RESEARCH PAPER

Assessment of Groundwater Quality over the Erbil Plain Based on Water Quality Index

Bakhtyar A. Othman, Esmail S. Ibrahim

1. Department of Biology, Koya University, Koya KOY45, Kurdistan Region – F.R. Iraq.

ABSTRACT:

Groundwater is used for drinking, household and agricultural activities by the growers surrounding Erbil city. Therefore, it was necessary to determine its quality by measuring physical and chemical parameters according to standard method. Thus, water samples have been collected from sixteen wells during December 2016, March, Jun, and September 2017 within 1 liter polyethylene bottles and transported to the laboratory for analysis and analyzed according to Canadian Water quality Index Formula (WQI). The WQI of groundwater was based on 22 parameters including pH, electrical conductivity, total hardness, calcium hardness, magnesium hardness, total alkalinity, chloride, dissolved oxygen, biological oxygen demand, sodium, potassium, sulphate, orthophosphate, nitrate, oil and grease, zinc, copper, iron, nickel, lead, cadmium and mercury. WQI was found to be 38.87, which indicates a poor quality that the water was not suitable for direct consumption and must be treated before use to avoid water-related diseases.

KEY WORDS: Erbil plain, groundwater quality, physicochemical characteristics, and water quality index.

DOI: http://dx.doi.org/10.21271/ZJPAS.33.s1.1
ZJPAS (2021), 33(s1):1-10.

1. INTRODUCTION:

Clean and safe water is vital to the survival of living organisms and the smooth functioning of ecosystems, communities, and economies. Declining water quality has become a global challenge of concern as populations grow, industrial and agricultural activities expand, and climate change threatens causes significant alterations to the hydrological cycle (Krishan et al., 2016). Both natural processes and human activities influence the quality of water. Water naturally contains dissolved substances, non-dissolved particulate matter, and living organisms; indeed, such materials and organisms are necessary components of good-quality water, as they help maintain vital biogeochemical cycles. Occurring substances trigger water quality challenges detrimental to ecological health (Poonam et al., 2013). Agriculture and industrial activities increase groundwater pollution, especially using a high amount of fertilizers and pesticides during farming. It has been estimated that less than 0.1% of the product applied to crops reaches the target pest, the rest enters the environment gratuitously, contaminating soil, water, and air where it can poison or otherwise adversely affect non-target organisms. The presence of a large number of petroleum projects around agricultural land area caused an increasing concentration of oil and grease, and sulfate in groundwater (Marouane et al., 2014).

The water quality of any specific area or specific water resource can be assessed using physical, chemical, and biological parameters. The values of these parameters are harmful to human health if they exceed than a defined limit. Therefore, the

* Corresponding Author:
Bakhtyar A. Othman
E-mail: bakhtyar.abdullah@koyauniversity.org

Article History:
Published: 15/03/2021
suitability of water resources for human consumption can be described in terms of water quality index (WQI) that provides a single number that expresses overall water quality at a specific location and time, based on several water quality parameters. WQI reduces the bulk of information into a single value to show the data, and logically that is understandable by the public agencies (Tyagi et al., 2013). Agricultural activities in Erbil city depends on groundwater with inappropriate farming practices, using a high amount of fertilizer and pesticides, especially in greenhouse cultivations. Massive extraction of groundwater, the rapid development of oil refinery and petrochemical factories around agricultural land without any environmental specifications, caused decreasing groundwater level and altering physical and chemical characteristics in ways that can threaten ecosystem integrity and human health.

Accordingly, this study was initiated to investigate the groundwater quality in Erbil south plain by analyzing different physical and chemical parameters that existed and reviewed some of the significant water quality variables used in water quality assessment and provides their mathematical structure, set of parameters, and calculations along with their merits and demerits, which used worldwide.

### 2. Materials and Methods

Groundwater samples were collected from 16 wells that scattered within the south and west Erbil plain. Depth of groundwater level ranges from 48m to 165 m that used for irrigation, drinking, and household purposes without any treatments. Studied sites located within villages of: Jmka, Dhemat, Meer, Grdazaban, Perdawd, Sherawa, Quchabibas, Qarachnagha, Murtka, and Sablakh. The water samples were collected in December 2017, March, Jun, and September 2018 and stored polyethylene bottles at 4°C and kept until use. Next the samples were analyzed for the following variables: potential hydrogen (pH), electrical conductivity (EC), total hardness, calcium hardness, magnesium hardness, alkalinity, chloride (Cl), dissolved oxygen (DO), biological oxygen demand (BOD$_5$), oil and grease (O&G), sodium (Na), potassium (K), sulphate (SO$_4$), orthophosphate (PO$_4$), nitrate (NO$_3$), lead (Pb), cadmium (Cd), and mercury (Hg). During the investigation, the Canadian water quality index (CWQI) has calculated by using the World Health Organization (WHO, 2008 and UNEPA, 2018) standards for drinking water quality.

CWQI calculated by using three leading factors: F$_1$ means (Scope): The percentage of variables that exceed the guideline:

$$F_1 = \frac{\text{number of failed variables}}{\text{total number of variables}} \times 100$$

F$_2$ means (frequency): The percentage of individual tests with each parameter that exceeded the guideline:

$$F_2 = \frac{\text{number of failed tests}}{\text{total number of tests}} \times 100$$

F$_3$ means (Range): This factor represents the number of failed experiments that do not meet their objectives and calculated in three steps:

First, the excursion calculated:

$$\text{Excursion} = \frac{\text{failed test value}}{\text{guideline value}} - 1$$

Second, the normalized sum of excursions (nse) is calculated as follows:

$$\text{nse} = \frac{\sum_{i=1}^{n} \text{excursion}}{\text{total number of tests}}$$

F3 is then calculated using a formula that scales the nse to range between 1 and 100: $F_3 = \frac{nse}{0.01nse+0.01}

The CWQI equation was calculated using three factors as follow:

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

### 3. Results and Discussions

The pH value of groundwater samples in this study has ranged between 6.89 and 8.87. All water samples were found to be in the permissible range of pH value recommended by WHO except for one sample on-site 15 during September. All the samples were shown on the alkaline side of neutrality throughout the study period with statistically significant differences at P<0.01 show figure 1. The obtained results were similar to (Appavu et al., 2016; Toma et
EC used for indicating the total concentration of ionized constituents of water. EC fluctuated between 306-1421 μS/cm during the studied period, with the statistically significant difference among them at P<0.01 (Figure 1). It seems that in some cases water EC was above permissible limits of WHO, and it could be an indicator of intrusion of pollutants to groundwater, and increasing EC value during dry season due to decreasing groundwater level and rising dissolved ions, as suggested by (Al-Barzingly, 2018; Appavu et al., 2016; Toma et al., 2013; GEMS, 2007).

T. Alkalinity in the investigated water samples ranged from 82 to 372 mg CaCO₃/l, and there were statistically significant differences at P<0.05 among studied samples (figure 1) except for the samples that had collected from December to June. Alkalinity of some examples are higher than WHO allowable limits, due to the variability between consecutive measurements among the sites which was most likely caused by seasonal controls on the groundwater levels and fluctuation its scale, with mixing of organic and inorganic discharges through industrial and agricultural activities, same observations were discussed by (Ahmad and Faizan, 2014; Toma et al., 2013; Yogendra and Puttaiah., 2008). Chlorides occur naturally in water. The high concentration of chlorides is considered an indicator of pollution by organic wastes of animal or industrial origin. Chlorides are troublesome in irrigation water and also harmful to aquatic life. Chloride concentration within collected samples was ranged from 29.17 to 139.44 mg/l with a statistically significant difference at P<0.05 among studied samples (Figure 1) during the studied period. The low concentration of chloride may be due to geological formation of studied sites and deeps of groundwater level (Sayyed and Bhosle, 2011), which were within the acceptable limit as prescribed by WHO, that similar to (Chandra et al., 2017; Dhok et al., 2013) results.

Water hardness is an essential consideration in determining the suitability of water for public uses. T. hardness, Ca hardness, and Mg hardness during the studied period ranged from 752-243 mgCaCO₃/l, 525-165 mgCaCO₃/l, and 241-78 mgCaCO₃/l respectively, with statistically significant differences at (P<0.05) among water samples during the studied period (Figure 1). Results of groundwater hardness showed that most of the water samples are higher than permissible limits described by WHO and might be naturally occurring from weathering of limestone, sedimentary rock, and calcium-bearing minerals. Hardness can also occur locally in groundwater from chemical and mining industry effluent or excessive application of lime to the soil during agricultural activity, and also decreasing groundwater level has its effect on increasing water hardness through increasing solubility of attached minerals, Same results were noticed by (Marín et al., 2018; Khan and Jhariya, 2017; Dhok et al., 2013; GEMS, 2007; Emagbetere et al., 2014; Toma et al., 2013; Othman, 2008).

Oil and grease concentration in water can induce human health risks when discharged to surface or groundwater. The level of OG in groundwater samples of the study area ranged from 0.4 to 4.76 mg/l, with statistically significant differences at P<0.01 among water samples during the studied period (Figure 1). The presence of OG in this investigation was due to oil spillage during delivery, leakage from poorly maintained or damaged tanks, lack of oil separators and waste oil disposal into drainage systems, waste oil dumped onto or into the ground. With the high number of oil refinery projects around studied sites that use a considerable amount of water for operations, such as desalting, cooling, and also cooking oil from wastewater channels, results were similar to (Adewuyi and Olowu, 2012; Michelle, 2002).

DO, and BOD₅ content values fluctuated from 2.9 to 6.91mg/l and 0.62 to 4.83mg/l, respectively. Results showed that all studied sampled within the permissible limit of WHO standards, with statistically significant differences at P<0.01 among groundwater samples during the studied period for DO show figures (2). While there was a non-significant correlation among water samples for BOD₅ (Figure 2), the same observation was noticed by (Sirajudeen et al., 2014; Ngang and Agbazue, 2016; Ugbe, 2012). Potassium is an essential element for humans and is seldom if ever found in drinking water at a high level that could be a concern for human’s health adverse. The concentration of potassium in groundwater samples of the study area were ranged between 0.3 and 4.2 mg/l with statistically significant differences at P<0.05 among studied samples (figure 2). The potassium concentration at all sites was within permissible limits as prescribed by WHO (Chandra et al., 2017; Saeedi, et al., 2010; Othman, 2008). Sodium is a very reactive metal, so it does not exist in free form in nature. High sodium intake can have adverse effects on humans with high blood pressure or pregnant women suffering from toxemia. The concentration of sodium in groundwater samples of the study area ranges between 11.8 and 122.7 mg/l, with a statistically significant difference at P<0.01 among studied samples (figure 2). All samples were within the prescribed limit for sodium concentration as described by WHO, and it was similar to results of (Hanna et al., 2018; Chandra et al., 2017; Saeedi et
al., 2010; Othman, 2008).

SO\textsubscript{4} concentration was recorded as 218 to 1390 mg/l, with high statistically significant differences at p<0.01 among sampling sites during the studied period (Figure 2). Increasing sulfate concentration could be due to occurrence of high amount of gypsum in soil and dissolving during water percolation to aquifers, decomposition of organic matter, fertilizers, animal wastes, agricultural activities, steel factory and high number of oil refinery projects near studied sites that cause intrusion high amount of sulfate to groundwater, same results obtained by (Yu et al., 2018; Dhok, 2013; Labar et al., 2012). NO\textsubscript{3} concentration within groundwater samples ranged between 10.2 and 101 mg/l, with statistically significant differences at p<0.05 among sampling sites (Figure 2). In most studied groundwater samples NO\textsubscript{3} concentration was higher than permissible limits that accepted within WHO standers. Elevated levels of nitrate could be due to decaying agricultural activity during spraying fertilizers and pesticides, organic matter, human and animal wastes, industrial discharges and wastewater channel nutrients intrusion to groundwater or leaching from natural vegetation as noticed by (Kachi et al., 2016; Toma et al., 2013; Marouane, 2014) results.

PO\textsubscript{4} is rarely found in high concentrations in water as plants actively absorb it. High levels of phosphate can indicate the presence of pollution. PO\textsubscript{4} concentration was found between 0.48 and 25.2 mg/l, with a statistically significant difference at P<0.01 among studied samples during the studied period (Figure 2). Increasing phosphate concentration in studied sites might be because of anthropogenic additions of phosphorus during agriculture activity, steel factory wastewater that contains a high amount of phosphate, also intrusion of main wastewater channel that derived from Erbil city, and flows through agricultural areas, same results obtained by (Appavu et al., 2016; Singh et al., 2012; Boehm et al., 2004; Ganjo and Toma, 2004; Chnaray, 2003).

Groundwater samples analyzed for the determination of seven heavy metals (Cd, Hg, Zn, Cu, Fe, Ni, and Pb) within the studied period. The concentration of Cd, Hg, Zn, Cu, Fe, Ni, and Pb in the analyzed groundwater samples ranged from 0.0 to 2.924 µg/l, 0.99 to 2.78 µg/l, 5.902 to 10.32 mg/l, 1.73 to 3.76 mg/l, 192 to 355 µg/l, 5.275 to 68.33 µg/l, and from 12.22 to 39.68 µg/l respectively. There were statistically significant differences among samples of Cd, Zn, Cu, Fe, Ni, and Pb at P<0.01 (Figures 2 and 3) while, non-significantly between Hg trace metal in groundwater samples during the studied period (Figure 3).

Results showed that the concentration of heavy trace metals in most groundwater samples exceeded the maximum limits of WHO standards, except for Cd concentration, which indicates contamination of groundwater by metals. The high level of those groundwater heavy metals might be attributed to agricultural activities as pesticide spraying, especially for Zn and Cu (Sakizadeh and Mirzaei, 2016; Oyem et al., 2015), and industrial operations. Also intrusion of wastewater that derived from Erbil primary domestic sewerage system that flows through agricultural areas, oil refinery projects around studied area and sometimes naturally occurred by eroding minerals and leaching of ore deposits, similar results obtained by (Tadiboyina and Ptsrk, 2016; Malassa, et al., 2013; Sharma et al., 2013; Adewuyi and Olowu, 2012; Othman, 2008 and Ramakrishnaiah., 2009).
Figure 1: pH, EC, T. alkalinity, Cl, T. H, Ca. H., Mg. H. and OG values of the groundwater samples during studied period.
Figure 2: DO, BOD, K, Na, SO₄, NO₃, PO₄ and Cd values of the groundwater samples during studied period.
3.1 Water Quality Index

Water quality indices of groundwater quality were assessed to determine its suitability in terms of drinking purposes, derived based on physical and chemical characteristics of groundwater that expressed the quality level of potable water in underground resources of the studied area. Twenty two different parameters (pH, EC, T.H., Ca, H, Mg, H, T. Alkalinity, Cl, DO, BOD, K, Na, SO₄, PO₄, NO₃, O&G, Cd, Hg, Zn, Cu, Fe, Ni, and Pb) as an essential components of healthy water, were selected to be involve in the index with their standard values according to the drinking water quality standards of (WHO, 2008 and USEPA, 2018). To develop WQI for the studied area, 368 observations of selected parameters within 16 sites collected during 2017 and 2018. According to calculations of water quality index for both Jmka, Dhemat, Meer, Grdazaban, Perdawd, Sherawa, Quchablbas, Qarachnagha, Murtka and Sablakh (Figure 4) by using the CWQI software, the results of all samples were within 38.87 as a whole water quality within studied sites (table 1) and classified as in poor conditions that needs much treatment and purification before using. According to farmer and villagers, they could not use groundwater directly for drinking, since it sometimes causes inflammation and disease, especially for children,
similar results were obtained by (Hamlat and Guidoum, 2018; Krishan et al. 2016; Suneetha et al., 2015; Abdulwahid, 2013).

Table 1: Shows factors and CWQI.

| Factors | F1     | F2     | nse  | F3     | CWQI  |
|---------|--------|--------|------|--------|-------|
| Results | 77.2727| 48.44  | 1.163| 53.768 | 38.874|

Figure 4: Map showing Erbil and black spots, which indicate the studied area.
4. Conclusion

The status of groundwater quality in the study area found to be critical; out of 22 different parameters, 17 of them were above permissible levels that obtained by WHO standards for drinking. The WQI results illustrate that studied groundwater was within a weak level that needs treatment and purification before using it for drinking and household purposes. Finally, we recommend that, provision governmental water treatment units like reverse osmosis, desalination, ion-exchange process, is necessary to prevent the consumption of poor-quality water. Public awareness programs need to develop for sustainable management of groundwater, and construction of oil refineries and petrochemical plants according to environmental specifications under governmental control.

5. References:

Abdulwahid, S.J., (2013), Water quality index of Delizhiyan springs and Shawrawa river within Soran district, Erbil, Kurdistan Region of Iraq. J Appl Environ Sci, 3, pp.40-48.

Adewuyi, G.O., and Olouw, R.A. (2012), Assessment of oil and grease, total petroleum hydrocarbons and some heavy metals in surface and groundwater within the vicinity of NNPC oil depot in Apatra, Ibadan metropolitan, Nigeria. International Journal of Research and Reviews in Applied Sciences, 13(1), pp.166-174.

Ahmad, A. and Faizan, A., (2014), Study on assessment of underground water quality. International Journal of Current Microbiology and Applied Sciences, 3(9), pp.612-616.

Al-Barziny, Y.O.M., (2018), Water quality assessment for Duhok reservoir. ZANCO Journal of Pure and Applied Sciences, 30(6), pp.66-71.

Appavu, A., Thangavelu, S., Muthukannan, S., Jesudoss, J.S., and Pandi, B. (2016), STUDY OF WATER QUALITY PARAMETERS OF CAUVERY RIVER WATER IN ERODE REGION. Journal of Global Biosciences, 5(9), pp.4556-4567.

Boehm, A.B., Shellenberg, G.G. and Paytan, A., (2004), Groundwater discharge: potential association with fecal indicator bacteria in the surf zone. Environmental science & technology, 38(13), pp.3558-3566.

Chandra, S.D., Asadi, S.S., and Raju, M.V.S., (2017), Estimation of water quality index by weighted arithmetic water quality index method: a model study. Int J Civil Eng Technol, 8(4), pp.1215-1222.

Chmaray, M.A.K., (2003), Hydrology and hydrochemistry of Kapran basin Arbil north of Iraq (Doctoral dissertation, Ph. D. Thesis, Univ. of Baghdad, Iraq.

Dhok R. P., Patil A. S., and Ghole V. S., (2013), The hardness of Groundwater Resources and its Suitability for Drinking Purpose. International Journal of Pharmaceutical and Chemical Science. Vol. 2 (1). Pp169-172.

Emagbetere, J.U., Oroka, V.O., Ugbee, U., and Edjere, A., (2014), Assessment of the Level of Groundwater Contamination and Its Implications in Oil Pipeline Areas of Delta State, Nigeria. Assessment, 4(6).

Ganjo, D.A.G. and Toma, J.J., (20040, Daily variation in chemical stratification and algal population throughout vertical profiles of Dokan lake. Kurdistan region, Iraq. J. Babylon Univ.; Vol. 10. (3).

Hamlat, A. and Guidoum, A., (2018), Assessment of groundwater quality in a semiarid region of Northwestern Algeria using water quality index (WQI). Applied Water Science, 8(8), p.220.

Hanna, N.S., Jarjes, F.Z. and Toma, J.J., (2018), Assessing Sheikh Turab Water Resources for Irrigation Purposes by Using Water Quality Index. ZANCO Journal of Pure and Applied Sciences, 30(5), pp.17-28.

Kachi, N., Kachi, S. and Bousnoubra, H., (2016), Effects of irrigated agriculture on water and soil quality (case perimeter Guelma, Algeria). Soil and Water Research, 11(2), pp.97-104.

Khan, R. and Jhariya, D.C., (2017), Groundwater quality assessment for drinking purpose in Raipur city, Chhattisgarh using water quality index and geographic information system. Journal of the Geological Society of India, 90(1), pp.69-76.

Krishan, G., Lapworth, D.J., Rao, M.S., Kumar, C.P., Smilovic, M., and Semwal, P. (2014), Natural (baseline) groundwater quality in the Bist-Doab catchment, Punjab, India: a pilot study comparing shallow and deep aquifers. International Journal of Earth Sciences and Engineering, 7(01), pp.16-26.

Krishan, G., Kumar, C.P., Purandara, B.K., Ghosh, N.C., Gurjar, S., and Chachadi, A.G. (2016), Assessment of variation in water quality index (WQI) of groundwater in North Goa, India.

Labar, S., Hani, A. and Djabri, L., (2012), Biochemical approach to assess groundwater pollution by petroleum hydrocarbons (case skikda Algeria). Journal of Water Resource and Protection, 4(07), p.493.

Malassa, H., Al-Qutob, M., Al-Khatib, M., and Al-Rimawi, F. (2013), Determination of different trace heavy metals in ground water of South West Bank/Palestine by ICP/MS. Journal of Environmental Protection, 4(08), p.818.

Marín Celestino, A., Martínez Cruz, D., Otazo Sánchez, E., Gavi Reyes, F. and Vásquez Soto, D., (2018), Groundwater quality assessment: an improved approach to K-means clustering, principal component analysis and spatial analysis: a case study. Water, 10(4), p.437.

Marouane, B., Belhsain, K., Jahdi, M., El Hajjaji, S., Dahchour, A., Dousset, S., and Satrallah, A. (2014), Impact of agricultural practices on groundwater quality: Case of Gharb Region-Morocco. J. Mater. Environ. Sci, 5, pp.2151-2155.

Michelle P. (2002), Water Pollution Prevention
Opportunities in Petroleum Refineries. Jacobs Consultancy Inc. Ecology Publication No.02-07-017.

Ngang, B.U. and Agbazue, V.E., (2016), A seasonal assessment of groundwater pollution due to biochemical oxygen demand, chemical oxygen demand and elevated temperatures in Enugu northern senatorial district, south east Nigeria. IOSR J. Applied Chem, 9(7), p.66.

Othman, B.A. (2008), Limnology and hygiene status of some water resources within Koya district (M. Sc. Thesis. Biology department. College of Science, University of Koya, Erbil. Iraq).

Oyem, H.H., Oyem, I.M. and Useese, A.I., (2015), Iron, manganese, cadmium, chromium, zinc and arsenic groundwater contents of Agbor and Owa communities of Nigeria. Springer Plus, 4(1), p.104.

Poonam, T., Tanushree, B. and Sukalyan, C. (2013), Water quality indices important tools for water quality assessment: a review. International Journal of Advances in chemistry, 1(1), pp.15-28.

Ramakrishnaiah, C.R., Sadasiviahia, C., and Ranganna, G. (2009), Assessment of water quality index for the groundwater in Tumkur Taluk, Karnataka State, India. Journal of Chemistry, 6(2), pp.523-530.

Saeedi, M., Abassi, O., Sharifi, F., and Meraji, H. (2010), Development of groundwater quality index. Environmental monitoring and assessment, 163(1-4), pp.327-335.

Sakizadeh, M. and Mirzaei, R., (2016), Health risk assessment of Fe, Mn, Cu, Cr in drinking water in some wells and springs of Shush and Andimeshk, Khuzestan Province, Southern Iran. Iranian Journal of Toxicology Vol, 10(2).

Sirajudeen, J., Mohidheen, M.K. and Vahith, R.A., (2014), Physico-chemical contamination of groundwater in and around Tirunelveli district, Tamil Nadu. Advances in Applied Science Research, 5(2), pp.49-54.

Sharma, P., Dubey, A., and Chatterjee, S.K. (2013), Determination of heavy metals in surface and ground water in an around (Agrang Block) Raipur District, Chhattisgarh, India. Int. J. Scient. Eng. Res, 4, pp.722-724.

Singh, A.L., Tripathi, A.K. and Singh, V.K., (2012), Nitrate and phosphate contamination in ground water of Varanasi, Uttar Pradesh, India. Journal of Industrial Research & Technology, 2(1), pp.26-32.

Suneetha M., Sundar S. B. and Ravindranath K., (2015), Calculation of water quality index (WQI) to assess the suitability of groundwater quality for drinking purposes in Vinukonda Mandal, Guntur District, Andhra Pradesh, India. Journal of Chemical and Pharmaceutical Research, No. 7 (9):538-545.

Tadiboyina, R. and Ptsrk, P.R. (2016), Trace Analysis of Heavy Metals in Ground Waters of Vijayawada Industrial Area. International Journal of Environmental and Science Education, 11(10), pp.3215-3229.

Toma, J.J., Assad, Z.S. and Baez, D.R. (2013), Water quality assessment of some well water in Erbil city by quality index, Kurdistan REGION-Iraq. Journal of Advanced Laboratory Research in Biology, 4(4), pp.125-130.

Tyagi, S., Sharma, B., Singh, P. and Dobhal, R. (2013), Water quality assessment in terms of water quality index. American Journal of Water Resources, 1(3), pp.34-38.

Ugbe, F.C. (2012), Environmental Groundwater Monitoring of Jones Creek Field, Niger Delta, Nigeria. Research Journal of Environmental and Earth Sciences, 4(5), pp.570-575.

UNEP (2018), USEPA (US Environmental Protection Agency), 2012. 2012 Edition of the drinking water standards and health advisories.

GEMS, U. (2007), Global drinking water quality index development and sensitivity analysis report. United Nations Environment Programme Global Environment Monitoring System/Water Programme, [Online: www. gemswater. org]

WHO, (2008), Guidelines for Drinking-water Quality, Third Edition Volume 1: Recommendations. World Health Organisation, Geneva.

Yogendra, K., and Puttaiah, E.T. (2008), Determination of water quality index and suitability of an urban waterbody in Shimoga Town, Karnataka. In Proceedings of Taal2007: The 12th world lake conference (Vol. 342, p. 346).

Yu, L., Rozemeijer, J., Van Breukelen, B.M., Ouboter, M., Van Der Vlugt, C. and Broers, H.P., (20180, Groundwater impacts on surface water quality and nutrient loads in lowland polder catchments: monitoring the greater Amsterdam area. Hydrology & Earth System Sciences, 22(1).