Impact of Medical City and Al-Rasheed Power Plant Effluents on the Water Quality Index Value of Tigris River at Baghdad City

2nd Conference on Environment and Sustainable Development 28-29-Oct-2015

Dr. Abdul Hameed M. Jawad Al-Obaidy
Environmental Research Center, University of Technology
Eman S. Awad
Environmental Research Center, University of Technology
EMAIL: eman.erc@gmail.com
Zahraa Zahraw
Environmental Research Center, University of Technology

Abstract:
Water quality deterioration in surface water is the impact of anthropogenic activities due to rapid industrialization. Tigris River within Baghdad city is of particular importance in the study of surface water quality because; industrial and municipal wastes, agricultural and runoff from developing areas were mixing with river flow and surrounding water body thereby deteriorating the quality. The aim of the study was to assess the WQI on the basis of Weighted Arithmetic Index in order to evaluate the water quality of the Tigris River for drinking purposes from three stations within Baghdad city during 2013. The WQI was calculated based on the concentration of eleven parameters (pH, Total Dissolved Solid (TDS), Total Hardness, Calcium, Magnesium, Chloride, Turbidity, Nitrite (NO_2), Nitrate (NO_3), sulphate (SO_4) and Zinc). The calculation of WQI showed that the water quality of Tigris river can be rated as very poor and unsuitable conditions at winter and summer, respectively, in the 1st site which is situated at the north of the study area while the water quality of the 2nd site can be categories as unsuitable conditions at all season of study and for 3rd site can be rated as poor and very poor conditions at winter and summer season, respectively. Therefore, there is need a regular monitoring of water quality in order to detect the changes in physio-chemical parameter concentrations.

Keywords: Weighted Arithmetic Index, WQI, Drinking water, Tigris River, and sulphate.

تأثير تصاريف مدينة الطب ومحطة كهرباء الرشيد في قيم دليل نوعية مياه نهر دجلة عند مدينة بغداد

الخلاصة:
ان تدهور نوعية المياه في المياه السطحية هو نتيجة تأثير الأنشطة البشرية الناتجة من عمليات التصنيع السريعة. ان نهردجلة داخل مدينة بغداد له أهمية خاصة في دراسة نوعية المياه السطحية بسبب النفايات

https://doi.org/10.30684/etj.34.4A.3
2412-0758/University of Technology-Iraq, Baghdad, Iraq

الصناعية والمنزلية والزراعية واعادة التصريف من المناطق النامية والتي تخلط مع تدفق النهر وتحيط به وبالتالي يؤدي ذلك الى تدهور نوعية المياه. وكان الهدف من هذه الدراسة هو تقييم WQI بأستخدام دليل الحساب الوزني من أجل حساب نوعية المياه لنهر دجلة لأغراض الشرب من ثلاث محطات داخل مدينة بغداد خلال عام ٢٠١٣. تم احتساب WQI على أساس تركيز أحد عشر متغير (درجة الحموضة pH، مجموع المواد الصلبة الذائبة TDS، العسرة الكلية، الكالسيوم، المغنيسيوم، الكلوريد، العكارة، النتريت NO_2، النترات NO_3 ، الكبريتات SO_4 والزنك Zn. أظهر حساب WQI أن نوعية مياه نهر دجلة يمكن أن تصنف كمياه فقيرة جدا (very poor) وغير ملائمة (unsuitable) في فصلي الشتاء والصيف، على التوالي، في الموقع الاول الذي يقع في شمال منطقة الدراسة في حين أن نوعية المياه في الموقع الثاني فهو من النوعية غير الملائمة (unsuitable) في كل فصول الدراسة ومياه الموقع الثالث يمكن تصنيفها كمياه فقيرة (poor) و مياه فقيرة جدا (very poor) في فصلي الشتاء والصيف، على التوالي. لذلك هناك حاجة إلى الرصد المنتظم لنوعية المياه من أجل الكشف عن التغيرات في تراكيز المتغيرات الفيزيائية والكيميائية.

الكلمات المرشدة: دليل الحساب الوزني، دليل نوعية المياه، مياه الشرب، نهر دجلة، الكبريتات.

INTRODUCTION

Water resources are of great environmental issues and studied by a wide range of specialists consisting hydrologists, engineers, ecologists, and geologists [1]. It has become an important issue for them as it affects not only human uses, but also plant and animal life. Potable safe water is absolutely essential for healthy living. It is a basic need of all human beings to get the sufficient supply of safe and fresh drinking water [2]. Rivers in urban areas play a main role in carrying of industrial and municipal wastewater, manure discharges and run-off from agricultural fields and streets, which are responsible for river pollution [3,4]. Nowadays, surface water quality became a critical issue in many countries; therefore, water quality monitoring is necessary for the protection of freshwater resources [5]. Water quality is usually used to describe the condition of the water, including its chemical, physical and biological characteristics, with respect to its suitability for a particular purpose (i.e., drinking, fishing or irrigation) [6,7]. Water quality Index (WQI) is a dimensionless number that combines multiple water-quality factors into a single number and simple terms (e.g., excellent, good, bad, etc.) for reporting to managers and the public in a consistent manner [8]. Factors to be included in WQI model could vary depending on the designated water uses and local preferences. Water quality indices (WQIs) have been developed to combine water quality variables [9- 11]. There are four stages in the development of WQI: 1st-parameter selection 2nd - the transformation of parameters to the same scale 3rd - the development of parametric weightings, and 4th - the selection of an appropriate aggregation function [12,13]. Numerous studies of water quality index for the Tigris River have been recommended by many researchers under different condition [14-17]. However, this research was conducted to evaluate the water quality of the Tigris River for Iraqi standard guideline for drinking water by using the Weighted Arithmetic Index method [9].

Materials and Methods

Study Area

Baghdad is the capital of Iraq at latitude 33° 18′ 0″ North, longitude 44° 24′ 0″ East. Tigris River is the main source of drinking water in Baghdad. It stretches of the Tigris River extends from Al-Tajee in the north of Al-Zafaraniah in the south before the river confluence with Diyala River. The River divides the city into a right (Karkh) and left (Risafa) sections with a flow direction from north to south. The area is characterized by arid to semi-arid climate with dry, hot summers and cold winters; the mean annual rainfall is about 151.8 mm [18].

In order to determine the water quality index, three sites were chosen for sample collection in the study area along the Tigris River from January to June 2013 (Figure 1). As it is described in Table (1), the 1st sample station (S1) was located north of Baghdad, the 2nd station (S2) at the middle part of the city and the 3rd station (S3) was located at the south part.

Table (1). Description of water quality sampling sites

Station No.	Description	Longitude	Latitude
S1	Near to Al-Muthana Bridge	44°20'47.35"E	33°25'41.51"N
S2	Near to Wathba WTP and The Medical City	44°22'20.56"E	33°21'0.64"N
S3	Near to Al-Rasheed Power Plant-2 and State Company for Vegetable Oils Industry	44°27'22.95"E	33°14'0.74"N

Figure (1). Map of Bagdad City illustrates the study sites on Tigris River

Sampling and Analysis

Water sample collection was made monthly from January to June 2013 from three selected sites in the Tigris River. Water samples were collected in stopper fitted polyethylene bottles and refrigerated at 4°C in order to be analysed as soon as possible. pH was measured on the site using portable measuring devices. Procedures followed for analysis have been in accordance with the Standard Method for Examination of Water and Wastewater [19].

The data were merged (seasonal average values for each parameter) to obtain a data set covering two seasons of data for three sites. Water Quality Index was calculated based on the concentration of eleven water quality parameters: pH value, Total Dissolved Solid, Total Hardness, Calcium, Magnesium, Chloride, Turbidity, Nitrite, Nitrate, sulphate, and Zinc

Calculations Water Quality Index (WQI)

Water Quality Index (WQI) is a very useful and efficient method, can provide a simple indicator of water quality and it's based on some very important parameters. In this study, Water Quality Index (WQI) was calculated by using the Weighted Arithmetic Index method as described by [9]. In this model, different water quality components are multiplied by a weighting factor and are then aggregated using simple arithmetic mean. In assessing the quality of water in this study, **firstly**, the quality rating scale (Qi) for each parameter was calculated by using the following equation:

$$Q_i = 100 * \left[\frac{V_{actual} - V_{ideal}}{V_{standard} - V_{ideal}}\right] \quad (1)$$

Where,

Qi = Quality rating of i^{th} parameter for a total of n water quality parameters.

V_{actual} = Actual value of the water quality parameter obtained from laboratory analysis.

V_{ideal} = Ideal value of that water quality parameter can be obtained from the standard Tables.

V_{ideal} for pH = 7 and for other parameters, it is equal to zero, but for DO V_{ideal} = 14.6 mg/l

$V_{standard}$ = Recommended Iraqi standard guidelines of the drinking water [20].

This equation ensures that *Qi* = 0 when a pollutant is totally absent in the water sample and *Qi* = 100 when the value of this parameter is just equal to its permissible value. Thus the higher the value of *Qi* is, the more polluted is the water.

Secondly, after calculating the quality rating scale (Qi), the Relative (unit) weight (Wi) was calculated by a value inversely proportional to the recommended standard (Si) for the corresponding parameter using the following expression:

$$W_i = \frac{K}{V_{standard}} \quad (2)$$

Where,

Wi = Relative (unit) weight for n^{th} parameter.

K = Proportionality constant, K=1/∑ (1/Si).

That means, the Relative (unit) weight (WI) to various water Quality parameters are inversely proportional to the recommended standards for the corresponding parameters.

Finally, the overall WQI was calculated by aggregating the quality rating with the unit weight linearly by using the following equation:

$$WQI = \frac{\sum Q_i{}^{W_i}}{\sum W_i} \qquad (3)$$

Where,

Qi = Quality rating, Wi = Relative weight.

In this study, the water quality index was applied and tested for all the sites on the Tigris River using of Iraqi standard guidelines for drinking water [20]. The standards (permissible values of various pollutants) for the drinking water and unit weights are given in Table 2.

Table (2). The Iraqi standard guidelines for drinking water [20] and Unit Weights

Parameters	Iraqi Standard [20]	Unit Weights (Wi)
pH	6.5-8.5	0.117629
TDS (mg/L)	1000	0.000941
Total Hardness (mg/L)	500	0.001882
Calcium (mg/L)	50	0.018821
Magnesium (mg/L)	50	0.018821
Chloride (mg/L)	250	0.003764
Turbidity (NTU)	5	0.188206
Nitrite (mg/L)	3	0.313676
Nitrate (mg/L)	50	0.018821
Sulfate (mg/L)	250	0.003764
Zinc (mg/L)	3	0.313676

Results and Discussion

In general, WQI is defined for a specific and intended use of water. In this study the WQI was considered for human consumption or uses and the maximum permissible WQI for the drinking water was taken as 100 scores. The classification of water quality types is given according to [21] as shown in Table 3.

Table (3). Water Quality Index categorization schema [21]

Score	**0-25**	**26-50**	**51-75**	**76-100**	**>100**
Water Quality Index	Excellent	Good	Poor	Very Poor	Unsuitable

Applying the equations on the results of water analysis data of the Tigris River, seasonally WQI for three sites in 2013 have been plotted in Figure 2. The results of water quality index showed values in winter 96.1, 129.3, and 77.4, while in summer the values were 127.27, 137.25, and 94.6 in sites 1, 2, and 3, respectively.

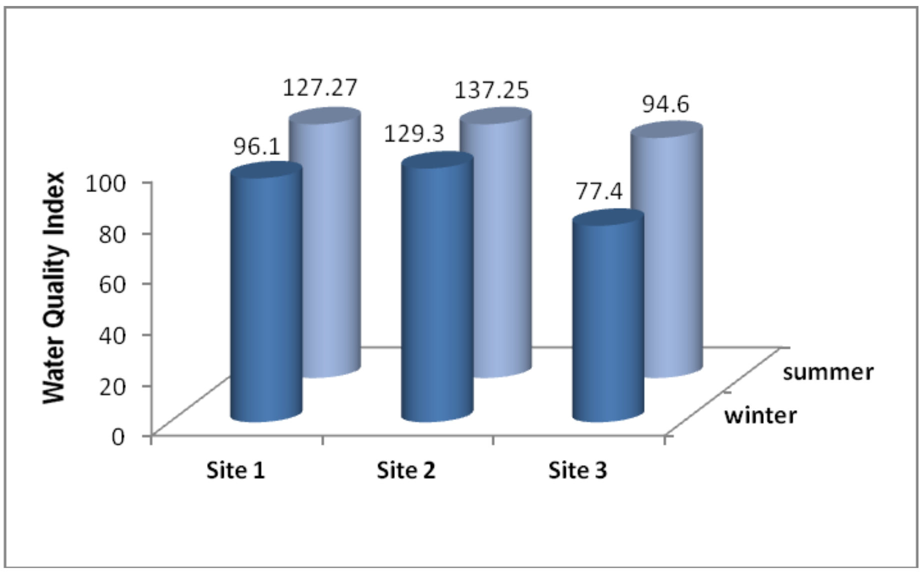

Figure (2). Water quality index for drinking water at different locations along Tigris River

Average values of WQIs indicate that water quality index for drinking uses can be rated as very poor conditions at winter season and unsuitable conditions at summer season in the 1st site which is situated at the north of the study area before entrance the river into Baghdad city, which it means that Tigris river are uploaded by contaminants before its entering the city; while the water quality index on the 2nd site can be categories as unsuitable conditions (> 100) for the human uses during all season of the study, that denoted an increase in pollution due to the discharge of various domestic and industries wastewater and also other anthropogenic hazardous waste from the Medical City.

WQI values indicate that the water quality index can be rated as poor conditions at winter season and very poor conditions of summer season in the 3rd site. Exceeding the

WQI values refer to the following parameters: Calcium, Turbidity, and Sulfate were exceeding the standard value for drinking uses all the time in all sites. Descriptive statistics: the range and (average±standard deviation) of water quality parameters of the study area are presented in Table 4

Table (4). The range and (average±standard deviation) of water quality parameters of study area

Parameter	Site 1	Site 2	Site 3
pH	8.10 - 8.40 8.27±0.126	7.80 - 8.70 8.23±0.44	8.00 - 8.40 8.13±0.19
TDS (mg/L)	10.00 - 641.00 175.25±310.64	10.00 - 584.00 168.50±277.36	6.00 - 600.00 162.25±291.95
Total Hardness (mg/L)	340.00-950.00 576.25±267.99	340.00-910.00 573.75±246.35	310.00-580.00 462.50±112.36
Calcium (mg/L)	80.00-188.37 128.71±44.87	80.10-228.45 140.26±64.40	76.15 - 148.29 111.22±29.52
Magnesium (mg/L)	34.02-116.64 61.96±38.95	34.02-82.62 54.37±20.84	29.16 - 51.03 44.96±10.59
Chloride (mg/L)	34.99 - 94.97 69.98±26.45	24.99-149.00 69.74±54.75	24.99 - 274.90 114.96±110.04
Turbidity (NTU)	14.50-30.90 23.15±6.74	18.80-37.20 28.75±8.88	6.64 - 23.10 16.59 ± 7.32
Nitrite (mg/L)	0.00 - 0.06 0.036±0.027	0.00 - 0.089 0.039±0.037	0.00 - 0.487 0.138±0.233
Nitrate (mg/L)	0.00 - 21.70 8.19 ± 9.58	0.00 - 2.66 0.886±1.253	0.00 - 4.43 1.77±2.17
Sulphate (mg/L)	180.0 -1120.0 473.75±437.36	142.00-2000.00 705.50±868.19	144.00-1960.00 733.50±828.08
Zinc (mg/L)	ND - 0.097 0.061±0.045	ND - 0.368 0.143±0.158	ND - 0.368 0.143±0.158

The pH value is a measure of the intensity of acidity or alkalinity and the concentration of hydrogen ion. pH value has no direct adverse effects on health; however, High pH value induces the formation of tri-halo methane which is toxic. pH value below 6.5 starts corrosion in pipes, thereby releasing toxic metals such as Cd, Cu, Zn, and Pb etc. [22]. The pH values of water samples of present study varied from 7.8 to 8.7 for all sites. These values are within the prescribed limit of standard [20]. Dissolved Solids in natural water are generally consistent from bicarbonate, calcium, magnesium, chloride, sodium and sulfate [23]. The TDS in the Tigris river water in this study varies from 6 to 641 mg/L. However, the results denoted that the mean concentrations of dissolved solid within permissible levels recommended by Iraqi standard guideline value for drinking water [20].

Total Hardness concentration varies from 310 to 950 mg/l, However, the results showed that the mean concentrations of total hardness within permissible levels in all study area except 1st and 2nd sites at winter season, which exceed the permissible level (500 mg/L) recommended by Iraqi standard guideline value for drinking water [20]. The observed mean values of Calcium (Ca^{2+}) concentrations were found well above all the time in all sites, where the values range from (76.15 to 228.45 mg/l). While the observed mean values of Magnesium (Mg^{2+}) concentrations were found within the recommended values for Iraqi standard guidelines all the time except 1st and 2nd sites at winter season (75.33 mg/l) and (63.78 mg/l), respectively, which well above the permissible level (50 mg/l). Chloride concentration varies from 24.99 to 274.90 mg/l, and the mean concentrations of Cl^- ion was within the recommended values for Iraqi standard guidelines all the time.

Turbidity concentration varies from 6.64 to 37.2 mg/l, and the mean concentrations exceeded the recommended values for Iraqi standard guidelines for drinking water (5 NTU) [20] all the time in all sites.

Nitrite and Nitrate are naturally occurring ions in water system that are part of the nitrogen cycle. Nitrate is the stable form of combined nitrogen for oxygenated systems, and can be reduced by microbial action. Nitrite ion contains nitrogen in a relatively unstable oxidation state; many processes can reduce nitrite to ammonia or oxidize it to nitrate [24]. NO_2 concentrations vary from 0.0 to 0.487 mg/l and NO_3 concentration varies from 0.0 to 21.7 mg/l. The result showed that the mean value of NO_2 and NO_3 concentrations within the recommended values for Iraqi standard guidelines all the time. While the mean values of Sulfate (SO_4) concentrations were found to exceed the recommended values (250 mg/l) for Iraqi standard guidelines all the time, where values ranged from 142 to 2000 mg/l.

For the mean values of Zn concentration was within the permissible level (3 mg/l) recommended by Iraqi standard guidelines for drinking water [20] all the time, where value ranged between (ND- 0.368 mg/l). The degree of a linear correlation between the water quality parameters, as measured by the correlation coefficient (R), is presented in Table 5. pH display positive correlation with Ca (0.738) and total hardness display strong correlation coefficient with both Ca and Mg (0.962 and 0.953, respectively) which denotes a strong correlation at the 0.01 significance level, indicates that its occurrence in the surface water was mainly due to natural or anthropogenic sources. Calcium and Chloride are also strongly correlated with Magnesium (0.833) and Sulfate (0.80), respectively. While Nitrite exhibited positive correlations with Zinc (0.755), suggesting it originated from some common sources.

Table (5). The correlation coefficient matrix of all water quality parameters

	pH	TDS	TH	Ca	Mg	Cl	Turb	NO_2	NO_3	SO4	Zn
pH	1										
TDS	-0.469	1									
TH	0.658	-0.271	1								
Ca	**0.738**	-0.221	**0.962**	1							
Mg	0.510	-0.301	**0.953**	**0.833**	1						
Cl	0.101	-0.513	0.173	0.167	0.164	1					

Turb	0.188	-0.062	-0.018	0.065	-0.109	-0.379	1				
NO_2	0.311	-0.178	0.187	0.262	0.087	-0.087	-0.299	1			
NO_3	0.235	-0.177	0.269	0.168	0.357	-0.072	0.042	0.101	1		
SO4	0.308	-0.272	0.631	0.650*	0.553	**0.800**	-0.256	-0.044	-0.089	1	
Zn	0.459	-0.122	0.303	0.382	0.189	-0.146	-0.253	**0.755**	0.058	-0.001	1

Conclusions

Water Quality index (WQI) of the present study for Tigris river was calculated from important various physiochemical parameters in order to evaluate the suitability of water for drinking purposes. The water quality rating of the sampling sites clearly showed that the status of the water was poor and unsuitable for the human uses during the period of study. It has been concluded that the discharging of domestic and industrial wastewater, discharging stormwater, agriculture runoff and also other anthropogenic activities were the main factors for contaminating Tigris River.

References

[1] Kumar, A. and Dua, A. (2009). “Water Quality Index for Assessment of Water Quality of River Ravi at Madhopur, India,” *Global Journal*, 8(1), 49-57, (2009).

[2] Behmanesh, A. and Feizabadi, Y. “Water Quality Index of Babolrood River in Mazandaran, Iran,” *International Journal of Agriculture and Crop Sciences*, 5(19), 2285-2292, 2013.

[3] Al Obaidy, A.H.M.J, Al Mashhady, A.A.M., Awad, E.S., and Kadhem, A.J. “Heavy metals pollution in surface water of Mahrut river, Diyala, Iraq,” *International Journal of Advanced Research*, 2(10), 1039-1044, 2014.

[4] Al Obaidy, A.H.M.J., Maulood, B.K., and Kadhem, A.J. “Evaluating raw and treated water quality of Tigris River within Baghdad by index analysis,” *Journal of Water Resource and Protection*, 2, 629-635, 2010.

[5] Pesce, S.F. and Wunderlin, D.A. “Use of water quality indices to verify the impact of Córdoba city (Argentina) on Suquía river,” *Water Research*, 34, 2915–2926, 2000.

[6] Sargaonkar, A. and Deshpande, V. “Development of an overall index of pollution for surface water based on a general classification scheme in Indian context,” *Environmental Monitoring and Assessment*, 89, 43–67, 2003.

[7] Khan, F., Husain, T. and Lumb, A. “Water quality evaluation and trend analysis in selected watersheds of the Atlantic Region of Canada,” *Environmental Monitoring and Assessment*, 88, 221–242, 2003.

[8] Khwakaram, A.I., Majid, S.N. and Hama, N.Y. “Determination of water quality index (Wqi) for qalyasan stream in Sulaimani city/ Kurdistan Region of Iraq,” *International Journal of Plant, Animal and Environmental Sciences*, 2(4), 148-157, 2012.

[9] Cude, C. “Oregon water quality index: A tool for evaluating water quality management effectiveness,” *Journal of the American Water Resources Association*, 37, 125–137, 2001.

[10] Said, A., Stevens, D., and Selke, G. “An innovative index for evaluating water quality in streams,” *Environmental Management*, 34, 406–414, 2004.

[11] Liou, S., Lo, S. and Wang, S. "A generalized water quality index for Taiwan," *Environmental Monitoring and Assessment*, 96, 35–52, 2004.

[12] Al Obaidy, A.H.M.J., Al-Janabi, Z.Z. and Shakir, E. "Assessment of water quality of Tigris River within Baghdad city," *Mesop. Environ. j.*, 1(3), 90-98, 2015.

[13] Al Obaidy, A.H.M.J, Awad, E.S., Kadhem, A.J. and Al Mashhady, A.A.M. "Evaluating water quality of Mahrut river, Diyala, Iraq for irrigation," Eng. &Tech.Journal, 33A(4), 830-837, 2015.

[14] Alsaqqar A.S., A.S., Hashim, A. and Ali A.M. "Water quality index assessment using GIS case study: Tigris River in Baghdad city," *International Journal of Current Engineering and Technology*, 5(4), 2515-2520, 2015.

[15] Flaieh, H.M., Mohammed-Ridha, M.J. and Abdul-Ahad, M.Y. "Assessing Tigris River water quality in Baghdad city using water quality index and multivariate statistical analysis," *International Journal Of Engineering Sciences & Research Technology*, 3(7), 687-699, 2014.

[16] Hassan, F.M., AL-Zubaidi N.A.J. and Al- Dulaimi W.A.A. "An ecological assessment for Tigris River within Baghdad, Iraq," *Journal of Babylon Univ*. Special Issue -Proceding of 5th International Conference of Environmental Science, University of Babylon/ Environmental Research Center, 3-5 December, 26-30, 2013.

[17] Al-Janabi Z.Z., Al-Kubaisi, A. and Al-Obaidy A.H.M.J. "Assessment of water quality of Tigris River by using water quality index (CCME WQI)," *Journal of Al-Nahrain University*, 15(1), 119-126, 2012.

[18] Al-Adili, A.S. "Geotechnical Evaluation of Baghdad Soil Subsidence and their Treatments," Ph.D. Thesis, University of Baghdad, Iraq. (1998).

[19] APHA, AWWA and WEF Standard Methods for Examination of Water and Wastewater, 21st Edition, American Public Health Association, Washington DC, 2005.

[20] Standard Specification of Drinking Water, Iraq. IQS (no.417), First modernization, the Council Of Ministers, Central Organization for Standardization and Quality Control, 5pp. [in Arabic], 2001.

[21] Tiwari, T. N. and Mishra, M. "A preliminary assignment of water quality index of major Indian rivers," *Indian Journal of Environmental Protection*, 5(4), 276-279, 1985.

[22] Trivedi, R.K and Goel, P.K. Chemical and Biological Methods for Water Pollution Studies, Environmental Publication, India, 1986.

[23] Charles, E.R. Investigating Water Problems: A Water Analysis Manual. Publishing by LaMotte Chemical Products Company, Chestertown, Maryland. 72pp, 1970.

[24] ICAIR Life Systems, Inc. Drinking water criteria document on nitrate/nitrite, Washington, DC, United States Environmental Protection Agency, Office of Drinking Water, 1987.