Romanian Journal of Ecology & Environmental Chemistry, 6(2), 2024

https://doi.org/10.21698/rjeec.2024.202

27th International Symposium "Environment and Industry", SIMI 2024, 19-20 September 2024, Constanta, Romania

Article

Impact assessment of wastewater on water quality using new quality indices and multiple linear regression

FLORINELA PIRVU*, IULIANA PAUN, VASILE IANCU, NICOLETA VASILACHE, DANIEL RUDARU, MARCELA NICULESCU, ANDA GABRIELA TENEA, FLORENTINA LAURA CHIRIAC

National Research and Development Institute for Industrial Ecology ECOIND Bucharest, 51-73 Drumul Podul Dambovitei Street, 060652 Bucharest, Romania.
**Corresponding author: florinela_pirvu@yahoo.com*

Received:	Accepted:	Published:
17.07.2024	27.11.2024	23.12.2024

Abstract
The Wastewater Quality Index (WWQI) is a unique measure that synthesizes the overall quality of wastewater. The main objective of the study was to evaluate whether the quality of wastewater reaching the treatment plant is suitable for optimal disposal using the WWQI approach. To understand the correlation between the determined indicators, Pearson correlation coefficients were calculated, so that the results of the analyses reflect the overall quality of the evaluated wastewater. Additionally, statistical analysis was employed to develop a simple prediction model through multiple linear regression (MLR) to predict WWQI based on various wastewater quality parameters. The results indicate good and regular quality of treated wastewater for safe disposal, according to the classification of WWQI levels, and the prediction model yielded values similar to those estimated..

Keywords: *wastewater quality index, multiple linear regression, wastewater, Pearson correlation coefficients*

INTRODUCTION
According to the United Nations World Water Development Organization in 2018, nearly six billion people worldwide could face severe water shortages by the year 2050 [1]. Globally, many rivers are affected by chemical pollution. Water quality in these rivers can be influenced by various anthropogenic factors, including accidental or intentional emissions of industrial waste. According to various studies, numerous developing countries face pollution from industrial discharges, leading to eutrophication [2, 3]. Water quality is a general concept used to describe the physical, chemical, and biological characteristics of water resources. It is essential for the health of aquatic ecosystems and humans. Concerns about water quality are global due to pollutants being extensively released into freshwater ecosystems [4]. Maintaining the ecological integrity of rivers is crucial, as they are essential for human and animal life, and deteriorating water quality is a major global challenge. As economic and social development progresses, the issue of deteriorating water quality in rivers becomes increasingly apparent [5]. Monitoring and maintaining good water quality in rivers are essential for sustainable development and human health [6]. Studies on changes in water quality and their causes are highly relevant [7]. Increasing awareness of environmental protection has led to increased attention to monitoring water quality in rivers to ensure sustainable urban development. Physicochemical water quality parameters play a crucial role in assessing and monitoring river water quality [8]. Strong economic growth and urbanization contribute to the generation of industrial and domestic waste. This waste can be discharged directly into rivers without proper treatment, leading to decreased water quality. Although rivers are essential natural resources that support socioeconomic

development through various uses such as human needs, animal watering, irrigation, industries, transportation, recreation, etc., they have been heavily affected by various anthropogenic sources of pollution [9]. According to Worku and Giweta, inadequately treated or untreated industrial wastewater discharged into rivers has led to river pollution in Ethiopia [10]. Although industrial development brings economic benefits, its environmental costs, such as water pollution and biodiversity loss, lead to the degradation of ecosystem functions and services. To manage this situation, a well-developed and science-based approach to aquatic ecosystems is required, which includes assessing water quality (physical, chemical, and biological) and other relevant information. Wastewater treatment is an essential factor in producing effluents with minimal harmful effects on human health and the environment, and their quality is monitored through continuous analysis and assessment of collected samples. Wastewater analysis provides a significant amount of information about quality parameters, which are not always suitable and easily understandable for the general public or legislative decision-makers.

The Water Quality Index (WQI) is a single, unitless measure that can synthesize the overall quality of water at a particular time and space, based on the investigated parameters. WQI is used to evaluate the quality of water resources and the safety of various water matrices [11÷13] and to serve as a decision-making tool for government authorities, facilitating intelligent management of water quality issues [13, 14]. The Wastewater Quality Index (WWQI) can be an efficient and scientific tool to highlight the general characteristics of wastewater, integrating a set of data on its quality and generating a unique value to facilitate data interpretation for simple monitoring of spatial and temporal variations in water quality [11,15÷18]. It is important to note that treated wastewater intended for use in agriculture, industry, or other non-potable purposes is possible only if it meets all the required standard quality parameters.

The Weighted Arithmetic Water Quality Index Method (WAWQIM), is a technique used for developing and classifying WQI [14]. Ibrahim, in 2019 applied WAWQIM to evaluate whether the effluent from a wastewater treatment plant (WWTP) in Jordan can be used for irrigation. The quality of treated wastewater was assessed as suitable for various types of crops based on the estimated quality indices. Researchers concluded that WAWQIM is an efficient approach that ensures the evaluation, monitoring, and impact assessment of various water matrices [19÷22].

The main purpose of this study was to investigate the quality of wastewater entering the sewer system using WQI approach.

MATERIALS AND METHODS

Monitoring the quality of wastewater discharged into the sewer systems of localities is based on measuring a set of parameters and indicators that allow their classification within the maximum allowable limits, followed by establishing necessary measures in case of exceeding regulated values. Verifying compliance with the values imposed by permits/agreements for the discharge of wastewater into sewer systems, determining the quantity of pollutants discharged annually, and designing and verifying the operation of treatment stages in wastewater treatment plants are among the purposes of water management services.

Monitoring the discharge of wastewater into aquatic environments is carried out in accordance with Government Decision 352/2005, which represents the national transposition of Directive 91/271/1991 on urban wastewater treatment, respectively through NTPA 002 [23].

The collection of samples

To assess water quality, monthly determinations were made over 36 months (2020÷2022). Samples were collected in clean 2-litre plastic containers, each labeled with full information on sample code, date and time. Samples were then stored in a refrigerator at 4°C. Collected samples were sent for analysis as quickly as possible to avoid damage.

Reagents and chemicals
Reference Materials (MR) and Certified Reference Materials (CRM) were used for the calibration of the equipment used, the calculation of the measurement uncertainty, as well as for the plotting of the control points. All reagents (Merck, Darmstadt, Germany and Scharlau, Hamburg, Germany) used in the determinations were of analytical purity.

Data collection
Physical-chemical parameters: pH, suspended solids (SS), chemical oxygen demand (COD), biochemical oxygen demand (BOD_5), anionic surfactants (AS), nonionic surfactants (NS), solvent extractable substances (TSS), nickel (Ni), lead (Pb), copper (Cu), total chromium (Cr).
The selected parameters were analyzed using electrochemical, volumetric, UV-VIS spectrometry, and ICP-EOS spectrometry methods. All analyses were performed following the accreditation system, according to the reference standard SR EN ISO/IEC 17025:2018 [24]. The maximum allowed values of the investigation parameters according to in force legislation are present in table 1.

Table 1. Maximum admissible value (MAV) according to NTPA-002 Quality Norm [23]

Determined parameter	MU	MAV	Determined parameter	MU	MAV
pH	pH units	6.5÷8.5	TSS	mg/L	30
SS	mg/L	350	Ni	µg/L	20
COD	mg O2/L	500	Pb	µg/L	7.2
BOD_5	mg O2/L	300	Cu	µg/L	1.3
AS	mg/L	25	Cr total	µg/L	2.5
NS	mg/L	25			

Calculation method of WAWQIM
In this study, the weighted arithmetic water quality index method (WAWQIM) was applied to calculate the WQI using the following equation [25]:

$$WQI = \frac{\sum QnWn}{\sum Wn} \quad (1)$$

where: Qn is the quality rating of n^{th} water quality parameter and Wn is the unit weight of n^{th} water quality parameter;

$$Qn = \left(\frac{\mathrm{Vn-Vid}}{\mathrm{Sn-Vid}}\right) \text{X } 100 \quad (2)$$

where: Vn is the estimated value of n^{th} water quality parameter, Vid is an ideal value for the n^{th} parameter (for pH, Vid = 7.0, and Vid = zero for the other parameters, Sn is the standard permissible value of n^{th} water quality parameter;

$$Wn = \frac{\mathrm{K}}{\mathrm{Sn}} \quad (3)$$

where: Sn is the standard permissible value of n^{th} water quality parameter and K is the constant of proportionality;

$$K = \frac{1}{\sum 1/Sn} \quad (4)$$

By applying this WQI concept to wastewater, its quality can be assessed using the WWQI.
The evaluation of WWQI and the corresponding classification of treated wastewater are presented in table 2.

Table 2. The degree of quality of the wastewater for corresponding WWQI levels [12, 16]

WWQI Level	Rating of wastewater quality / Grade
0÷25	Excellent / A
26÷50	Good / B
51÷75	Regular / C
75÷100	Bad / D
>100	Very bad / E

RESULTS AND DISCUSSION

For the appropriate determination of wastewater quality indices, the quality parameters should be selected and classified based on their importance for human health and environmental protection.

The water quality index will provide an assessment of wastewater quality issues.

Due to the presence of organic matter in wastewater, its contamination occurs, and the determination of certain parameters has an important role in health, such as heavy metals that can accumulate and transfer in the food chain.

WWQI uses a scale from 0 to 100 to evaluate wastewater quality, with 100 representing the highest possible score. Once the overall score WWQI is determined, it can be compared against the following scale to assess how healthy the water is over a certain period. Water sources with scores in the good or excellent range can support a high diversity of aquatic life. The water would be suitable for all forms of recreation, including those involving direct contact with the water. Water sources that only achieve a medium score generally have a lower diversity of aquatic organisms and often show increased algae growth. Water sources that fall into the acceptable range can support only a reduced diversity of aquatic life and likely have pollution issues. Water sources in the poor category may support only a limited number of aquatic life forms and are expected to have significant quality problems. A water source with a poor-quality score would not normally be considered acceptable for activities involving direct contact with the water, such as swimming.

The advantages of the weighted arithmetic mean method used are: this method incorporates data from multiple water quality parameters into a mathematical equation that evaluates the health of the water body with a single number. It requires fewer parameters compared to evaluating all water quality parameters for a specific use. It is useful for communicating general water quality information to interested citizens and decision-makers. It reflects the composite influence of different parameters, which is important for the assessment and management of water quality.

Following the analyses, the WWQI were calculated for each month during the study period as shown in Table 3.

Table 3. Average monthly results of the analyzed parameters and the corresponding WWQI values from 2020 to 2022

Year	pH	SS mg/L	TSS mg/L	AS mg/L	NS mg/L	COD mgO_2/L	BOD_5 mgO_2/L	Ni µg/L	Pb µg/L	Cu µg/L	Cr total µg/L	WWQI
2020	7.1	174	1.9	0.9	0.8	737	273	1.8	1.5	1.0	2.2	47.9
2021	7.3	305	4.5	1.1	1.2	531	178	1.5	1.4	0.8	2.1	59.0
2022	7.3	292	4.2	0.9	1.1	526	176	1.5	1.4	0.8	2.1	50.0

Pearson correlation coefficient

To calculate the Pearson coefficient, also known as the Pearson correlation coefficient or the Pearson product-moment correlation coefficient, the two variables are plotted on a scatter plot. A certain degree of linearity is necessary to determine the coefficient; a scatter plot that does not show a linear relationship will be useless. The closer the scatter plot resembles a straight line, the stronger the association between the variable is. Numerically, the Pearson coefficient is represented in the same way as a correlation coefficient used in linear regression, with values ranging from -1 to +1.

A value of +1 indicates a perfect positive relationship between two variables, meaning that both variables move in the same direction. A value of -1 indicates a perfect negative relationship, meaning that as one variable increases, the other decreases; they are inversely related. A value of zero indicates the absence of any correlation (table 4).

Table 4. The scale of Pearson's correlation coefficient

The scale of the correlation coefficient	Value
$0< r \leq 0.19$	Very Low Correlation
$0.2 \leq r \leq 0.39$	Low Correlation
$0.4 \leq r \leq 0.59$	Moderate Correlation
$0.6 \leq r \leq 0.79$	High Correlation
$0.8 \leq r \leq 1.0$	Very High Correlation

Table 5. Correlation analysis between the eleven selected parameters for the year 2020

2020	pH	SS	TSS	AS	NS	COD	BOD_5	Ni	Pb	Cu	Cr total
pH	1										
SS	-0.26	1									
TSS	0.03	-0.09	1								
AS	-0.04	0.83	0.06	1							
NS	-0.04	0.77	0.05	0.95	1						
COD	-0.73	0.59	-0.15	0.42	0.42	1					
BOD_5	-0.72	0.57	-0.10	0.38	0.26	0.91	1				
Ni	-0.38	0.14	-0.02	0.15	0.11	0.32	0.36	1			
Pb	-0.31	0.25	-0.16	0.12	0.13	0.39	0.33	0.30	1		
Cu	-0.17	0.50	-0.13	0.22	0.22	0.07	0.10	0.37	0.30	1	
Cr total	-0.13	0.35	0.25	0.35	0.23	0.06	0.16	-0.20	0.44	0.01	1

A very high correlation was observed between NS and AS with a value of 0.95, between BOD_5 and COD with a value of 0.91, and between AS and SS with a value of 0.83 (table 5). These values indicate that both variables move in the same direction. As for the relationship between TSS and pH, the results show that they have a very weak correlation, with a value of 0.03.

The value of +1 between BOD_5 and COD indicates a perfect positive relationship between the two variables (Table 6 and Table 7). According to the annual average values obtained for COD and BOD_5, and by calculating the biodegradability index (BOD_5/COD), which was 0.37 in 2020 and 0.33 in 2021 and 2022, a good correlation can be observed between the two analyzed parameters, indicating that the wastewater has good treatability characteristics.

Table 6. Correlation analysis between the eleven selected parameters for the year 2021

2021	pH	SS	TSS	AS	NS	COD	BOD5	Ni	Pb	Cu	Cr total
pH	1										
SS	-0.80	1									
TSS	-0.35	0.70	1								
AS	-0.59	0.82	0.65	1							
NS	-0.52	0.72	0.64	0.95	1						
COD	-0.79	0.98	0.65	0.82	0.69	1					
BOD_5	-0.79	0.97	0.65	0.82	0.69	1.00	1				
Ni	-0.24	0.44	0.15	0.23	0.09	0.49	0.49	1			
Pb	0.22	-0.45	-0.36	-0.59	-0.50	-0.51	-0.51	0.22	1		
Cu	0.04	0.17	0.54	0.02	0.15	0.10	0.11	0.17	0.22	1	
Cr total	0.14	-0.34	-0.52	-0.53	-0.61	-0.25	-0.26	0.21	0.19	-0.31	1

Table 7. Correlation analysis between the eleven selected parameters for the year 2022

2022	pH	SS	TSS	AS	NS	COD	BOD5	Ni	Pb	Cu	Cr total
pH	1										
SS	-0.80	1									
TSS	-0.35	0.68	1								
AS	-0.40	0.80	0.60	1							
NS	-0.50	0.66	0.61	0.92	1						
COD	-0.64	0.98	0.65	0.84	0.72	1					
BOD_5	-0.62	0.96	0.63	0.83	0.70	1.00	1				
Ni	-0.19	0.40	0.15	0.23	0.09	0.49	0.45	1			
Pb	0.20	-0.40	-0.34	-0.60	-0.50	-0.50	-0.49	0.21	1		
Cu	0.02	0.15	0.52	0.02	0.10	0.11	0.10	0.15	0.21	1	
Cr total	0.12	-0.30	-0.52	-0.52	-0.61	-0.20	-0.20	0.20	0.18	-0.28	1

The calculated Pearson coefficients for the indicators NS and AS, COD and AS, as well as BOD_5 and AS show significant values ranging from 0.82 to 0.95. This demonstrates a very strong correlation between these parameters, which can lead to favorable changes in water quality assessment.
The use of the Pearson correlation coefficient in wastewater analysis helps identify the relationships between various water quality parameters. This aspect is crucial for understanding the factors that influence wastewater quality and for developing strategies to improve treatment processes and reduce environmental impact.

The model developed for predicting WWQI

The MLR model was applied as a statistical tool for predicting WWQI based on the analyzed wastewater quality parameters [25]. The data obtained from the analysis of variance (ANOVA) model are shown in Table 8, while the coefficients and statistical results from the MLR model are represented in Table 9.

Table 8. Output data from the analysis of variance (ANOVA) model

Source of Variation	df	SS	MS	F	P-value	F crit
Between Groups	10	4550405	455040.5	10.2752	4.64833E-07	1.909
Within Groups	121	6617039	54598.76			
Total	131	11167443				

Table 9. Coefficients and statistical results of MLR

Specification	Coefficients	Lower 95%	Upper 95%	Average	Variance
Intercept	0	#N/A	#N/A	#N/A	#N/A
pH	0.035	0.234	0.854	0.374	0.487
SS	-0.143	-0.426	0.685	0.039	0.099
TSS	-0.099	-0.058	-0.893	-0.350	-0.434
AS	0.309	0.562	0.866	0.579	0.669
NS	-1.157	-1.307	3.548	0.361	0.868
COD	-0.246	-0.103	0.666	0.105	0.223
BOD_5	0.487	0.415	1.571	0.824	0.937
Ni	0.883	1.118	3.107	1.702	1.976
Pb	0.805	0.170	0.817	0.597	0.528
Cu	-0.416	0.249	0.406	0.079	0.245
Cr total	0.531	0.290	1.174	0.665	0.710

#N/A: not assigned

The predicted WWQI from the MLR model can be calculated using the derived equation (5).

$$WWQI = 0.035pH - 0.143S - 0.099TSS + 0.309AS - 1.157AS - 0.246COD + 0.487BOD_5 + 0.883Ni + 0.805Pb - 0.416Cu + 0.531Cr\ total \quad (5)$$

WWQI was considered a dependent variable, while the wastewater quality parameters were treated as independent variables in the MLR model. Therefore, MLR proves to be a simple and direct model for assessing the wastewater quality. The estimated WWQI values and those predicted using the MLR model are presented in Figure 1, in relation to the study period (2020÷2022).

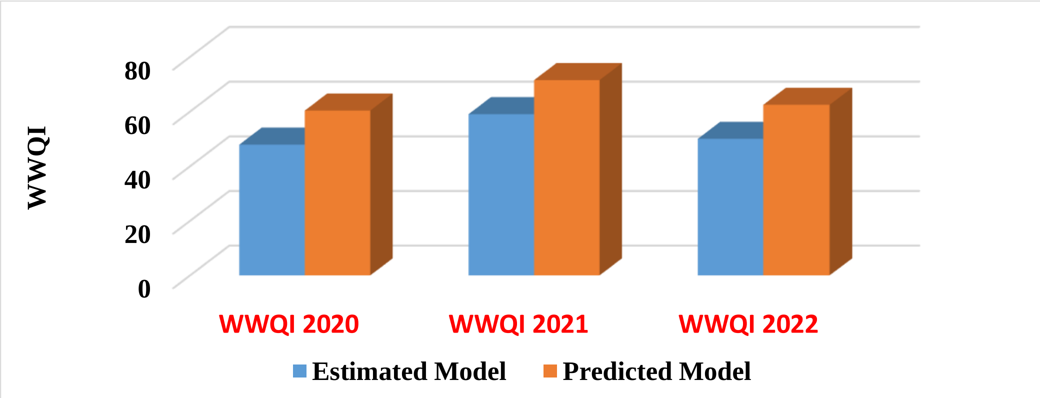

Fig. 1. Variation of estimated and predicted WWQI during the period 2020÷2022

The similar values of the estimated and predicted wastewater quality indices indicate that the predicted WWQI using the MLR model is valid for assessing the wastewater quality, considering the values of the wastewater characteristics.

CONCLUSIONS

The WWQI can be defined as a single value that reflects the overall quality of wastewater in relation to its constituent parameters. The annual WWQI values ranged between 47.9 and 59.8 during the study period, indicating generally good and typical quality of wastewater for safe disposal. The MLR model is a simple and direct method for evaluating the quality of wastewater discharged into the treatment plant, and the values obtained from the prediction model are similar to the estimated values calculated during the study period from 2020 to 2022.

REFERENCES

[1] LAMESA, F., Sustainability, **15,** no. 5, 2023, p. 4290, https://doi.org/10.3390/su15054290.

[2] NKWANDA, I.S., FEYISA, G.L., ZEWGE, F., MAKWINJA, R., Int. J. Energy Water Resour., **5**, 2021, p. 193, https://doi.org/10.1007/s42108-021-00125-5.

[3] YANG, S., LIANG, M., QIN, Z., QIAN, Y., LI, M., CAO, Y., Sci. Rep., **11**, 2021, p. 8714, https://doi.org/10.1038/s41598-021-87671-4.

[4] UDDIN, G., NASH, S., RAHMAN, A., OLBERT, A.I., Water Res., **219**, 2022, https://doi.org/10.1016/j.watres.2022.118532.

[5] TIYASHA, TUNG, T.M., YASEEN, Z.M., J. Hydrol., **585**, 2020, https://doi.org/10.1016/j.jhydrol.2020.124670.

[6] TRIPATHI, M., SINGAL, S.K., Ecol. Indic., **96**, 2019, p. 430, https://doi.org/10.1016/j.ecolind.2018.09.025.

[7] CHAKRAVARTY, T., GUPTA, S., Environ. Chall. **5**, 2021, https://doi.org/10.1016/j.envc.2021.100392.

[8] RAHAMAN, A., CHE RUS, S.F., OMAR, M.A., ISMAIL, W.R., Kemanusiaan **23** (Suppl. S1), 2016, p.109.

[9] BARAKAT, A., EL BAGHDADI, M., RAIS, J., AGHEZZAF, B., SLASSI, M., Int. Soil Water Conservat. Res., 4, 2016, p. 284.

[10] WORKU, Y., GIWETA, M., J. Pollut. Eff. Cont., **6**, 2018, p. 228, https://doi.org/10.4172/2375-4397.1000228.

[11] PRAUS, P., Water **11**, 2019, p. 2376, https://doi.org/10.3390/w11112376.
[12] WHO, 2018, Guidelines on sanitation and health. World Health Organization [18.08.2024].
[13] TSAKIRIS, V., European Water, **54**, 2016, p.19.
[14] HOSSEN, M.A., JISHAN, R.A., Appl. J. Environ. Eng. Sci, **4** no. 4, 2018, p. 4.
[15] CHMIELOWSKI, K., BEDLA, D., DACEWICZ, E., JURIK, L. Pol. J. Environ. Stud., **29** no. 2., 2020, https://doi.org/10.15244/pjoes/99902.
[16] JAMSHIDZADEH, Z., & BARZI, M.T., Environ. Sci. Pollut. R., **27,** no.7, 2020, p. 7366, https://doi.org/10.1007/s11356-019-07090-x.
[17] IBRAHIM, M.N., J. Ecol. Eng., **20,** no**.** 10, 2019, p. 206, https://doi.org/10.12911/22998993/112491.
[18] LEVIN, P.S., FOGARTY, M.J., MURAWSKI, S.A., FLUHARTY, D., Plos Biol., **7**, no. 1, 2009, https://doi.org/10.1371/journal.pbio.1000014.
[19] CHMIELOWSKI, K., BEDLA, D., DACEWICZ, E., JURIK, L., Pol. J. Environ. Stud. **29**, no. 2, 2020, p.1, https://doi.org/10.15244/pjoes/99902.
[20] PAUN, I., CHIRIAC, F.L., MARIN, N.M., CRUCERU, L.V. PASCU, L.F. LEHR , C.B., ENE, C., Rev. Chim. **68,** no. 8, 2017, p. 1732, https://doi.org/10.37358/RC.17.8.5754.
[21] PIRVU, F., CRUCERU, L., NICULESCU, M., PETRE, J., IANCU, V.-I., PASCU L.F., GALAON T., International Symposium "The Environment and the Industry" SIMI 2019, Proceedings Book, p. 302, http://doi.org/10.21698/simi.2019.fp38.
[22] DINU, C., SCUTARIU, R.E., VASILE, G.G., TENEA, A.G., PETRE, J., CRUCERU L.V., Rom. J. Ecol. Environ. Chem., **2**, no.2, 2020, p. 99, https://doi.org/10.21698/rjeec.2020.213.
[23] NTPA 002 Quality Norms regarding the conditions for discharging wastewater into municipal sewage networks or directly into treatment plants, according to HG352/2005, in Romanian.
[24] SR EN ISO/IEC 17025:2018, General requirements for the competence of testing and calibration laboratories, in Romanian.
[25] MOHAMED, A., EL-MORSY, A., J. Ecol. Eng. **22,** no. 2, 2021, p. 128, https://doi.org/10.12911/22998993/130893.

Citation: Pirvu, F., Paun, I., Iancu, V., Vasilache, N., Rudaru, D., Niculescu, M., Tenea, A.G., Chiriac, F.L, Impact assessment of wastewater on water quality using new quality indices and multiple linear regression, *Rom. J. Ecol. Environ. Chem*., **2024**, 6, no.2, pp. 21÷28.