treatment is to retain large particulate matter and suspended solids in the wastewater and settle the suspended solids using physical-mechanical procedures; for their retention, grates, screens, desanders, grease separators, and decanters are used.

Water quality management is applied to determine its characteristics for various uses [20 – 22]. A key element of this management is to control the quality of water resources. Monitoring involves collecting relevant information on the physicochemical and biological parameters of water. In this case, this monitoring consists of collecting data for all parameters of interest and assessing compliance with the permissible limits in water quality regulations [20, 23 – 25].

Reclaimed water is a water resource that can be managed locally, where water demand is highest and most precious. Closing the water loop is technically feasible in agriculture, industry, and urban sectors and is economically important. Society can no longer afford to use water only once [26].

Also, overseeing the quality of influent and effluent wastewater in a treatment plant is essential to evaluating the efficiency of treatment processes and ensuring that the treated water meets water quality standards. Further, a single index that allows simple data interpretation while reducing the number of parameters used to assess water quality is needed. One such tool is the method developed by Romanian researchers for evaluating the impact on the environment, which uses the Global Pollution Index [9, 27].

This work studied the assessment of the quality of the treated wastewater from the treatment plant of Arad Municipality. The evaluation method was based on the Global Pollution Index [9] for physicochemical parameters recorded daily in four years (2018 - 2021).

MATERIALS AND METHODS

Study Area

Arad Municipal Wastewater Treatment Plant (WWTP) is situated in Arad City and is the largest in the county. It includes a mechanical stage with primary settling and a biological step, including aeration tanks with activated sludge, secondary settling tanks, and a recirculation sludge pumping station. Its activity considers the development of industrial parks and new residential areas that feed the sewage system. The activity is carried out following European standards so that the quality of the effluent discharged from the WWTP into the Mures River is within the limits established by the European Union and Romanian standards.

Data collection and analysis

This study analyzed the quality of the raw wastewater (influent) and treated wastewater (effluent) of Arad municipal WWTP. The collection and experimental data used in this study were provided by Arad Water Company from 2018 until 2021 and are available on request. The data collected for the study period represented daily and monthly values for each of the following parameters for the influent: *p*H, total suspended solids (TSS), chemical and biochemical oxygen demand (COD and BOD5), ammonium, nitrites, nitrates, total nitrogen, total phosphorus, and the following parameters for the effluent: *p*H, TSS, filterable solids at 105 °C, chemical and biochemical oxygen demand, ammonium, nitrate, nitrites, total nitrogen, total phosphorus, total anionic surfactants, extractables, chlorides, sulfates, sulfides, phenols, copper, zinc, cadmium, nickel, total chromium, lead, total iron and manganese.

Methodology for the determination of Global Pollution Index (I^*_{GP})

The global pollution index, a unitless number between 0 and 6, indicates the general characteristics of wastewater and provides a quality value for the collected measurable physical, chemical, and biological data [9, 27]. This index aids in developing a trustworthy model for optimizing treatment procedures and assessing the suitability of the effluent to be discharged into the Mureş River.
The methodology for the determination of I^*_{GP} has several steps. Firstly, it is determined a Quality Index (EQ_i) for each parameter, considering the measured value for the parameter (C_i) and its corresponding maximum allowable value (MAC_i) [28, 29], as shown in equation 1 [27]:

$$EQ_i = \frac{C_i}{MAC_i} \quad (1)$$

Each calculated EQ_i has attributed an evaluation score (ES_i), according to Table 1.

Table 1. *Determination of the evaluation scores based on the calculated Quality Indexes* [27]

Evaluation Score (ES_i)	**Quality Index (EQ_i)**
10	$EQ_i = 0$
9	$0.00 < EQ_i \leq 0.20$
8	$0.20 < EQ_i \leq 0.70$
7	$0.70 < EQ_i \leq 1.00$
6	$1.00 < EQ_i \leq 2.00$
5	$2.00 < EQ_i \leq 4.00$
4	$4.00 < EQ_i \leq 8.00$
3	$8.00 < EQ_i \leq 12.00$
2	$12.00 < EQ_i \leq 20.0$
1	$EQ_i > 20.00$

After identification of each evaluation score (ES_i), the value of the Global Pollution Index I^*_{GP} was calculated following equation (2) [27], by considering the total number of measured parameters (n):

$$I^*_{GP} = \frac{100*n}{ES_1*ES_n+\sum_{i=1}^{n-1} ES_i*ES_{i+1}} \quad (2)$$

Table 2 was used to classify the effluent quality from Arad municipal WWTP by using the I^*_{GP} calculated values. The wastewater was divided into six groups, ranging from severely polluted to excellent water.

Table 2. *Water Quality Classification based on I^*_{GP} value* [27]

Values for I^*_{GP}	**Water Quality**
1	Excellent
$1 \leq I^*_{GP} < 2$	Good
$2 \leq I^*_{GP} < 3$	Poor
$3 \leq I^*_{GP} < 4$	Very poor
$4 \leq I^*_{GP} < 6$	Polluted
$I^*_{GP} \geq 6$	Very polluted

RESULTS AND DISCUSSIONS

The typical BOD5/COD ratio values for untreated municipal wastewater range between 0.3 and 0.8. Waste is easily treated biologically if the ratio is 0.5 or higher. If the ratio is less than 0.3, additional degradation processes should be applied in the presence of some microorganisms or toxic compounds. For the treated sewage, this ratio drops to 0.1 - 0.3 [30].

Analyzing the data collected for the period 2018 - 2021, the ratio BOD5/COD for the influent had an average value of 0.52, while for the effluent its mean value was 0.21. This shows that the WWTP applies a good plan for biological treatment.

Figures 1 - 4 show the studied period's mean monthly global pollution indexes. Although a distinct seasonality pattern cannot be observed, there are hints that the minimal values of the ratios between the Global Pollution Indexes of the influent and those of the effluent are usually obtained in the months with the highest mean temperature and fewer precipitations.

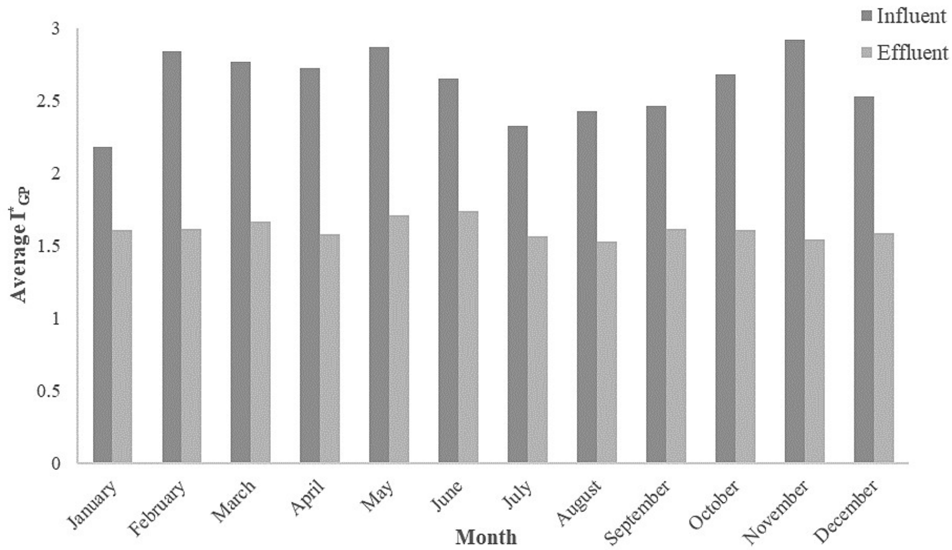

Figure 1. *Monthly calculated* I^*_{GP} *for the influent and effluent in 2018, Arad municipal WWTP*

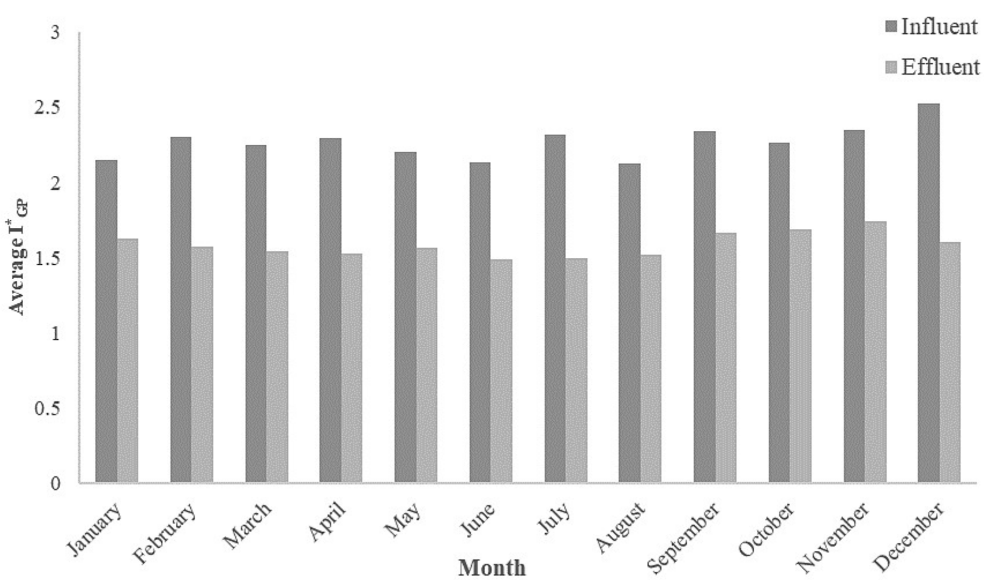

Figure 2. *Monthly calculated* I^*_{GP} *for the influent and effluent in 2019, Arad municipal WWTP*

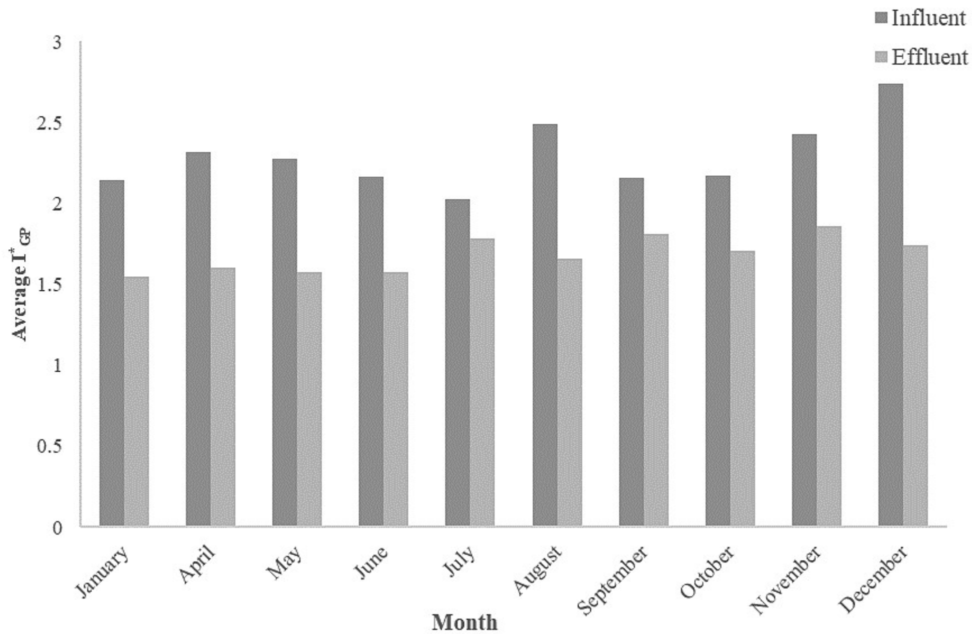

Figure 3. *Monthly calculated* I_{GP}^{*} *for the influent and effluent in 2020, Arad municipal WWTP*

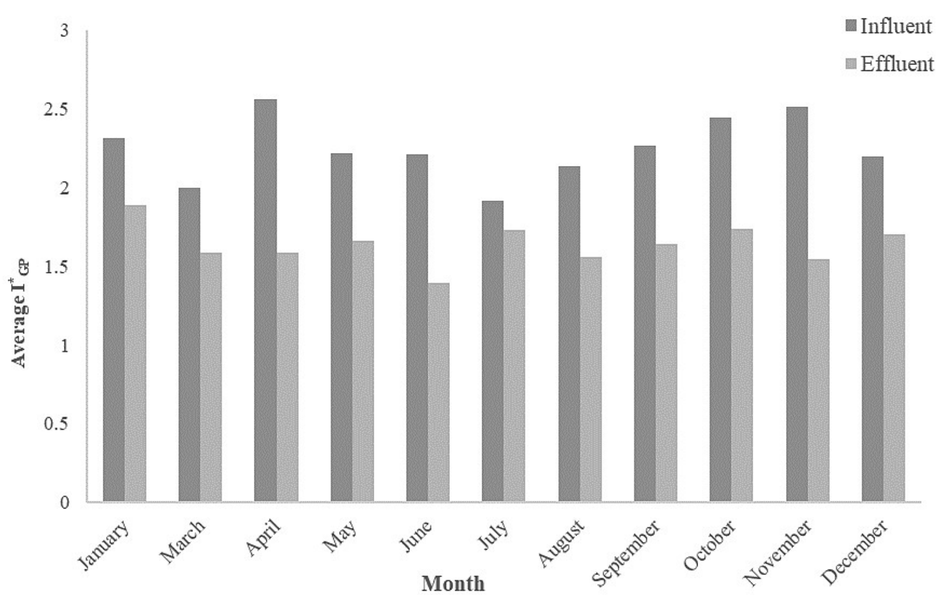

Figure 4. *Monthly calculated* I_{GP}^{*} *for the influent and effluent in 2021, Arad municipal WWTP*

The results presented in Figures 1 - 4 show that the highest global pollution index value registered for the influent was registered in November 2018, while the minimal value was in July 2021. The maximum value registered for the influent was in January 2021, with a minimal value registered in June 2021.
According to the data presented in Table 2, the yearly mean values of I_{GP}^{*} were calculated for the influent and effluent from the Arad municipal WWTP, using the values represented in Figures 1 - 4.
Table 3 displays these values over the study period of 2018 - 2021. Overall, the findings showed that the treated effluent wastewater maintains values for good quality during the entire period. Considering the quality of the influent, it can be observed that for the years 2018, 2019, and 2021, the quality index ranged as poor, while in 2020, the average value indicated a good quality at the entrance in the WWTP, possibly due to the SARS-CoV-2 pandemic lockdown when the industrial activity was reduced for several months.

Table 3. *Wastewater Quality Classification during 2018-2021*

Year	Influent		Effluent	
	Values for I^{*}_{GP}	Water Quality	Values for I^{*}_{GP}	Water Quality
2018	2.61	Poor	1.61	Good
2019	2.27	Poor	1.59	Good
2020	1.91	Good	1.41	Good
2021	2.07	Poor	1.50	Good

Based on the presented results, the effluent from the Arad Municipal WWTP could be discharged into the Mureș River as no significant environmental and health risks were identified. Moreover, the treatment plant applied effective treatment processes that followed stringent regulations and used innovative technologies to minimize environmental impacts and protect water quality. Further attention should be focused on sustainable practices, such as reducing pollution at the source and reusing treated effluent, which are critical in mitigating the effects of wastewater discharge on river ecosystems.

CONCLUSIONS

The study assessed the influent and effluent wastewater from the Arad municipal wastewater treatment plant to comprehend the treatment plant's efficacy and the effects that effluent discharge has on the quality of Mureș River.
The results showed that wastewater was adequately treated and that its disposal into the Mureș River does not affect water quality, permitting further use for other activities.
The effects of the treated effluent from the Arad Municipal Wastewater Treatment Plant are comprehensively outlined using the water quality index for surface water quality profiling. Decision makers and treatment plant operators will find this information crucial for improving the operation and sustainability of municipal wastewater treatment facilities in line with the goals of the European Union and Romania.
The interest parameters evaluated in the present study targeted the general physical-chemical ones used as references in the field. Further, the investigation could be

orientated to a more profound sense and focus on assessing the pathogen microbial aspects of the influent and effluent, as well as the presence of different antibiotics, drug residues, and different toxic or microplastics. Another point of interest could be the establishment of possible correlations between all sewage characteristics in the post-pandemic period. The interest comes from the currently extended concerns in such aspects since the resources for freshwater are constantly decreasing, and the applicability of wastewater reuse in different areas increases continuously. Depending on the domain, these have to respect the specific safety requirements. Many studies highlight possibilities currently available to limit the presence of various hazards from wastewater in the effluents resulting from local administrative plant facilities [31, 32]. There are also indications of distinctive antibiotic resistance microbiota in the treated sewage that could affect the aquatic ecosystems [33] but are not limited to it [34], and further on, could be found in human nourishment. Such a situation strictly controls all water resources used in different areas [35].

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