Scientific Review – Engineering and Environmental Sciences (2021), 30 (2), 271–282
Sci. Rev. Eng. Env. Sci. (2021), 30 (2)
Przegląd Naukowy – Inżynieria i Kształtowanie Środowiska (2021), 30 (2), 271–282
Prz. Nauk. Inż. Kszt. Środ. (2021), 30 (2)
http://iks.pn.sggw.pl
DOI 10.22630/PNIKS.2021.30.2.23

Abdulamir Hussein QASIM
University of Kirkuk, College of Engineering

Causes and side effects of changing water quality in Khassa-Chai river in Kirkuk, Iraq

Key words: water quality assessment, water availability, surface water, physiochemical characteristics

Introduction

Thanks to water, human civilization has been found and developed on our planet. Due to the water crisis, the source of life has become a major concern in recent years. In the face of population growth and industrial developing water demand increased and safe water supply been a pre-requisite. The impact of climate change is evident in reducing the natural flow of seasonal rivers in Iraq (Qasim, 2017; Pham & Tran, 2020).

The river's flow in an urban area is often highly variable and much polluted (Covarrubia, Rayburg & Neave, 2016; Joshua & Adeniyi, 2020). Due to human activities, a significant decrease in water quantity alongside dramatic deterioration of water level is still increasing. In Iraq, there is evidence that the decline in water quantity is still seen in Iraqi main rivers. In addition to that, there is sufficient evidence of a decline in the water quality of the rivers and their tributaries that enter the country since 1990 (Qasim, 2017). As a consequence, the changes in the physicochemical parameters of the water (i.e. temperature, pH, electrical conductivity, turbidity, salinity, suspended solids, etc.) will surely affect the living conditions of aquatic organisms.

One of the important steps in achieving an effective pollution control of surface water is the monitoring and assessment of water quality. Water quality changes may be due to climate change and due to anthropogenic activities. The solubility of salts and minerals in the water may originate by weathering and erosion of fractured bedrock into water bodies. Therefore, there is a need to reduce or prevent activities that can increase the pollution level of the rivers. Various investigations and studies have shown that

anthropogenic activities will negatively impact on changes in water availability (Izonfuo & Bariweni, 2001; Akpan-Idiok, Ibrahim & Udo, 2012; Taiwo, Arowolo, Adekunle & Adetunji, 2013; Taiwo, Beddows, Shi & Harrison, 2014; Awomeso, Taiwo, Idowu, Gbadebo & Oyetunde, 2019). Urban runoff was recognized as one of the ordinary causes of water pollution. Municipal and agricultural wastes such as food processing, textile making, poultry, and abattoir wastes would be put at the top of these activities (Ayantobo, Awomeso, Oluwasanya, Bada & Taiwo, 2014; Ojekunle et al., 2014).

In Iraq, as a result of the discharge of untreated wastewater, many rivers, and urban streams are polluting (Qasim, 2019). Washing, bathing, and periodic watering of livestock are considering other sources of pollutions. The lack of development and maintenance programs is causing water crisis. It is therefore a multipurpose dam (58 m high with a total length of 2.36 km) designed to maintain water supply into the Khassa-Chai river during all seasons (Zedan, Faris & Abdulsattar, 2017; Khassaf & Madhloom, 2019).

However, over the past three decades, the subsequent absence of funds led to contamination of the Khassa-Chai river by urban, industrial and agricultural activities. In addition, no academic environmental research has been done to explain the serious deterioration in the river's condition. The lack of research and studies in this area has not helped decision-makers to react adequately to protect the river environment. In order to call for quick action and cooperation with local government and individuals, this research will bring further attention to river safety.

Material and methods

Study area

Khassa-Chai river is a seasonal tributary of Zaghaitun river, which is in turn flowing into the Al-Adhaim dam reservoir (10 km) northeast of Kirkuk near Kuchuk village. The section of the river studied lies within latitude 35°21.010′––35°35.103′N and longitude 44°18.107′––44°39.045′E (Fig. 1). The study was carried out in Khassa-Chai river located in Kirkuk, Northeast Iraq. The water in the river and the reservoir behind the dam may allow for recreational activities such as boating and fishing. In addition to recreation and leisure purposes, major human activities within the study area are farming and gravel dredging. To determine the characteristics of the river and evaluate its water quality, eight sites have been identified along the Khassa-Chai river. The results of these eight sites may highlight the concept of water pollution and its effects. Consequently, the results will determine how the river was affected by the pollution associated with the urban development of the city of Kirkuk.

Observation point 1 is located in village Dollowar (15 km north Kirkuk city). Several small buildings and rehabilitation activities are going on in the watershed. Thanks to land topography, the storm-waters from the mountains discharge towards the river. At this point, the Khassa-Chai river is relatively shallow with rocky bed, banks, and reaches with sandy or muddy bottoms. Observation point 2 is located in the village of Coran, 3 km downstream of the first point. Activities like irrigation

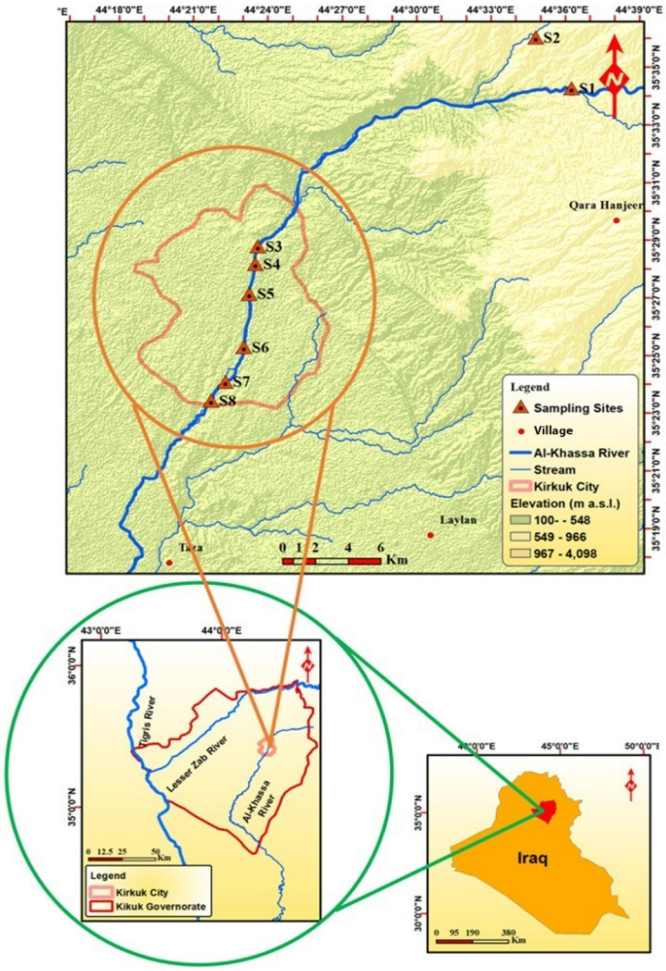

FIGURE 1. Map of Khassa-Chai river shows water observation points

and periodic watering of livestock were observed during the whole year. To provide potable water to the villagers and their domestic animals, several drinking water compact units have been started in construction by non-governorate organizations (NGOs) after 2005 but without enough preliminary research studies on the river. Thus, this point was abandoned as a drinking water source yet. Observation points 3–8 are located inside Kirkuk city along 18 km. These points are relatively shallow with sandy or muddy bottoms. In the absence of minimum maintenance flow and insufficient wastewater treatment plants, the Khassa-Chai river is affected by changes in water characteristics. Therefore, gray-water discharges into these points from multiple and single residences and building sectors along the edge of the river.

Sampling technique

To ensure the conservation of a stretch of water of the Khassa-Chai, it is necessary to study the importance of the river, its connection to the health and enjoyment of Aboriginal people who live here. Thus, this seasonal river has two important roles for Kirkuk citizens. The first role is depending on the water quantity. During the winter and spring seasons, the Khassa-Chai river provides sufficient water amounts for agricultural lands. More than 74 ha of agricultural land play the sole subsistence income for more than 38 multiple families. These lands produced various types of agricultural products like onions, cabbage, celery, etc. which can be sold locally by the villagers, or sold through local distribution facilities and markets or directly along the interior roads of the city.

The second important role of the Khassa-Chai river is represented in receiving municipal wastewater and residual runoff from agricultural land. In addition to those two important roles, the river coast turns of a free wide disposal site for solid waste during dry seasons (summer and autumn). This uncontrolled disposing of solid waste, such as garbage, glass, plastic, etc. is adding more challenge to the local government in Kirkuk. However, these roles could represent a conflicting interest with the recreational purposes and presence of natural aquatic life in the Khassa-Chai river.

To study and analysis those vital topics, 37 water samples were collected from eight monitoring points along the Khassa-Chai river. Two of these points are outside of Kirkuk city in, while the other six points located inside the city as illustrated schematically in Figure 1. To achieve reliable results, the study covered both rainy and dry seasons between April 2017 and January 2018. Two types of parameters have been considered here: physical and chemical. These physicochemical parameters are including temperature, color, pH, total suspended solids (TSS), total dissolved solids (TDS), electrical conductivity (EC), and dissolved oxygen (DO). These two types of water quality parameters (chemical and physical) are determined by using the standard procedures of the American Public Health Association (APHA). The water samples are collected from the eight mentioned points in prewashed one- and two-liter plastic bottles along the Khassa-Chai river.

Water temperature was determined in-situ. To determine the other mentioned physicochemical parameters, water samples were brought to the Sanitary Engineering Laboratory of the College of Engineering (Department of Civil Engineering) and the scientific laboratory of the Environmental Research Unit (ERU) in the College of Sciences – Kirkuk University. The Sanitary Engineering Laboratory is an important laboratory that concerns with the physicochemical analysis of water samples in the university. The water parameters were measured electronically by using various types of tools and devices. For example, Hanna HI 98130 (Hanna Instruments) was used to determine TDS and EC, whereas TSS was determined gravimetrically. Color and turbidity values were determined by using Hanna HI 98130. Colorimeter MD 600 (Lovibond) device was used to determine DO. To examine the water pH levels, the collected water samples were tested by

using the device MultiMeter Instrument SensoDirect 150 (Lovibond).

Statistical analysis

The Statistical Package for Social Science 22.0 was used to analyze the collected data. In this study, the SPSS was assigned to simplify the statistical analysis of the physiochemical measures were performed on all observation points. To achieve a consistent analysis appropriately, the data was entered into pre-prepared tables based on the Microsoft Office Excel 2007. These programs provide users with a good possibility to change statistical requirements according to site data, also to give a measure of how the data distributes itself about the expected value.

By analyzing water samples, the quality of the water, and the causes of environmental degradation which are directly related to the health inside the city of Kirkuk will be able to determine easily. Despite the vast size of the mass of information collected in this study, the predictive nature of the data and outcome produces a minimum probability of error. For future studies, many locations of the Khassa-Chai river could provide promising possibilities to obtain further results on the river's self-purification and existing of hazards ions and heavy metals in the river. Thus, the statistical analysis will simplify the path to better define the expected outcomes of both new and existing outcomes.

Results and discussion

Analytical results

Seasonal variations in the physicochemical parameters of river water quality at different points are shown in Figure 2. During the survey and the case study period, the average monthly temperature was 21.4°C (70.5°F), ranging from an average minimum of 13.2°C (52.2°F) to a maximum of 24.8°C (76.6°F). This wide variation in water temperature has a significant influence on the activity of many types of aquatic organisms. Aquatic organisms are generally more sensitive

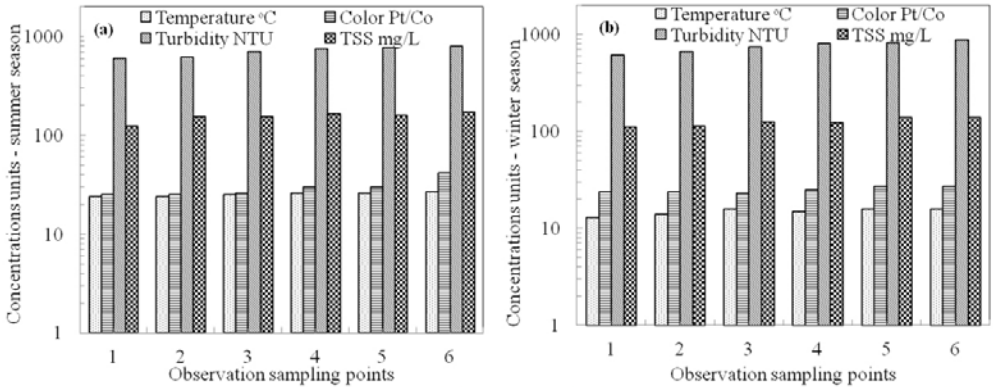

FIGURE 2. Average seasonal concentrations of physicochemical parameters (first group) of Khassa--Chai river during summer (a) and winter (b) season

to the temperature fluctuations than the other terrestrial counterparts (Brown, Le Tissier & Bythell, 1995; Snydner & Rossi, 2004; Hains, 2010; Wałkuska & Wilczek, 2010). Further, seasonal temperature changes often affect the rate of fish eggs development. These changes are a signal to begin the development of the life cycle in the environment.

The concentration of turbidity was ranging between 610 and 882 (±6) NTU during winter and summer seasons respectively. Levels of TSS were ranging between 155 and 130 (±5) $mg \cdot L^{-1}$ during the same period (Fig. 2). Loading of sediment, mud, silt material, and other pollutants from the landscape might compromise the purity of the waters waters (Hunsaker & Levine, 1995; Dodds & Oakes, 2008; Hall & Hossain, 2020). The highest concentration of turbidity during the summer is evidence of a considerable reduction in flow rate compared to the winter season. These high values of turbidity and TSS, especially during the dry season, refer to water pollution dramatically. Hence, as a consequence of this, aquatic ecosystems are affected by increased turbidity due to reduced photosynthesis (Henley, Patterson, Neves & Dennis, 2000; Holliday, Rasmussen & Miller, 2003).

Upstream sampling sites are offering less sediment quantity. By increasing the flow rate of water, small water vortex leads the river to become more turbid due to fine mud practices, and therefore, turbidity levels of the river water are increasing towards the Khassa-Chai river downstream in the southwest of Kirkuk city.

In terms of color, the most common cause of color is usually the presence of minerals. Although there were no significant changes in color during summer and winter, the data showed a slight change in color between several observation points located outside and inside of Kirkuk city (Fig. 2). However, this variation in color might refer to changes taking place in soil types and composition.

Figure 3 brings out the variation of physicochemical parameters of the Khassa-Chai river during the study period. The mean concentration levels of EC were ranging between 961 and

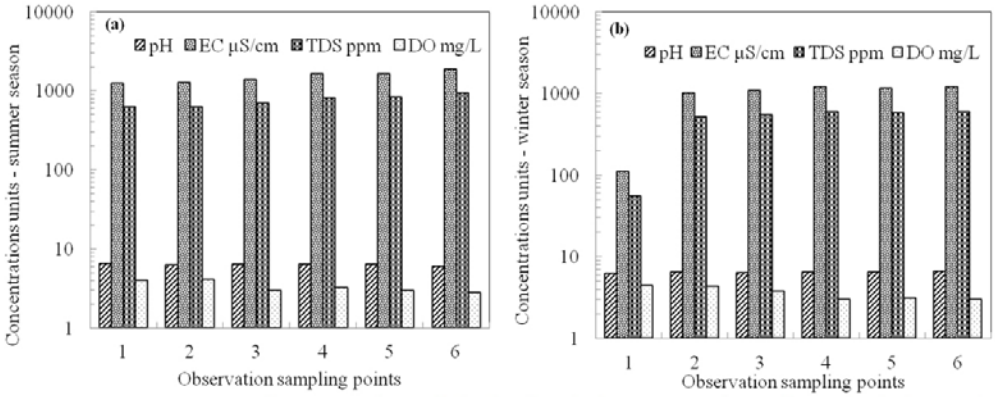

FIGURE 3. Average seasonal concentrations of physicochemical parameters (second group) of Khassa--Chai river during summer (a) and winter (b) season

1,509 (±5) $\mu S \cdot cm^{-1}$ during the winter and the summer seasons respectively; and TDS was ranging between 480 and 755 (±4) $mg \cdot L^{-1}$. The results show that the pH values were ranging from 6.29 to 6.51 (±0.29). The pH values of the Khasa-Chai river did not change significantly over the two seasons. The variation of pH values is due to the buildup of organic material from plant leaves and animals, in addition to other pollutant resources, such as water mixed with chemicals, paints, and hot water that discharge from various local factories along the river. However, the results showed that the pH values did not exceed the specific standard of the World Health Organization (WHO) and are almost acceptable.

The results presented in Figure 4 of this study is showing that, in most cases, the water quality of the Khassa-Chai river towards the south of Kirkuk city does not meet the WHO guidelines of the water quality. These values are greatly exceeding the recorded level in the north of the city. To summarize the results, three main findings can be drawn from figures described above.

Factor 1 is related to the turbidity of water. This factor is linked to the visible problems due to suspended waste and the pollutant that producing from the point and non-point sources. By the accumulation of large amounts of solid waste on the bank of the Khassa-Chai river, the surface water will be subject to the collected pollutant from various kinds of toxic wastes. Subsequently, during the rainfall, different materials including soil, leaves, solid and liquid wastes, pesticides, and chemicals are washed into the surface water bodies. As known, the presence of high levels of turbidity will contribute to increasing the microorganisms and germs in the river. So, degraded water quality in the southwest of Kirkuk can no longer regulate its self-purification and self-recovery capacity; thereby this problem risks accelerating the decline in water quality and availability.

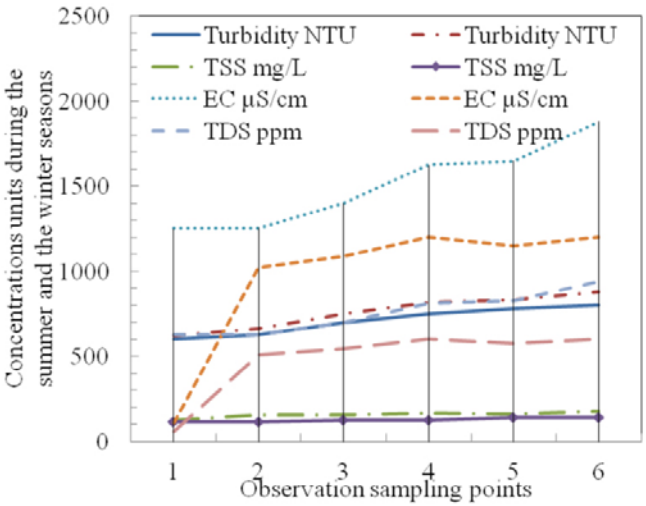

FIGURE 4. Spatial variation of physicochemical parameters (first and second group) of the Khassa-Chai river

Increasing concentrations of TDS and EC toward the south side of Kirkuk is highlighted by Factor 2. Mixing of the river with untreated wastewater is one of the reasons for increasing the EC and TDS (Cole & Ryan, 2003; Taiwo et al., 2014; Ondoo et al., 2019). Anthropogenic sources of water pollution are resulting from farming activities, the use of composted animal manures for soil amendment in addition to other sources such as domestic, and restaurant pollution sources. Increasing population density towards the south of the city (fourth, fifth and sixth locations) will contribute to increasing the accumulation rate of TDS and EC.

Factor 3 refers to small fluctuations in the concentration of TSS at various locations along the river. The results in Figure 4 showed increases in the concentration of total suspended solids from 121 to 143 $mg \cdot L^{-1}$. The result of this factor indicates that most of the contaminants are due to the suspended particles, which are not dissolved in water. These suspended particles, including but not limited to, any minerals, salts or metals in the given watercourses. As a result, the particles could attach to sediment particles and clay minerals that have settled on the river bed and could be carried into water bodies.

Climate change concerns in water quality

Increased climate variability has made both rainfall and dryness patterns more inconsistent and unpredictable in many areas. The variations in temperature have increased since 1975 and affected the frequent recurrence of severe drought and floods (Pantula, 2016; Abed, Bouarbi, Hamidou & Bouzit, 2017; Qasim, 2017; Paredes, Castillo, Viteri, Fuentes & Bodero, 2019). Over the past dedicates, the Khassa-Chai river was experienced a serious drought. As Iraq shows high sensitivity to climate change concerns, it is interesting to assess and discuss some negative side effects. Although this serious problem has become more specific with the formation of different disciplines, it is interesting to assess and discuss some negative side effects. Additionally, the impact of climate change may be hard to isolate it from changes in natural water characteristics.

The effect of climate change on the Khassa-Chai river does not much different from the aggregate effect of climate change on the two main rivers in Iraq (the Tigris and the Euphrates). Historical information and photos show that the water volume of the Khassa-Chai river. The water was so abundant that it was able to help in increasing the amount of water of the tributaries of the Tigris river, especially the tributaries near the southwest of the city of Kirkuk. On the contrary to the previous years, evidence of the impact on water amount in the Khassa--Chai river can already be seen from the frequent drought that has been occurring over the past two decades.

Over the past decade, between the years 2005 and 2015, the lands around the Khassa-Chai river has strongly influenced by seasonal and climatic fluctuations. The impact of climate change on the river is varied between periods of severe drought and floods. The crop with the largest proportion of the cultivated area (more than 65%) was affected by severe and moderate floods. Afterward,

the areas that were severely affected by the floods had up to that point been affected by drought.

In 2012, for example, the torrential rain and flood led to a 1.5 m (5 ft) rise in river levels. The flood led to the collapse of many riverbanks stamens in the upper course of the river. Consequently, the upper soil layers have been eroded that made muddy stream along Khassa-Chai river course toward the river downstream. Returning to the accumulated waste beside the river, it was easy to imagine the amount of pollution caused by drift these pollutants into the riverbed during the rains. This matter led to a considerable loss for the farmers due to the destruction that takes place on their agricultural lands.

The rains and dry seasons have been changing over the years. The influence of high-temperature and low-humidity in Iraq will absolutely lead to higher evaporation rates. Towards its mouth, the drought of the river was a result of high temperatures and low precipitation. Because of these reasons, the climate challenge currently carries serious problems.

As a consequence, the significant elongated dryness pattern has added negative impacts on hundreds of people and increased the negative financial consequences of this problem for the families who are already suffering from the loss of their only financial income that has taken place over the last 15 years. As a result, this situation has caused crops to fail. This situation forced farmers to abandon their lands either due to lack of water (when the plants are young) or due to the extra water amount of irrigation when the plants do not need watering or rarely need water. Thus, although a good amount of water body in Iraq, there is a clear indication of the changes in water quality and quantity (De Stefano, Jacob, Eric, Jim & Aaron, 2017; Qasim, 2017). So, the local government needs to given more attention to water resources management.

Conclusions

The assessment of water quality from different locations in the Khassa-Chai river in Kirkuk showed a significant variation in many of the physicochemical parameters. As a result of human activities, the observed locations of inside the city area are already deteriorating. Four of the observation points inside the city have become a landfill and an accumulation field of solid waste and debris of demolished buildings during urban transformation. The impact of pollution on water quality toward the river downstream has recently become more observant amongst the different location changes. However, northeast of the city of Kirkuk, may provide a good source of irrigation water for defining agricultural activities, but not wholesome for drinking.

Acknowledgements

The researchers gratefully acknowledge the assistance of the Civil Engineering Department and the Environmental Research Unit of the Kirkuk University for their support in the research. The researchers would also like to express their gratitude towards the Faculty of Sciences at the University of Kirkuk for its full support and cooperation provided during the research period.

References

Abed, B., Bouarbi, L., Hamidou, M.K. & Bouzit, M. (2017). A numerical analysis of pollutant dispersion in street canyon: influence of the turbulent Schmidt number. *Scientific Review Engineering and Environmental Sciences*, *26*(4), 423-436.

Akpan-Idiok, A.U., Ibrahim, A. & Udo, I.A. (2012). Water quality assessment of Okpauku River for drinking and irrigation uses in Yala, cross river state, Nigeria. *Journal of Environmental Sciences*, *6*(6), 210-221.

Alex, J.H., Rodney, J., Hubert, L., Bill, F. & Marc, B. (2019). Hypolimnetic oxygenation 2: oxygen dynamics in a large reservoir with submerged down-flow contact oxygenation (Speece cone). *Journal Lake and Reservoir Management*, *35*(3), 323-337.

Awomeso, J.A., Taiwo, A.M., Idowu, O.A., Gbadebo, A.M. & Oyetunde, O.A. (2019). Assessment of water quality of Ogun River in southwestern Nigeria. *IFE Journal of Science*, *21*(2), 375-388.

Ayantobo, O.O., Awomeso, J.A., Oluwasanya, G.O., Bada, B.S. & Taiwo, A.M. (2014). Non-cancer human health risk assessment from exposure to heavy metals in surface and groundwater in Igun Ijesha, southwest Nigeria. *Journal of Environmental Sciences*, *10*(3), 301-311.

Brown, B.E., Le Tissier, M.D. & Bythell, J.C. (1995). Mechanisms of bleaching deduced from histological studies of reef corals sampled during a natural bleaching event. *Journal of Marine Biology*, *122*(2), 655-663.

Cao, X. & Liu, L. (2015). Ecological toxicity of engineered nano materials to the organisms in the environment. *Journal of Advanced Materials Research*, *1094*, 437-440.

Cole, J.M. & Ryan, M.C. (2003). Arsenic source and fate at a village drinking water supply in mexico and its relationship to sewage contamination. In J. Bundschuh, P. Bhattacharya, Chandrasekharam (eds.), *Natural Arsenic in Groundwater; Occurrence, Remediation and Management Conference* (pp. 67-71). London: Taylor & Francis Group.

Covarrubia, J.C., Rayburg, S. & Neave, M. (2016). The influence of local land use on the water quality of urban rivers. *International Journal of GEOMATE*, *11*(23), 2155-2161.

De Stefano, L., Jacob, D.P., Eric, A.S., Jim, E. & Aaron, T.W. (2017). Assessment of transboundary river basins for potential hydro-political tensions. *Journal of Global Environmental Change*, *45*, 35-46.

Dodds, W. & Oakes, R. (2008). Headwater influences on downstream water quality. *Journal of Environmental Management*, *41*(3), 367-377.

Hains, H. (2010). A review of "Freshwater ecology: concepts and environmental applications of limnology". *Journal Lake and Reservoir Management*, *26*(4), 347-348.

Hall, J. & Hossain, A.K. (2020). Mapping Urbanization and Evaluating Its Possible Impacts on Stream Water Quality in Chattanooga, Tennessee, Using GIS and Remote Sensing. *Journal of Sustainability*, *12*(5), 2-46.

Harmon, W.M. (2018). *Estimating watershed mercury contribution to Lake Fort Smith State Park, University of Arkansas, Fayetteville, USA* (MSc thesis). *Theses and Dissertations*, *2833*. Retrieved from: https://scholarworks.uark.edu/etd/2833 [access 20.06.2020].

Henley, W.F., Patterson, M.A., Neves, R.J. & Dennis, L.A. (2000). Effects of sedimentation and turbidity on lotic food webs: a concise review for natural resource managers. *Journal of Reviews in Fisheries Science*, *8*(2), 125-139.

Holliday, C.P., Rasmussen, T.C. & Miller, W.P. (2003). Establishing the relationship between turbidity and total suspended sediment concentration. In K.J. Hatcher (ed.), *Proceedings of the 2003 Georgia Water Resources Conference*. Athens: University of Georgia.

Hunsaker, C.T. & Levine, D.A. (1995). Hierarchical approaches to the study of water quality in rivers. *Bioscience Journal*, *45*(3), 193-202.

Izonfuo, L.W. & Bariweni, A.P. (2001). The effect of urban runoff water and human activities on some physico-chemical parameters of the Epie Creek in the Niger Delta. *Journal of Applied Science and Environmental Management*, *5*(1), 47-55.

Joshua, I.O. & Adeniyi, A. (2020). A comprehensive review of water quality monitoring and assessment in Nigeria. *Chemosphere*, *260*, 127569. https://doi.org/10.1016/j.chemosphere.2020.127569

Khassaf, S.I. & Madhloom, A.M. (2019). Stability analysis of zoned earth dam under effect of the most dangerous conditions (case study: Khassa Chai dam). *International Journal of Scientific & Engineering Research*, *10*(12), 110-118.

Ojekunle, Z.O., Ufoegbune, G.C., Oyebamiji, F.F., Sangowusi, R.O., Taiwo, A.M. & Ojekunle, V.O. (2014). Assessment of the effect of commercial activities on the surface water quality of Ogun River, Nigeria. *Merit Research Journal*, *2*(9), 196-204.

Ondoo, K.O., Kiptoo, J.K., Onditi, A.O., Shivaji, S.M., Omondi, B. E. & Ogilo, J.K. (2019). Determination of selected water quality parameters in river Sio, Busia County, Kenya. *International Research Journal of Pure and Applied Chemistry*, *18*(3), 1-16.

Pantula, M.R. (2016). *Drought early warning system: Identification of onset end magnitude (SPI and SPEI) and composite index*. Chennai: Notion Press.

Paredes, M., Castillo, T., Viteri, R., Fuentes, G. & Bodero, E. (2019). Microplastics in the drinking water of the Riobamba city, Ecuador. *Scientific Review Engineering and Environmental Sciences*, *28*(4), 653-663.

Pham, H.T. & Tran, T.K. (2020). The Effect of Urbanization on Temperature Trend in Some Regions across Vietnam during the Past Decade. *International Journal of Environmental Science and Development*, *11*(9), 419-424.

Qasim, A.H. (2017). *Impact du changement climatique et qualité de l'eau sur les bassins du Tigre et de l'Euphrate en Irak: effets sur la polution croissante de l'eau douce* [*Impacts of climate change on water resources (quantity and quality) in the Tigris and Euphrates basins in Iraq*] (PhD thesis). Poitiers: Université de Poitiers.

Qasim, A.H. (2019). International water model under productivity conditions: the case of the Tigris and the Euphrates. *International Journal of GEOMATE*, *17*(62), 29-34.

Shields, F.D., Lizotte, R.E. & Knight, S.S. (2013). Spatial and temporal water quality variability in aquatic habitats of a cultivated floodplain. *River Research and Applications Journal*, *29*(3), 313-329.

Snydner, M.J. & Rossi, S. (2004). Stress protein (HSP70 family) expression in intertidal benthic organisms: The example of Anthopleura elegantissima (Cnidaria: Anthozoa). *Journal of Marine Science*, *68*(1), 155-162.

Taiwo, A.M., Arowolo, T.A., Adekunle, I.M. & Adetunji, M.T. (2013). Evaluating the environmental impacts of poultry farming on stream water quality: A study from Abeokuta, Nigeria. *Journal of Environmental Quality Management*, *22*(4), 79-93.

Taiwo, A.M., Beddows, D.C., Shi, Z. & Harrison, R.M. (2014). Mass and number size distributions of particulate matter components: comparison of an industrial site and an urban background site. *Science of the Total Environment Journal*, *475*, 29-38.

Wałkuska, G. & Wilczek, A. (2010). Influence of discharged heated water on aquatic ecosystem fauna. *Polish Journal of Environmental Studies*, *19*(3), 547-552.

World Health Organization [WHO] (2016). *Guidelines for Drinking-Water Quality (Fourth edition incorporating the first addendum)*. Geneva: World Health Organization.

Zedan, A.J., Faris, M.R. & Abdulsattar, A.A. (2017). Seepage analysis through an earth dam (Khasa-Chai Dam) as a case study. *Engineering and Technology Journal*, *35*(2), 172-181.

Summary

Causes and side effects of changing water quality in Khassa-Chai river in Kirkuk, Iraq. Water quality of seasonal water rivers is on a quick decline due to various human activities arising as a result of urbanization and population growth. This study assessed the water quality of the Khassa-Chai river in Kirkuk during two seasons: winter and summer (wet and dry). Thirty-seven water samples were collected from eight monitoring observation points along the Khassa-Chai river during October 2019 and March 2020. Water samples were analyzed for various parameters such as temperature, pH, electrical conductivity (EC), turbidity, total suspended solids (TSS), total dissolved solids (TDS), color, and dissolved oxygen

(DO). These physicochemical parameters were analyzed using standards methods demonstrated by the American Public Health Association (APHA). To determine the significant difference, all the results obtained were statistically analyzed. In most results, higher concentrations are out of the indicated permissible limits of the World Health Organization (WHO). It can be concluded that the most domestic wastewater effluents are discharged into the river, such as sewage coming from nearby houses and restaurants in addition to the solid waste produced from close commercial stores. To reduce the negative impact on water and human health, pollution sources need to be properly managed. The paper calls for further research to figure out the ability of the Khassa-Chai river to make the use of city water in improving the environment.

Author's address:
Abdulamir Hussein Qasim – corresponding author
(https://orcid.org/0000-0002-4695-3021)
University of Kirkuk
College of Engineering
Department of Civil Engineering
Environmental Research Unit
36013, Kirkuk
Iraq
e-mail: aqasim01@uokirkuk.edu.iq