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Quality Monitoring of the Treated Water in Japanese Water Treatment Plant, El-Mahalla El-Koubra City, Egypt

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ABSTRACT

Water quality index (WQI) is a smart tool for the overall assessment of water quality. The present study aimed to monitor the treated water quality in Japanese water treatment plant located in El-Mahalla El-Koubra City, Egypt. Furthermore, statistical analysis was applied to develop a simple model for accurate prediction of WQI depending on the different water quality parameters. The results indicate good quality of the treated water for potable uses in general. On the other hand, the statistical analysis using multiple linear regression (MLR) model revealed that there is a very strong correlation between WQI and parameters of water quality confirmed by R-squared value of 0.998. Likewise, the relationship between the estimated WQI and the predicted WQI using MLR model expresses a very strong correlation confirmed by R-squared value of 0.947. Therefore, MLR model is simple as well as accurate approach for estimation of WQI.

Keywords: Assessment of water quality; multiple linear regression; water treatment; water quality index

1. INTRODUCTION

Water quality index (WQI) provides a single value that reflects overall water quality in specified conditions of time and location depending on various water quality parameters. In most cases, WQI is used to evaluate quality of water resources and potability of the treated water (Oni and Fasakin, 2016; Phadatare and Gawande, 2016; Tsakiris, 2016; WHO, 2011). The idea of WQI was created by Horton (1965) and developed by Brown et al. (1970) to be a decision making tool for stakeholders, researchers in addition to the governmental authorities and agencies to facilitate smart management of water quality issues (Badr et al., 2013; Libânio and Lopes, 2009; Tsakiris, 2016; Vijayan et al., 2016).

Several methods were accomplished to develop and categorize WQI. The most commonly methods used are (i) Canadian Council of Ministers of Environment Water Quality Index (CCMEWQI), (ii) National Sanitation Foundation Water Quality Index (NSFWQI), and (iii) Weighted Arithmetic Water Quality Index Method (WAWQIM) (Bharti and Katyal, 2011; CCME, 2001; Chauhan and Singh, 2010; Damo and Icka, 2013; Hamlat et al., 2014; Kumar and Alappat, 2009; Lumb et al., 2006; Manju et al., 2014; Oni and Fasakin, 2016; Rao et al., 2010; Tyagi et al., 2013).

Oni and Fasakin (2016) applied Weighted Arithmetic WAWQIM to assess the potability of the surface and ground water in Nigeria. In addition, Yogendra and Puttaiah (2008) applied

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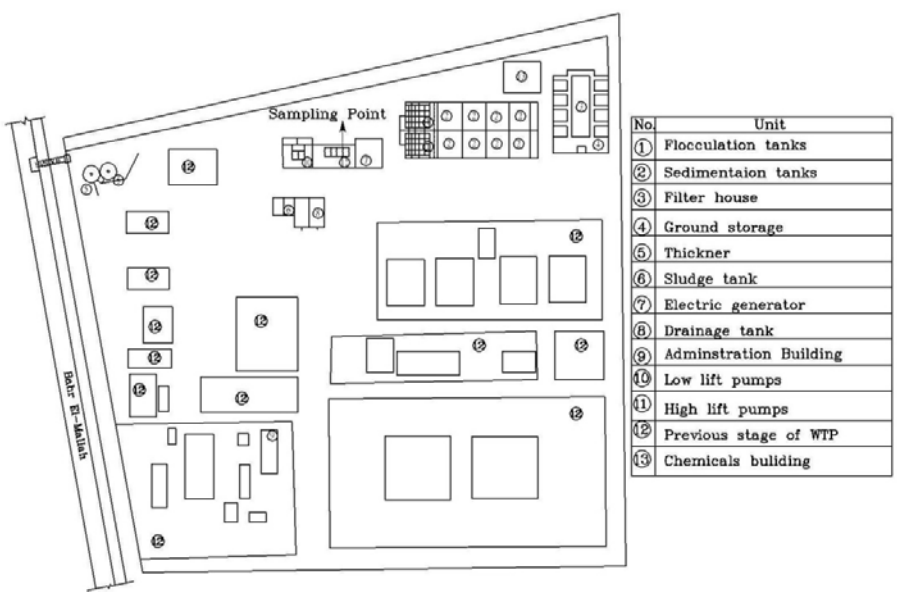
the same approach of WAWQIM to evaluate suitability of an urban water body in Shimoga Town, Karnataka. These researchers concluded that WAWQIM is a powerful approach assures suitability of water for human consumption in case of fresh water bodies. On the other hand, Badr et al. (2013) applied NSFWQI method to survey water quality in 24 sites allocated in Damietta Branch of the Nile River, Egypt. Moreover, Chaturvedi and Bassin (2010) applied the same method of NSFWQI to evaluate potability of water from water treatment plant and bore wells in Delhi, India. They concluded that NSFWQI was effective method for achievement objectives of their studies through identification changes in water quality by evaluating different areas.

Phadatare and Gawande (2016) prepared a review paper on development of WQI. They compared WAWQIM versus NSFWQI method. However, Phadatare and Gawande (2016) reported that both WAWQIM and NSFWQI methods are useful internationally for monitoring, assessment and impact studies for different water bodies with different regions.

The present study aimed to monitor the treated water quality in Japanese WTP located in El-Mahalla El-Koubra City, Egypt through calculating WQI after comparing results of the treated water quality analyses with the international standards of potable water. Furthermore, statistical analysis was applied to develop a simple model for accurate prediction of WQI depending on the different water quality parameters.

1.1 Study area

Japanese WTP shown in Fig. 1 is located in El-Mahalla El-Koubra City, El-Gharbia Governorate, about 120 km north Cairo, Egypt. The plant receives surface water from Bahr El-Mallah Canal distributed from Bahr Shebeen Canal in Egypt to treat 34000 m^3/d of surface water. The plant covers the potable water needs for about 120000 capita from the population of El-Mahalla El-Koubra City (Ayoub and Abdelfattah, 2016; GHWSC, 2016).



(a)

Figure 1 Japanese-El-Mahalla El-Koubra WTP in (a) general layout, (b) aerial photo adapted from Google Earth, August 2015 (to be continued)

(b)

Figure 1 Japanese-El-Mahalla El-Koubra WTP in (a) general layout, (b) aerial photo adapted from Google Earth, August 2015

2. METHODOLOGY

2.1 Monitoring of the treated water quality

The treated water analyses were conducted on the basis of the Standard Methods for the Examination of Water and Wastewater (APHA, 2012). These experiments were conducted from January 2015 till December 2016 under supervision of El-Gharbia Water and Sanitation Company (GHWSC, 2016). The water quality parameters were selected for calculation of WQI according to WHO (2011) as shown in Table 1.

2.2 Calculation method of water quality index

Calculation of WQI was carried out in this study using the WAWQIM by Eq. 1 (Oni and Fasakin, 2016; Phadatare and Gawande, 2016):

$$WQI = \frac{\sum q_n W_n}{\sum W_n} \quad (1)$$

Where,

q_n = quality rating of n^{th} water quality parameter, and W_n = unit weight of n^{th} water quality parameter; The quality rating (q_n) was calculated by Eq. 2:

$$q_n = \left(\frac{V_n - V_{id}}{S_n - V_{id}}\right) \times 100 \quad (2)$$

Where,

V_n = estimated value of n^{th} water quality parameter, V_{id} = ideal value for n^{th} parameter in pure water (V_{id} = zero for all parameters except for pH, V_{id} = 7.0), and S_n = standard permissible value of n^{th} water quality parameter; The unit weight (W_n) was calculated using the Eq. 3:

$$W_n = \frac{K}{S_n} \quad (3)$$

Where,

S_n = standard permissible value of n^{th} water quality parameter, and K = constant of proportionality and it was calculated using the Eq. 4:

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

Rating of WQI and the corresponding status of water quality were summarized in Table 2 (Oni and Fasakin, 2016; Phadatare and Gawande, 2016).

3. RESULTS AND DISCUSSION

3.1 Water quality index (WQI) through the study period

Comparing the results of the treated water quality analyses shown in Table 3 with the international standards of potable water shown in Table 2 revealed that the treated water quality is conformed to the international standards of potable water (WHO, 2011). Furthermore, WQI was calculated using WAWQIM for each month during the study period as shown in Table 3.

Table 1 Descriptive statistics of the treated water parameters and their corresponding standard values according to WHO (2011)

Parameter	**Results of the statistical analysis***				**Standards (WHO, 2011)**
	Max.	**Min.**	**Mean**	**Standard deviation**	
pH	8.6	7.5	8.0	0.32	8.0
Turbidity, NTU	0.30	0.10	0.21	0.06	1.0
Total hardness (TH), mg/L	210	95	146	30.6	300
Total alkalinity (TA), mg/L	93	53	77	10.3	120
Total dissolved solids (TDS), mg/L	260	180	220	20.3	500
Calcium (Ca^{2+}), mg/L	59	28	44	7.9	75
Magnesium (Mg^{2+}), mg/L	28	8	18	5.2	30
Chlorides (Cl^-), mg/L	50	32	40	5.6	250
Sulfates (SO_4^{2-}), mg/L	40	16	23	6.1	200
Nitrates (NO_3^-), mg/L	3.0	0.8	2.0	0.7	45

*Note: The results were obtained from January 2015 till December 2016

Table 2 Rating of water quality for corresponding levels of WQI

WQI level	**Rating of water quality / Possible usage**
0-25	Excellent / Potable, Irrigation and industrial purposes
26-50	Good / Potable, Irrigation and industrial purposes
51-75	Poor / Irrigation and industrial purposes
75-100	Very poor / Industrial purposes
>100	Unsuitable for drinking / Treatment is required before usage

Table 3 Average monthly results of the different parameters and corresponding values of WQI from January 2015 till December 2016

No	Month	pH	Turbidity NTU	TH mg/L	TA mg/L	TDS mg/L	Ca^{2+} mg/L	Mg^{2+} mg/L	Cl^- mg/L	$SO4^{2-}$ mg/L	NO_3^- mg/L	WQI
1	Jan-15	8.2	0.15	135	62	210	42	12	35	18	2.8	27.1
2	Feb-15	8.6	0.3	112	71	195	38	8	42	22	1.8	43.2
3	Mar-15	8.4	0.18	95	53	225	45	14	39	17	2	31.8
4	Apr-15	7.9	0.22	140	80	240	43	16	32	29	0.8	30.2
5	May-15	8.1	0.19	163	93	230	50	9	34	31	1.5	29.4
6	Jun-15	7.8	0.26	130	77	188	39	17	39	18	1.3	32.5
7	Jul-15	7.7	0.3	210	69	212	43	21	35	22	1.6	35.2
8	Aug-15	8	0.1	190	93	180	45	17	37	30	0.9	21.6
9	Sep-15	7.6	0.15	195	89	260	35	16	40	19	1.2	21.4
10	Oct-15	8.4	0.2	170	85	242	52	17	32	22	3	34.1
11	Nov-15	8.2	0.3	163	79	225	39	22	33	40	2.7	40.5
12	Dec-15	7.8	0.25	174	73	210	43	24	50	19	2.9	32.5
13	Jan-16	8.5	0.16	132	80	218	58	13	48	22	3	31.5
14	Feb-16	8.3	0.11	182	79	205	47	17	37	28	1.1	25.5
15	Mar-16	8	0.17	99	60	195	56	12	50	17	1.9	26.9
16	Apr-16	7.7	0.2	120	72	250	59	19	37	24	2.6	27.1
17	May-16	7.5	0.26	128	85	244	37	23	42	34	2.2	30.1
18	Jun-16	8.1	0.24	134	71	212	28	24	45	18	2.5	34.5
19	Jul-16	7.6	0.3	148	69	208	42	20	47	19	1.8	34.1
20	Aug-16	8.2	0.3	144	85	210	34	18	35	26	2.7	40.1
21	Sep-16	8.4	0.2	154	83	223	35	16	39	27	1.6	33.7
22	Oct-16	8.1	0.25	112	69	240	41	22	48	16	2.8	35.3
23	Nov-16	7.5	0.18	116	82	238	54	28	39	20	1.7	24.1
24	Dec-16	7.9	0.15	155	87	221	42	26	41	22	1.8	25.5

The monthly WQI values ranged between 21.4 and 43.2 with average value of 31.3 through the study period, which indicate good quality of the treated water for potable uses in general. Moreover, it is apparent that about 13% of WQI values recorded excellent quality referring to classification of WQI levels in Table 2 (Oni and Fasakin, 2016; Phadatare and Gawande, 2016).

3.2 Model development for predicting WQI

Multiple linear regression (MLR) model was applied as a statistical tool for the prediction of WQI depending on the recorded water quality parameters (Vijayan et al., 2016). The output data from analysis of variance (ANOVA) model are shown in Table 4, whereas co-efficients and statistical results from MLR model are represented in Table 5.

The predicted WQI from MLR model can be

calculated using the Eq. 5:

$$WQI = 4.347\ pH + 69.153\ Turbidity - 0.014\ TH - 0.010\ TA - 0.042\ TDS - 0.079\ Ca^{2+} - 0.092\ Mg^{2+} - 0.131\ Cl^{-} + 0.026\ SO_4^{2-} + 1.634\ NO_3^{-} \quad (5)$$

WQI was considered a dependent variable, while parameters of water quality were independent variables in MLR confirmed by R-squared value of 0.998. Therefore, MLR is simple, direct, and very accurate model in order to sustainable assessment of the treated water quality in Japanese-El-Mahalla El-Koubra WTP.

The estimated WQI using WAWQIM and the predicted WQI using MLR model were outlined as shown in Fig. 2 in relationship with time of the study period (from January 2015 till December 2016). The close values of estimated and predicted water quality indices are very noticeable.

Likewise, the estimated WQI using WAWQIM and the predicted WQI using MLR model were represented as shown in Fig. 3. It can be noticed that the relationship between estimated and predicted water quality indices expresses a very strong correlation confirmed by R-squared value of 0.947. Therefore, MLR model is an accurate approach for estimation of WQI, in addition to its simplicity in determination of WQI by just informing results of the treatment parameters at a given time and without reference to the previous cumulative results as in the case of WAWQIM.

Table 4 Output data from analysis of variance (ANOVA) model

Source	df	SS	MS	F	Significance F
Regression	10	24008.71708	2400.871708	858.9241	1.22057E-16
Residual	14	39.13291651	2.795208322	-	-
Total	24	24047.85	-	-	-

Table 5 Coefficients and statistical results of multiple linear regression model

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95.0%
Intercept	0.000	#N/A	#N/A	#N/A	#N/A	#N/A
pH	4.347	0.666	6.528	1.34E-05	2.919	5.776
Turbidity, **NTU**	69.153	6.696	10.328	6.25E-08	54.793	83.514
TH, **mg/L**	-0.014	0.014	-1.019	0.325488	-0.045	0.016
TA, **mg/L**	-0.010	0.050	-0.199	0.845163	-0.117	0.097
TDS, **mg/L**	-0.042	0.018	-2.327	0.035496	-0.080	-0.003
Calcium, **mg/L**	-0.079	0.049	-1.604	0.131006	-0.185	0.027
Magnesium, **mg/L**	-0.092	0.083	-1.111	0.285265	-0.270	0.086
Chlorides, **mg/L**	-0.131	0.074	-1.760	0.100154	-0.290	0.029
Sulfates, **mg/L**	0.026	0.080	0.318	0.75489	-0.146	0.197
Nitrates, **mg/L**	1.634	0.599	2.728	0.016338	0.349	2.918

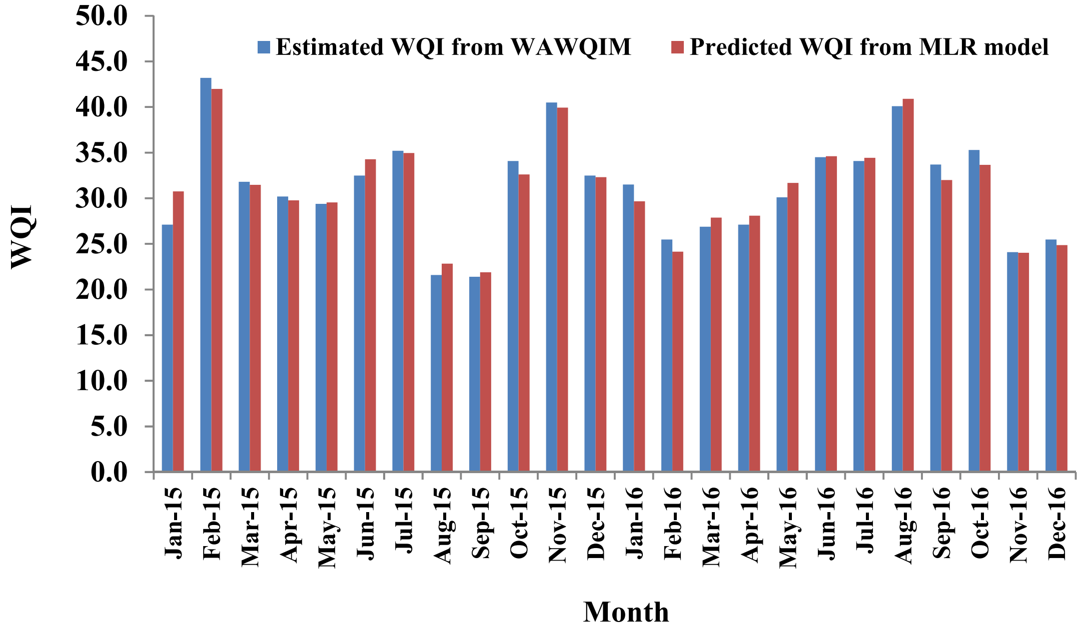


Figure 2 Variation of estimated and predicted WQI through study period

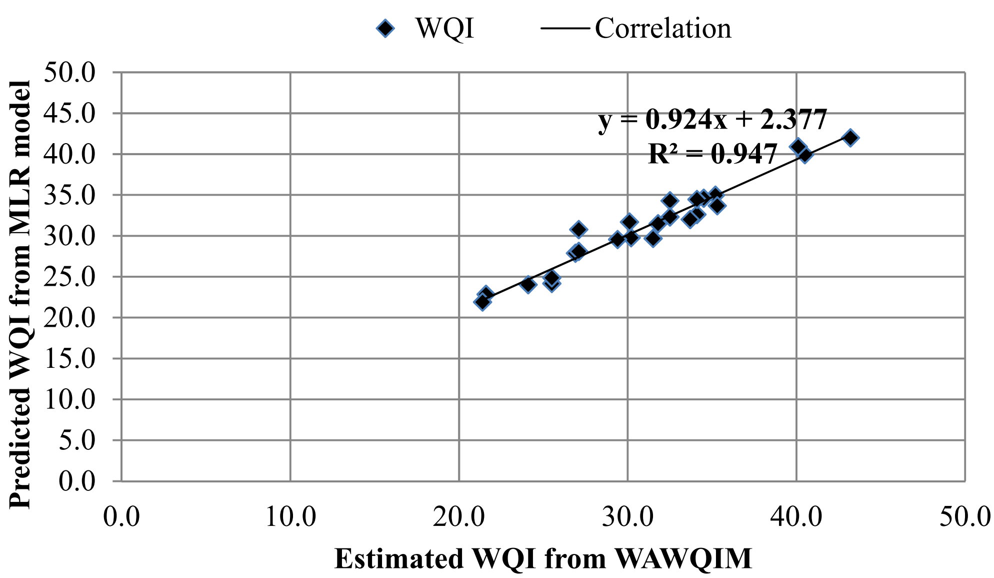


Figure 3 Correlation between estimated and predicted WQI

CONCLUSIONS

Water quality index (WQI) is a smart tool for the overall assessment of water quality. The monthly WQI values ranged between 21.4 and 43.2 with average value of 31.3 through the study period, which indicate good quality of the treated water from Japanese El-Mahalla El-Koubra WTP for potable uses in general. Moreover, it is apparent that about 13% of WQI values recorded excellent quality in the present study. On the other hand, the statistical analysis using multiple linear regression (MLR) model revealed that there is a very strong correlation between WQI and parameters of water quality confirmed by R-squared value of 0.998. Likewise, the relationship between the estimated WQI using the weighted arithmetic water quality index method (WAWQIM) and the predicted WQI using MLR model expresses a very strong correlation confirmed by R-squared value of 0.947. Therefore, MLR model is an accurate approach for estimation of WQI, in addition to its simplicity in determination of WQI by informing results of the treatment parameters at a given time and without reference to the previous cumulative results as in the case of WAWQIM.

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