DOI: http://doi.org/10.21698/simi.2019.fp38

NEW TOOLS FOR ASSESSMENT OF WASTEWATER QUALITY. CASE STUDY, ONE RURAL REGION FROM ROMANIA

Florinela Pirvu[1,2], Liliana Cruceru[1], Marcela Niculescu[1], Jana Petre[1], Vasile-Ion Iancu[1], Luoana Florentina Pascu[1], Toma Galaon[1]

[1]National Research and Development Institute for Industrial Ecology ECOIND, 71-73 Drumul Podu Dambovitei Street, Sector 6, code 060652, Bucharest, florinela_pirvu@yahoo.com, Romania
[2]University Politehnica of Bucharest, 313 Splaiul Independentei Street, sector 6, code 060042 Bucharest, Romania

Abstract

Global population growth is associated with an increase in the amount of water used. A consequence of this increase is the high amount of wastewater volume resulted, which can affect ecosystems balance. For this reason, the authorities are forced to account and improve wastewater treatment processes to minimize environmental impact. The physical-chemical properties of the effluent are unique and depend on the origin of the leakage, the sewer system infrastructure, the level of development of the area, the climatic conditions, and hence the wastewater stream has a unique composition of organic and inorganic loads.

For a quick and easy understanding of wastewater quality, two types of water quality indices were developed. This study presents the results of a complex analytical investigation of effluents discharged from six rural WWTP's situated in southern part of Romania compared with a simplified interpretation of wastewater quality by using a pollution index (PI) and a wastewater quality index (WWQI). Data recorded with a monthly frequency between 2013 and 2017 were used. Regarding the WWQI values calculated in this study, all wastewater analysed from the six WWTP's, fit to the 'Marginal' Designation.

Keywords*: pollution index, water quality index, wastewater*

Introduction

The discharge of effluents resulting from wastewater treatment plants (WWTP) into surface waters became a cause of concern at national level (Pirvu et al. 2018). The main reason is that most part of surface waters are used as raw water for drinking purposes (Stoica et al. 2016, Paun et al. 2016, Paun et al. 2017). For this reason, effluent quality assessment is required.

Measuring physical-chemical and biological parameters and comparing results with the limit values indicated in lows and regulations is a general approach to water quality assessment (Sapkal & Valunjkar 2013). This approach is time-consuming due to the assessment of the large number of measured indicators (Dede et al. 2017) and requires knowledge in environmental pollution control for understanding the significance of the results.

An easy and more simplified method that can be used to estimate water quality is represented by water quality indices. Practically, water quality indices are tools to

estimate water quality by reducing the great number of parameters into a single expression (Wisam et al 2018, Bharti & Katyal 2011) using an unitless number (Paun, 2016). Using simple terms (e.g., Excellent, Good, Fair, Marginal, Poor) water quality can be reported to management and to the public, in a consistent manner.The main applications of such indices include evaluation of drinking water, surface water and groundwater quality (Canadian environmental sustainability indicators, 2007).
Concerning effluent quality assessment few quality indices have been developed because, for such types of indices, multiple parameters that affect wastewater quality are basically required (Raut et al. 2017).
Two main types of water quality indices were used also for identification of wastewater quality. First one, refers to a pollution index whose reference value is 1 (Akpoveta et al. 2011, Winifred & Ifedayo 2014) and the second one is a water quality index (WQI) which is expressed as a numeric value ranging from 0 (Poor) and 100 (Excellent) (CCME 2001, CCME 2005).
This study presents the results of a complex analytical investigation of effluents discharged from some rural WWTP's situated in southern part of Romania compared with a simplified interpretation of wastewater quality by using a pollution index and a wastewater quality index (WWQI).

Experimental Part

The effluents investigated in this study were collected from six wastewater treatment plants (S1÷S6) situated in rural area from south part of Romania, with a monthly frequency, between 2013 and 2017.
A complex analytical investigation was performed using different analytical techniques like: molecular absorption spectrometry, atomic absorption spectrometry, volumetric, gravimetric and electrochemical methods. From 23 parameters which were initially investigated, according to NTPA 001 Norm, only 8 were selected for estimation of effluents quality: pH, Suspended solids (SS), Total dissolved solids (TDS), Chemical Oxygen Demand (COD), Bio-chemical Oxygen Demand (BOD_5), Ammonia (NH_4^+), Total oil and grace (TOG), Anionic surfactants (AS).
For calibration of the equipment, for calculation of the uncertainty of measurement, and also for plotting points in control charts Reference Materials (MR) and Certified Reference Materials (MRC) were used. All the reagents (Merck and Sigma) used in the determinations were of analytical purity.
Samples were collected in polythene or in glass bottles and preserved by acidulation at pH <2 or by keeping them at 4^0C, in the dark, function of the type of indicators.

Two types of quality indices were used in the investigations:
Pollution Index
Pollution index (Pi) is expressed as a function of the concentration of individual parameters against the baseline standard.

$$\text{Pollution index (Pi)} = \text{Concentration/Standard}$$

It provides information on the relative pollution of individual samples. The critical value is 1.0, values greater than 1.0 indicate a significant degree of pollution, while values less than 1.0 are not polluting (Winifred & Ifedayo 2014).
Wastewater Quality Index
The Canadian Water Quality Index (CCMEWQI) provides a comprehensive method of calculating quality indices that has become an important tool for authorities to

assess the degree of wastewater pollution. The WWQI measures the scope, frequency and amplitude of water quality and then combines the three measures into a score. The higher the score, the better the water quality is.
The mathematical expression for the Canadian Council Index (CCMEWQI) is:

$$\mathrm{WWQI} = 100 - \frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732} \quad (1) \qquad F_1 = \frac{Failed\ tests}{Total\ tests} \times 100 \quad (2)$$

$$\mathrm{excursion} = \frac{\text{Failed tests value}}{\text{guidelaine value}} - 1 \quad (3) \qquad \mathrm{nse} = \frac{\sum \text{excursion}}{\text{Total of tests}} \quad (4) \qquad F_3 = \frac{nse}{1.01nse + 0.01} \quad (5)$$

where:
Scope (F1) = number of quality indicators determined, whose values exceed the maximum allowed by law,
Frequency (F2) = Number of tests of determined quality indicators, the values of which exceed the maximum allowed by the legislation,
Amplitude (F3) = individual value for each test of the determined quality indicators, the values of which exceed the maximum allowed by the legislation. (CCME 2001, CCME 2005). The index values function of the main characteristics of wastewater are described in Table 1.

Table 1. Criteria according to Canadian Council of Ministers of the Environment, Water Quality Index (CCMEWQI)

Designation	Index Value	Description
Excellent	95-100	All measurements are within objectives virtually all of the time
Good	80-94	Conditions rarely depart from natural or desirable levels
Fair	65-79	Conditions sometimes depart from natural or desirable levels
Marginal	45-64	Conditions often depart from natural or desirable levels
Poor	0-44	Conditions usually depart from natural or desirable level

Results and Discussion

An analytical investigation of physical-chemical parameters from effluents discharged by wastewater treatment plants was performed. A number of 360 samples were collected over a 5-year period, starting from 2013. Initially 23 parameters were investigated from each sample, but only 8 of them, presenting an evident impact on pollution, were selected in the study.
On the basis of annual average values, the descriptive statistics were evaluated as mean, minimum, maximum and standard deviation (Table3).

Table 3. Basic statistics of physical - chemical variables for the wastewater treatment plants effluents (during 2013–2017)

WWTP	Basic statistics	Parameters							
		pH mg/L	SS mg/L	TDS mg/L	COD mg O_2/L	BOD mg O_2/L	NH_4^+ mg/L	TOG mg/L	AS mg/L
S1	Min	6.5	14.0	.	38.4	2.8	0.4	<20	0.1
	Max	8.0	219.0	789.0	806.4	315.5	115.7	28.6	5.0
	Median	7.4	54.0	435.5	112.8	41.5	24.6	<20	0.7
	SD	0.2	24.8	58.2	86.0	32.5	11.0	<20	0.6
	Average	7.4	65.1	419.8	152.6	52.6	35.1	<20	0.9
S2	Min	6.5	20.0	138.0	38.4	4.9	0.22	<20	0.1
	Max	7.9	197.0	962.0	1036.8	377.7	106.8	25.2	5.4
	Median	7.4	54.0	104.8	105.6	36.7	23.8	<20	0.5
	SD	0.1	19.3	59.2	130.2	48.3	13.5	<20	0.7
	Average	7.4	61.5	410.8	171.2	37.5	34.7	<20	0.9
S3	Min	6.1	24.0	246.0	38.4	1.8	0.1	<20	0.1
	Max	8.1	159.0	717.0	230.0	52.5	45.0	25.6	1.8
	Median	7.4	48.0	415.0	84.0	22.6	8.7	<20	0.5
	SD	0.2	11.9	38.1	26.7	3.7	3.8	<20	0.2
	Average	7.4	51.1	399.1	76.8	21.7	13.3	<20	0.5
S4	Min	6.8	18.1	190.0	38.4	2.0	0.1	<20	0.1
	Max	7.9	144.0	664.0	259.2	91.6	58.81	25.2	2.5
	Median	7.5	38.0	307.5	168.0	34.3	19.7	<20	0.5
	SD	0.1	12.6	32.0	29.9	6.0	4.3	<20	0.3
	Average	7.4	44.1	323.5	152.5	35.4	21.0	<20	0.6
S5	Min	6.5	12.0	327.0	6.7	2.4	0.02	<20	0.1
	Max	38.0	88.0	1379.0	503.0	147.1	75.6	22.4	4.4
	Median	7.6	40.0	561.0	52.8	14.9	7.4	<20	0.4
	SD	0.1	6.1	112.0	76.0	15.7	11.1	<20	0.6
	Average	7.6	40.8	588.3	83.8	20	16.9	<20	0.5
S6	Min	6.8	8.0	223.0	30	1.9	0.1	<20	0.1
	Max	8.3	88.0	987	393.6	147.1	88.1	<20	1.6
	Median	7.6	36.0	394.5	69.6	11.0	7.1	<20	0.4
	SD	0.1	6.5	82.4	64.0	15.9	10.6	<20	0.2
	Average	7.6	38.2	468.6	76.0	17.0	16.4	<20	0.5

Where: S1, S2, S3, S4, S5, S6 are wastewater treatment plants

The analytical results were compared with the maximum addmisible values imposed by NTPA-001 Quality Norm (Table 2).

Table 2. Maximum admissible values (MAV) according to NTPA-001 Norm

Determined parameter	MU	MAV
pH	pH units	6.5-8.5
SS	mg/L	35(60)
TDS	mg/L	2000
COD	mg O_2/L	125
BOD_5	mg O_2/L	25
NH_4^+	mg/L	2(3)
TOG	mg/L	20
AS	mg/L	0.5

The Influence of pH. The pH value of the water has an important effect on the body, health and diseases that can occur, because the human body consists of 50-60% water. The fluids in our body must be in the pH range of 7-7.2. If the pH is less than 5.3, vitamin or mineral uptake is not possible. When the body pH drops below 6.4, digestion does not take place properly. An acidic pH in the 1-4 range can cause emotional stress, toxic overload or any process that disposed cells oxygen and other nutrients. If the pH is greater than 11, it causes eyes irritation. (Santosh et al. 2008)

The results obtained for the pH are compared to the limits imposed by NTPA 001. For S1 wastewater treatment plant the minimum pH value is 6.5 and the maximum value is 8.0 with an average of 7.4 and an SD of 0.2, during 5 years of analytical investigation. At the S2, S3 and S4 wastewater treatment plants, an average pH of 7.4 was recorded, while for the S5 and S6 stations the pH values ranged between 6.5 and 8.3.

The Influence of Suspended Solids (SS). Organic and inorganic solids suspended in the wastewater are usually measured by filtration and normally are removed during the treatment process. In the case of solid suspensions, the average concentration for the six wastewater treatment plants are: S1 = 65.1 mg/ L ± 24.8 (SD); S2 = 61.5 mg/L ± 19.3 (SD); S3 = 51.1 mg/L ± 11.9 (SD); S4 = 44.1 mg/L ± 12.6 (SD); S5 = 40.8mg/L ± 6.1(SD); S6 = 38.2 mg /L± 6.5(SD).

The influence of Dissolved Solids (TDS). Total dissolved solids or filterable residue include salts and organic residues. Wastewater treatment plants S1 and S2 have the same TDS minimum value of 138 mg/L. A maximum of TDS values is observed in S5 wastewater treatment plant, 1379 mg/L. This can be correlated with an increase contribution of TDS by upstream discharges.

The Influence of Chemical Oxygen Demand (COD). Natural waters contain dissolved oxygen concentrations depending on altitude, salinity and water temperature. COD is the factor that determines whether chemical changes are brought by aerobic or anaerobic organisms. Thus, the measurement of COD is vital for maintaining aerobic treatment processes for domestic and industrial wastewater treatment (Santosh et al. 2008).

The values recorded in this study are between 138 mg O_2/L and 1379 mg O_2/L for stations S1, respectively S5. The maximum of this recorded indicator exceeds 11 times the maximum admissible value of NTPA 001.

The Influence of Bio-Chemical Oxygen Demand (BOD). Biochemical oxygen demand (BOD) determines the oxygen concentration needed to stabilize domestic and industrial waste. The maximum values obtained for the BOD for the 6 wastewater treatment plants are as follows: S3 with the lowest value of 52.5 mgO_2/L, followed by S4 with a maximum concentration of 91.6 mg O_2/L, the stations S5 and S6 have the same value of the maximum concentration of 147.1 mgO_2/L, the station S1 with a maximum concentration of 315.5 mg O_2/L and the highest value was recorded for station S6, 377.7 mg O_2/L, which exceeds 15 times the maximum admissible limit of NTPA 001.

The Influence of Ammonia (NH_4^+). In the wastewater treatment plants, the nitrogen compound is found mainly as ammonium and comes from two sources: the influent and the anaerobic digestion fluid returned from the treatment used in the treatment plants (Yiwen et al. 2019).

In this case the highest ammonia concentration values were recorded in this order: 115.7 mg/l (S1) > 106.8 mg/L (S2) > 88.1 mg/L (S6) > 75.6 mg/L (S5) 58.8 mg/l

(S4) > 45.0 mg/L (S3). It can be noticed that in case of S1 station the ammonium concentration exceeds 57 times the maximum admissible limit of NTPA 001.

This general approach for assessment of wastewater quality proved to be time-consuming due to the assessment of the large number of measured indicators and the correlation with the limits imposed by the environmental legislation. The conclusion of this evaluation is clear for specialists in environmental pollution control but less understandable for population that cannot interpret the significance of the results.

In this study two simplified methods to estimate wastewater quality, based on water quality indices, were tested. The pollution index (PI) and the wastewater quality index (WWQI) were calculated using the same results obtained from the analytical investigation performed during 5 years in some rural wastewater treatment plants from south part of Romania. The Pollution index (PI) for the 8 tested parameters is presented in Figures 1÷6. Parameters having PI values greater than 1 indicate a significant degree of pollution.

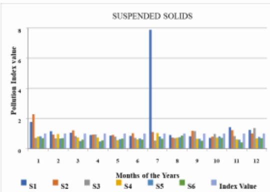

Figure 1. Pollution Index - Suspended Solids

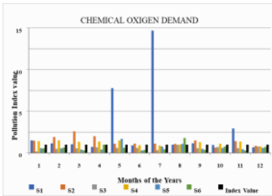

Figure 2. Pollution Index – Chemical Oxigen Demand

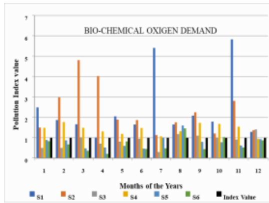

Figure 3. Pollution Index –Bio-Chemical Oxigen Demand

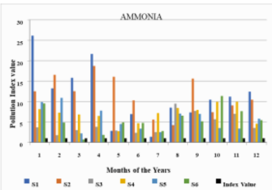

Figure 4. Pollution Index –Ammonia

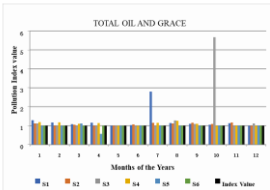

Figure 5. Pollution Index - Total Oil and Grace

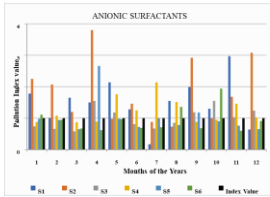

Figure 6. Pollution Index –Anionic Surfactants

The highest values of the pollution index (PI) were obtained in the order:

$NH4+ > COD > SS > BOD5 > TOG > AS$

The quality of effluents from six wastewater treatment plants in a rural area in southern Romania was also assessed using the wastewater quality index (WWQI) The index values and the designation for each sampling point are presented in Table 3.

Table 3. Values of water quality sub-index and index calculated for each sampling point

Sampling point	F1	F2	nse	F3	Index Value	Designation
S1	75.00	44.80	2.284	9.49	49.26	Marginal
S2	75.00	43.09	7.460	9.77	49.74	Marginal
S3	75.00	28.13	0.651	8.59	53.48	Marginal
S4	75.00	35.00	1.344	9.22	51.91	Marginal
S5	75.00	19.23	0.861	8.88	55.00	Marginal
S6	62.50	17.82	0.779	8.78	62.11	Marginal

The calculated index for all effluents corresponds to the marginal designation, which means that the values of the 8 determined parameters often exceed the limits imposed by NTPA 001 Norm.
The results offered by the water quality indices are well corelated with that one offered by the classical investigation of the pollution level of water effluents. The advantage of using quality indices in wastewater characterisation consists in the simplified mode of reporting the results to management and to the public.

Conclusions

The level of parameter concentrations from six wastewater treatment plants from a rural area in southern Romania were assessed. For this, a classical approach based on analytical investigation and comparison of the results with limits imposed by legislation and a modern one, based on water quality indices estimation, were used. The both approaches indicated an increased level of NH_4^+, COD, SS, BOD especially in effluents tested from S1 and S2 treatment plants. For all effluents, the calculated index corresponds to the marginal designation, which means that the values of the determined parameters often exceed the limits imposed by NTPA 001 Norm. The wastewater quality indices assessment provides us with information on effluent treatment efficiency, effluent quality and rapid assessment if it is appropriate for the final destination.

References

Akpoveta, OV, Okoh, BE & Osakwe SA 2011, 'Quality Assessment of Borehole Water used in the Vicinities of Benin, Edo State and Agbor, Delta State of Nigeria, *Current Research in Chemistry,* vol 3, pp.62-69.

Bharti, N, & Katyal, D 2011, 'Waterquality indices used for surface water vulnerability assessment', *International Journal of Environmental Sciences,* vol.2, no.1, pp.154-173.

Canadian water quality guidelines for the protection of aquatic life: CCME Water Quality Index 1.0, user's manual 1999. In Canadian environmental quality guidelines. *Canadian Council of Ministers of the Environment, Winnipeg, Manitoba*. Retrieved on March 29, 2007, from http://www.ccme.ca/assets/pdf/wqi_usermanualfctsht_e.pdf.

Canadian environmental sustainability indicators. Freshwater quality indicator: Data sources and methods. Catalogue no. 16-256-XIE. Retrieved on March 29, 2007, from http://www.statcan.ca/bsolc/english/bsolc?catno=16-256-XIE#formatdisp.

Dede, OT, Mısır, FY & Telci İT 2017, 'The Using of Principal Component Analysis for the Assessment of Water Quality in Kirmir Basin' *International Symposium "The Environment and the Industry"*, Proceedings Book, pp. 197-198.

NTPA 001 Quality Norms on the determination of the limits of pollutant loading of industrial and urban wastewater into natural receptors, according to HG 352/2005.

Paun, I, Cruceru LV, Chiriac FL, Niculescu, M, Vasile, GG & Marin, NM 2016 Water Quality Indices - Methods for evaluating the quality of drinking water, *International Symposium "The Environment and The Industry", Proceedings Book, SIMI 2016*, Bucharest, pp. 395-402.

Paun, I, Chiriac, FL, Marin, NM, Cruceru, LV, Pascu, LF, Lehr, CB & Ene C 2017 Water quality index, a useful tool for evaluation of danube river raw water, *Rev. Chim. (Bucharest)*, vol. 68, no. 8, pp. 1732-1739.

Pirvu, F, Petre, J, Cruceru, L, Paun, I, Niculescu, M, Pascu, LF, Vasilache, N & Chiriac, FL 2018 Physico–chemical characteristics and wastewater quality index for evaluating the efficiency of treatment process effluent, *International Symposium "The Environment and The Industry", Proceedings Book, SIMI 2018*, pp. 417-425.

Raut, SB, Anaokar, GS & Dharnaik, AS, 2017, ' Determination of Wastewater Quality Index of Municipal Wastewater Treatment Plant using Fuzzy Rule Base', *European Journal of Advances in Engineering and Technology*, vol.4, no.10, pp. 733-738.

Santosh, M, Avvannavar & Shrihari S 2008 ' Evaluation of water quality index for drinking purposes for river Netravathi, Mangalore, South India' *Environ Monit Assess* vol no. 143, pp 279–290.

Sapkal, RS & Valunjkar, SS 2013 ' Development and sensitivity analysis of water quality index for evaluation of surface water for drinking purpose', *International Journal of civil engineering and technology (IJCIET)*, vol.4, issue 4, pp 119-134.

Stoica, C, Camejo, J, Banciu, A, Nita-Lazar, M, Paun, I, Cristofor, S, Pacheco OR & Guevara, M 2016 Water quality of Danube Delta systems: ecological status and prediction using machine-learning algorithms, *Water Scence & Technology*, vol. 73, pp. 2413-2421.

Winifred, UA & Ifedayo, OA 2014, 'Assessment of trace metals in drinking water and groundwater sources in Ota, Nigeria', *International Journal of Scientific and Research Publications*, vol 4, issue 5, ISSN 2250-3153.

Wisam, T, Al-Mayah & Rabee AM 2018, 'Application of Overall Index of Pollution (OIP) for the Evaluating of the Water Quality in Al - Gharraf River southern of Iraq ' *Iraqi Journal of Science*, vol. 59, no.2A, pp: 660 - 669.

Yiwen, L, Huu, HN, Wenshan, G, Lai, P, Dongbo, W & Bingjie, N 2019 The roles of free ammonia (FA) in biological wastewater treatment processes: A review, *Environment International*, vol. 123 pp. 10-19.