Volume 11 Number 1 2016

ISSN 1816-9848

MARSH BULLETIN

College of Science and Marine Science Center -
University of Basrah

Evaluation of Water Quality by Applying Potable Water Supply Index (PWSI) and Geographical Information System (GIS) in Himreen Dam Lake, Iraq

Raaed S. Attee* and Laith F. Lazem**

**Department of animal production, College of Agriculture, Diyala University, Iraq*
***Department of Science, Open Educational College in Basrah, Iraq*
***E-mail: alhlfi@yahoo.com*

Abstract

The present study investigates the potential application of geographical information systems (GIS) and spatial analysis techniques to evaluate the water quality of Himreen Dam Lake. The Canadian version of WQI was applied in this study to assess the water quality of the Lake as Potable Water Supply Index (PWSI). The study was executed seasonally from summer 2014 to spring 2015. A total of 14 parameters were selected for water quality, namely: potential hydrogen ion (pH), electrical conductivity (EC), total dissolved solid (TDS), turbidity (Tur), dissolved oxygen (DO), total alkalinity (Alk), total hardness (Hrd), sodium (Na), calcium (Ca), magnesium (Mg), chloride (Cl), sulphate (SO_4), nitrate (NO_3) and fecal coliform bacteria (FC). The results showed that the pH ranged from 7.1- 7.9, EC varied from 558- 864 µS/cm and TDS ranged between 322- 522 mg/l. Turbidity differed from 3.3- 7.2 NTU and the dissolved oxygen range from 7- 12.1 mg/l. Total alkalinity changed from 24- 126 mg/l as CaCO3. Values of total hardness ranged between (221- 375) mg calcium carbonate/L. The ranges of sodium, calcium, magnesium, chloride, sulphate and nitrate were 13- 34 mg/l, 32.27- 86.34 mg/l, 35- 67.8 mg/l, 29- 88 mg/l, 129- 254 mg/l and 0.9- 3.6 µg N-NO3/l respectively. Fecal coliform bacteria ranged between (325- 3750) CFU/ 100 ml. Values of the potable water supply index (PWSI) ranged from 48.71 to 49.2 for all stations accordingly categorized as four grades (Marginal). The highest value was (49.2) in the second station while the lowest value (48.71) in the first station.

Keywords: Water Quality Index, Himreen Dam Lake, GIS, Iraq

Introduction

Surface water - lakes, rivers, streams - for most of the history of human life on this planet are the main source of water for communities (Diamond, 2011). Himreen Dam Lake is freshwater lakes in Iraq. It was built for flood control of Diyala River to protect the wide land plain for beneath Diyala

basin, as well as organizing the irrigation drainage and power generation needs (Saadalla, 1988).

Water quality is an important criterion to assess the health of a watershed and to take necessary management decisions to control current and future pollution received by water bodies (Behbahaninia *et al*., 2009). Thus, information on water quality is an important target for implementation of sustainable water-use management strategies (Bu *et al*., 2010). Furthermore, Nithyanandam (2015) concluded that WQI used as an indicator of water pollution by providing feedback on the quality of water to the policy makers and environmentalist. The water quality index is important to be measured in order to determine the health of the water body before consuming or safe to use for other purposes.

Many studies apply WQI (Canadian version) to evaluate water quality in Iraq, as in the study of Al-Obaidy *et al*. (2010a, b), Abd (2010), Hussain *et al*. (2010), Al-Saboonchi *et al*. (2011), Al-Meini (2010), Moyel (2010) and Eassa and Mahmood (2012). Several studies applied GIS to evaluate the quality of water in Iraq, as Salih *et al*. (2008), Sail *et al*. (2008), Abbas and Ziboon (2010), Jaber (2012) and Lazem (2014). The aim of present work is to calculate the water quality index (WQI) of the Himreen Dam Lake in order to assess water suitability for human uses and design a GIS database system for the Himreen Dam Lake.

Materials and methods

Three stations were chosen to execute the study from Himreen Lake (Fig. 1). Station 1 (495459 E, 3795485 N meters), station 2 (501870 E, 3781684 N meters) and station 3 (508469 E, 3770162 N meters).

Water samples were collected seasonally from each station from summer 2014 to spring 2015. At each location, the GPS waypoint was collected for spatial reference. Potential hydrogen ion (pH) values

were measured by a GTC pH-meter. Electrical Conductivity (EC) values were determined by using a Bischof 117 EC-Meter, Turbidity (Tur) level by using turbidity-meter. Nitrates (NO_3) were measured following the method described in Parsons *et al*. (1984). Analytical methodologies were used in the analysis of the different parameters (total dissolved solid (TDS), dissolved oxygen (DO), total alkalinity (Alk), total hardness (Hrd), sodium (Na), calcium (Ca), magnesium (Mg), chloride (Cl), sulphate (SO_4) and fecal coliform bacteria (FC)) were defined by the Standard Methods for the Examination of Water and Wastewater (APHA, 2005).

Water quality index (WQI)

The Canadian Water Quality Index (CCME WQI) was applied in the present study as Potable Water Supply Index (PWSI). A total of 14 parameters were measured in this work and were considered in calculating the PWSI. The Iraqi drinking water standard, No. (417) for the year 2001 and WHO (2008) standards were considered in the current study to assess the scope of water quality of the Himreen lake. The formulation of the WQI as specifies in the Canadian Water Quality Index 1.0-technical report (CCME, 2001) is as follows.

1. **F_1** (Scope): represents the percentage of variables that do not meet their objectives at least once during the time period under consideration (failed variables), relative to the total number of variables measured:

$$F_1 = (\text{Number of failed variables} / \text{Total number of variables}) \times 100$$

2. **F_2** (Frequency): represents the percentage of individual tests that do not meet objectives (failed tests):

$$F_2 = (\text{Number of failed tests} / \text{Total number of tests}) \times 100$$

3. **F_3** (Amplitude): represents the amount by which failed test values do not meet their objectives. F_3 is calculated in three steps.

a) The number of times by which an individual concentration is greater than (or less than, when the objective is a minimum) the objective are termed an excursion and is expressed as follows. When the test value must not exceed the objective:

Excursion = (Failed Test Value / Objective) -1

For the cases in which the test value must not fall below the objective:

Excursion = (Objective / Failed Test Value) -1

b) The collective amount by which individual tests are out of compliance was calculated by summing the excursions of individual tests from their objectives and dividing by the total number of tests (both those meeting objectives and those not meeting objectives). This variable, referred to as the normalized sum of excursions (nse), is calculated as:

$$nse = \sum_{i=1}^{n} excursion / Number\ of\ tests$$

c) F_3 is then calculated by an asymptotic function that scales the normalized sum of the excursions from objectives (nse) to yield a range between 0 and 100.

$$F_3 = nse / (0.01\ nse + 0.01)$$

The CCME Water Quality Index (CCME WQI):

$$WQI = 100 - \sqrt{(F_1^2+F_2^2+F_3^2)} / 1.732$$

The divisor 1.732 normalizes the resultant values to a range between zero and 100, where zero represents the worst water quality and 100 represent the best water quality. Once the WQI value has been determined, water quality was ranked by relating it to one of the following categories (Table 1).

Table (1): WQI categorization

Category	Index value	Description
Excellent	95-100	Very close to natural or pristine levels.
Good	80-94	Rarely depart from natural or desirable levels.
Fair	65-79	Sometimes depart from natural or desirable levels.
Marginal	45-64	Often depart from natural or desirable levels.
Poor	0-44	Usually depart from natural or desirable levels.

Results of water parameters at all stations were treated by using two statistical programs, SPSS (version 19). Whereas the multiple linear correlation analysis has carried out on water parameters to verify if there is any significant relationship by applying the multivariate analysis of ecological data using CANOCO program (Version 4.5; Cajo J. F. ter Braak, 2004). Geographic analyses were carried out in ArcGIS 9.3 to produce the spatial distribution of water quality over the lake.

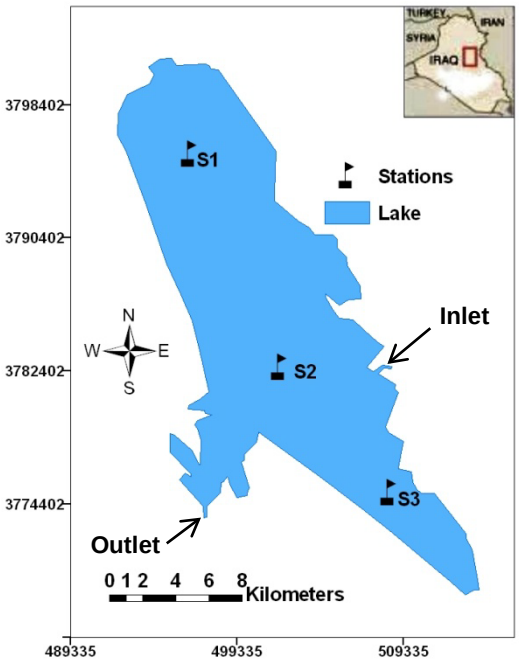

Fig. 1: Map of Himreen Dam Lake showing the study sites.

Results

Table 2 illustrates the seasonal variations of all water parameters among stations and the statistical details in Himreen Lake during the study period.

Table (2): seasonal variations of all water parameters among stations and statistical summary in Himreen Lake

		pH	EC (µS/cm)	TDS (mg/l)	DO (mg/l)	T Alk. (mg/l)	Har (mg/l)	Na (mg/l)	Ca (mg/l)	Mg (mg/l)	Cl (mg/l)	$SO4^{=}$ (mg/l)	$NO3^{-}$ (µg/L)	Tur (NTU)	E coli (CFU/ 100 ml)
S1	Sum	7.55	864	522	8	126	238	23	62.52	39	47	254	2.2	6.7	3400
	Aut	7.4	746	322	8.8	47	221	25	42.86	43.8	32	129	1	5.1	1650
	Win	7.7	558	387	12.1	24	350	17	86.34	36	41	162	0.9	3.8	620
	Spr	7.8	765	411	9.5	28	375	13	78.23	35	35	177	1.1	4.6	1100
S2	Sum	7.72	840	512	7	122	306	26	56.92	40.3	48	210	1.1	6.1	2950
	Aut	7.5	732	380	8.4	59	269	20	48.11	36.5	38	163	1	5.4	1945
	Win	7.2	722	425	10	53	344	13	33.12	63.8	81	143	1	3.3	430
	Spr	7.9	773	406	8.2	34	321	18	37.91	61.2	31	185	1.4	3.5	925
S3	Sum	7.33	833	505	7.6	117	363	34	53.01	39	46	218	1.5	7.2	3750
	Aut	7.8	739	345	9.1	51	294	18	32.27	37.7	29	143	1	4.9	2050
	Win	7.1	662	391	12	29	347	19	55.2	54.5	88	171	1	4.1	325
	Spr	7.77	782	419	8.6	36	363	15	36.32	67.8	37	180	3.6	3.9	475
Min		**7.1**	**558**	**322**	**7**	**24**	**221**	**13**	**32.27**	**35**	**29**	**129**	**0.9**	**3.3**	**325**
Max		**7.9**	**864**	**522**	**12.1**	**126**	**375**	**34**	**86.34**	**67.8**	**88**	**254**	**3.6**	**7.2**	**3750**
Mean		**7.56**	**751.33**	**418.75**	**9.11**	**60.5**	**315.92**	**20.08**	**51.9**	**46.22**	**46.08**	**177.92**	**1.4**	**4.88**	**1635**
Standard Deviation		**0.26**	**82.9**	**64.06**	**1.59**	**38.47**	**51.1**	**6.08**	**17.33**	**12.1**	**19.06**	**35.46**	**0.78**	**1.27**	**1203.05**

Water quality index (WQI)

Figures 2 illustrate geographic analyses pattern of PWSI values. The Canadian Water Quality Index (WQI) provides a modest difference in WQI values between stations. Values found to range from 48.71 to 49.2 that categorized as marginal during the whole study period. The lowest value of WQI was 48.71 recorded at station 1 and the highest was 49.2 encountered from station 2. The overall value of PWSI in Himreen Lake is 48.88 (Fig. 3).

The environmental habitat vectors on the principal components analysis (PCA) ordination plot represent the relationships between the

distributions of the environment variables in the Himreen Lake are given in Figure 4. Fecal coliform bacteria were a greater impact factor on the WQI compared with other factors. Red-solid rows are describing the parameters that affect the WQI in Himreen Lake.

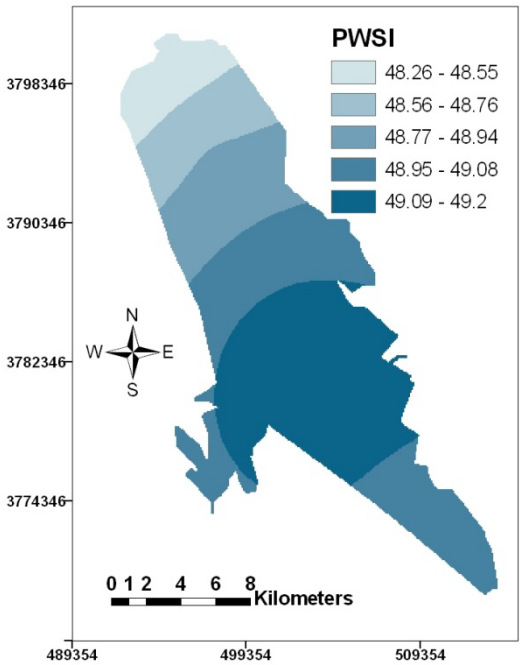

Fig. 2: Geographic analyses pattern of PWSI values in Himreen Lake

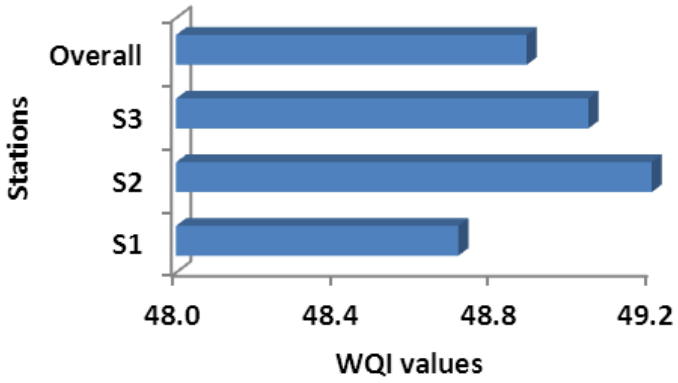

Fig. 3: PWSI values in Himreen Lake

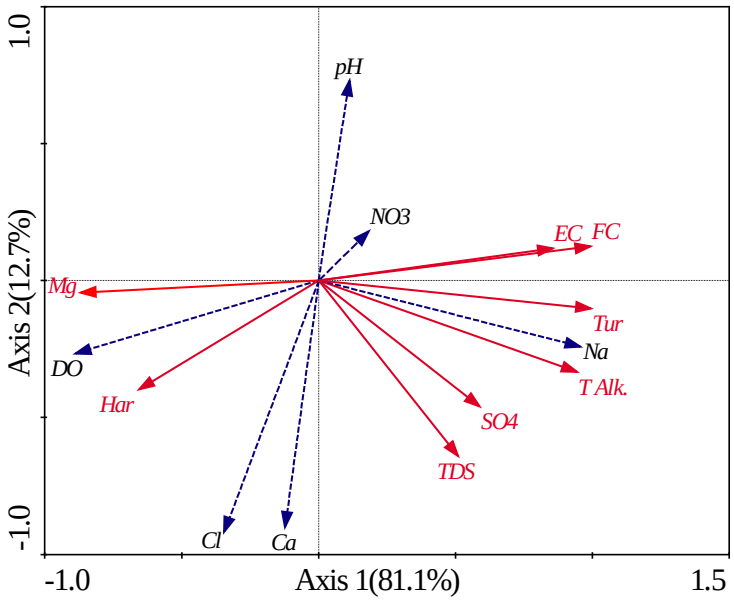

Fig. 4: PCA ordination plots showing the relationship among various ecological factors in the Himreen Lake

Discussion

Expanding human population brought about by the chances of good water supply, irrigation, fish production, recreation and navigation offered by reservoirs has put massive pressure and stress on the quality of water impounded by the reservoir (Mustapha, 2008).

Results revealed that all parameter values not exceed the standards were considered in the current study, except total hardness, electrical conductivity and fecal coliform bacteria. These affected the water quality of the Lake. Insignificant differences ($p > 0.05$) were detected in all parameters values among stations, except one Significant difference ($p<0.05$, $F= 3.557$) in calcium values were recorded between station 1 and the other stations .

The geographic analysis did not deduce a clear spatial change in values of water quality (PWSI). However, water quality at all stations categorized as marginal during the whole study period. This may relate, in general, to low water levels and increases in hardness, electrical conductivity and fecal coliform bacteria.

Hard water is usually defined as water, which contains of a high concentration of calcium and magnesium ions. However, several other dissolved metals can cause hardness; those forms divalent or multivalent cations, including aluminum, barium, strontium, iron, zinc, and manganese (Sengupta, 2013). Results of the current study showed that the water is very hard according to the classification of Lind (1979). This is in agreement with Al-Kinany and Almukhtar (2014) findings.

Sirajudeen and Vahith (2014) pointed out that the importance of Electrical Conductivity (EC) is due to its measure of cations that greatly affects the taste and thus has a significant impact on the user acceptance of the water as potable. It is an indirect measure of total dissolved salts. Electrical conductivity values increase during the study period may be due to the decline of water levels and increase the proportion of evaporation, or may have due to an anthropogenic source. This coincides with Ali (2010) finding.

Selvakumar (2006) cited that the microbial contamination of water is often of fecal nature related to humans (sewage water). Furthermore, microbial pollution in aquatic environments is one of the crucial issues with regard to the sanitary state of water bodies used for drinking water supply due to a potential contamination with pathogenic bacteria (Jung, 2014). Fecal coliform numbers in the study area were a great rise in general. This may associate with high values of turbidity water (strongly correlated with turbidity (r= 0.9)). Irvine *et al*. (2002) indicated that a positive correlation between turbidity and coliform, the suspended and colloidal matter which caused turbidity, become a hotbed for the growth, collect and protect bacteria from drifting with currents (Liu, *et al*., 2000). The Decrease in a number of coliforms measured in winter at all stations may due to low temperatures and

reduce sewage water disposal. The findings of the present study deduced that the water quality of Himreen Lake is unsuitable for use without extensive treatment.

Acknowledgments:

Many thanks goes to Prof. Dr. Sadek A. Hussein for reading the manuscript.

Reference

Abbas, A. and Ziboon, A. R. T. (2010). Using remote sensing and GIS technique to study soil physical properties for Hour Al-Hammar (South of Iraq). Eng. and Tech. J., 28 (1): 164-180.

Abd, I. M. (2010). Ecological assessment of Chebaish marsh by adopting environmental and biological indices. Ph.D. thesis, College of Agric., Univ. of Basrah, Iraq. 123p (In Arabic).

Ali, L. A. (2010). Seasonal variation in physico-chemical properties and zooplankton biomass in Greater Zab River –Iraq. Jordan J. Bio. Sci., 3(3): 115-120.

Al-Kinany, D. M. A. H. and Almukhtar, E. A. (2014). Organic Content in the Sediments of Tigris and Diyala Rivers, south of Baghdad, and its Relationship with some Environmental factors, Benthic Invertebrates Groups and Values of Diversity Indices. J. Bagdad Sci., 11 (3): 1354-1360

Al-Meini, A. J. K. (2010). A proposed index of water quality assessment for irrigation. Eng. and Tech. J., 28(22): 6557-6579.

Al-Obaidy, A. H. M. J.; Abid, H. S. and Maulood, B. K. (2010a). Application of water quality index for assessment of Dokan Lake ecosystem, Kurdistan region, Iraq. J. Wat. Res. and Prot., 2: 792-798.

Al-Obaidy, A. M. J.; Maulood, B. K. and Kadhem, A. J. (2010b). Evaluating raw and treated water quality of Tigris River within Baghdad by index analysis. J. Wat. Res. and Prot., 2: 629-635.

Al-Saboonchi, A.; Mohamed, A. R. M.; Alobaidy, A. H. M. J.; Abid, H. S. and Maulood, B. K. (2011). On the Current and Restoration Conditions of the Southern Iraqi Marshes: Application of the CCME WQI on East Hammar Marsh. J. Envi. Prot., 2: 316-322.

APHA (American Public Health Association) (2005). Standard method for the examination of water and waste water - 21th edition. Washington, D. C. 1193p.

Behbahaninia, A.; Mirbagheri, S. A.; Khorasani, N.; Nouri, J. and Javid, A. H., (2009). Heavy metal contamination of municipal effluent in soil and plants. J. Food, Agric. Environ., 7(3-4): 851-856.

Bu, H.; Tan, X.; Li, S. and Zhang, Q. (2010). Temporal and spatial variations of water quality in the Jinshui River of the South Qinling Mts., China. Ecotox. Environ. Safe., 73(5): 907-913.

CCME (Canadian Council of Ministers of the Environment) (2001). Canadian water quality guidelines for the protection of aquatic life: CCME Water Quality Index 1.0, User's Manual. In: Canadian environmental quality guidelines, 1999. Canadian Council of Ministers of the Environment, Winnipeg, 5p.

Diamond, M. G. (2011) Water resources assessment and Geographic Information System (GIS)-based storm water runoff estimates for artificial recharge of freshwater aquifers in New Providence, Bahamas. FIU Electronic Thesis and Dissertations. 396p.

Drinking-Water Standard (2001) IQS: 417, Central Organization for Quality Control and Standardization, Council of Ministers, Republic of Iraq.

Eassa, A. M. and Mahmood, A. A. (2012). An assessment of the treated water quality for some drinking water supplies at Basrah. J. Basrah Res. (Sci.), 38 (3-A): 95-105.

Hussain, N. A.; Resin, A. K.; Tahir, M. A. and Moyle, M. S. (2010). Water quality index (WQI) for three southern restored marshes (East Hammar, Al-Huwaza, Suq Al-Shouykh) during the years 2005, 2006, 2007 and 2008. Proc. 6th Int. Con. Biol. Sci. (Zool.), 6: 438-443.

Irvine, K. N.; Somogye, E. L. and Pettibone, G. W. (2002). Turbidity, suspended solids, and bacteria relationships in the buffalo river watershed. Middle States Geographer, 35:42-51.

Jaber, H. S. (2012). A Geographic Information System application for water resources of Iraq. J. Eng. and Devel., 16 (1): 23-31.

Jung, A. V.; Le Cann, P.; Roig, B.; Thomas, O.; Baures, E. and Thomas, M. F. (2014). Microbial Contamination Detection in Water Resources: Interest of Current Optical Methods, Trends and Needs in the Context of Climate Change. Int. J. Environ. Res. Public Health 11: 4292-4310

Lazem, L. F. (2014). Ecological evaluation of the Shatt Al-Arab River and fish assemblage by applying geographical information system (GIS). Ph.D. thesis, Coll. of Agric., Univ. of Basrah, Iraq, 134p.

Lind, O. T. (1979). Handbook of common method in Limnology- 2nd edition. The C.V. Mosby Co., ST. Louis. 199 pp.

Liu, Q.; Mamcl, K. M. and Tuovinen, O. H. (2000). High fat waste water remediation using layered sand filter biofilm system. In: proceeding of the einghth international symposiumon animals, Agricultural and Food proceeding wastes. Iowa Nils Road . St. Joseph, Mich. ASAE. P: 242-248.

Moyel, M. S. (2010).Assessment of water quality of the northern part of Shatt Al-Arab River, using water quality index (Canadian version). M.Sc. thesis, Coll. of Science, Univ. of Basrah, 100p.

Mustapha, M. K. (2008). Assessment of the water quality of Oyun Reservoir, Offa, Nigeria, using selected physico-chemical parameters. Turkish J. fish. & Aqua. Sci., 8: 309-319

Nithyanandam, R.; Huan, T. W. and Thy, N. H. T. (2015). Case Study: Analysis of water quality in Sungai Batu Ferringhi. J. Engi. Sci. & Tech. EURECA 2014 Special Issue, 15- 25.

Parsons, T. R., Matia, Y. and Lalli, C. M. 1984. A manual of chemical and biological methods for sea water analysis. Pergamon press. Oxford, 360pp

Saadalla, H. A. A. (1988). Ecological Study on the Effect of Himreen Impoundment on the Benthic and plankton Invertebrates of River Diyala. Ph.D. Thesis, University of Baghdad, Iraq. 254p.

Sail, K. N.; Al-Nuami, A. S. and Abd Al-Aziz, B. (2008). Assessment water quality of Al-Habania reservoir by using Remote Sensing Techniques and Geographical information system. Iraqi J. Civil Eng., 11: 27-38.

Salih, S. A.; Al-Hadithy and Al-Nuami, A. S. (2008). Water quality assessment of Haditha Dam lake-western Iraqi desert using remote sensing and GIS techniques. Iraqi J. Desert Research, 1(1): 15p.

Selvakumar, A.; Borst, M. J. (2006). Variation of microorganism concentrations in urban stormwater runoff with land use and seasons. J. Water Health, 4: 109-124.

Sengupta, P. (2013). Potential Health Impacts of Hard Water. International

Journal of Preventive Medicine, 4(8), 866–875.

Sirajudeen, J. and Vahith, A. R. (2014). Water quality assessment of groundwater resources between Tamilnadu and Pondicherry states, India. World Journal of Pharmacy and Pharmaceutical Sciences, 3 (7): 881-893.

WHO (2008). Guidelines for drinking-water quality [electronic resource]: incorporating 1st and 2nd addenda, Vol.1, Recommendations. 3rd ed. World Health Organization, Geneva. 515 pp.

تقييم نوعية المياه بتطبيق دليل تجهيز مياه الشرب (PWSI) ونظم المعلومات الجغرافية (GIS) في بحيرة سد حمرين، العراق

رائد سامي عاتي* ليث فيصل لازم**

* قسم الانتاج الحيواني، كلية الزراعة، جامعة ديالى، العراق
** قسم العلوم، الكلية التربوية المفتوحة- البصرة، العراق

المستخلص

بينت الدراسة إمكانية تطبيق نظم المعلومات الجغرافية (GIS) وتقنيات التحليل المكاني لدعم دراسة نوعية المياه للبحيرات. طبق النموذج الكندي في هذه الدراسة كدليل لتجهيز المياه الصالحة للشرب لتقييم نوعية المياه في بحيرة حمرين. انجزت الدراسة للمدة من صيف 2014 إلى ربيع عام 2015. اختير 14 عامل بيئي لتقييم نوعية المياه، وهي: الاس الهيدروجيني (pH)، التوصيلة الكهربائية (EC)، المواد الصلبة الذائبة (TDS)، العكارة (Tur)، الأوكسجين الذائب (DO)، القاعدية الكلية (Alk)، العسرة الكلية (Hrd) والصوديوم (Na)، الكالسيوم (Ca)، المغنسيوم (Mg) والكلوريد (Cl)، الكبريتات (SO_4)، النترات (NO_3) وبكتيريا القولون البرازية (FC). تراوحت قيمة الاس الهيدروجيني بين 7.1- 7.9، والتوصيلية الكهربائية من 558- 864 مايكروسيمنز/ سم وكانت قيم الـ TDS بين 322- 522 ملغم/ لتر. والكدرة من 3.3- 7.2 NTU، و الأوكسجين الذائب 7- 12.1 ملغم/ لتر. تراوحت القاعدية الكلية من 24- 126 ملغم/ لتر. وتراوحت قيم العسرة الكلية بين 221- 375 ملغم كربونات الكالسيوم/ لتر. وقيم كل من الصوديوم، والكالسيوم، والمغنيسيوم، والكلوريد، والكبريتات والنترات من 13- 34 ملغم/ لتر، 32.27- 86.34 ملغم/ لتر، 35- 67.8 ملغم/ لتر، 29- 88 ملغم/ لتر، 129- 254 ملغم/ لتر و 0.9- 3.6 ميكروغرام ذرة نترات/ لتر على التوالي. وتراوحت بكتيريا القولون البرازية بين (325- 3750) خلية/ 100 مل. تراوحت قيم دليل تجهيز مياه الشرب من 48.71 الى 49.2 لجميع المحطات اذ صنفت ضمن الفئة الرابعة (هامشية). وكانت أعلى قيمة 49.2 في المحطة الثانية بينما سجلت أدنى قيمة 48.71 في المحطة الأولى.