Nigerian Research Journal of Engineering and Environmental Sciences 8(1) 2023 pp. 220-227
p ISSN: 2635-3342; e ISSN: 2635-3350

Nigerian Research Journal of Engineering and Environmental Sciences
Journal homepage: www.rjees.com

Original Research Article

# Assessing the Quality Objective in Water Resource Management using Water Quality Index Within Apo Resettlement Area, Abuja, Nigeria

**[1]James, B.B., *[2]Oseke, I.F. and [2]Ugwu, S.J.**

[1]Nigerian Defense Academy, Kaduna State, Nigeria.
[2]National Water Resources Institute, Mando-Road, Kaduna State, Nigeria.
*engroseke@gmail.com

http://doi.org/10.5281/zenodo.8094964

**ARTICLE INFORMATION**

*Article history*:
Received 02 May 2023
Revised 30 May 2023
Accepted 01 Jun. 2023
Available online 30 Jun. 2023

*Keywords*:
Urbanization
Water quality index
Surface water
Physicochemical parameters
Federal Capital Territory

**ABSTRACT**

*This paper discussed the application of water quality index for the assessment of selected water quality parameters within the Apo resettlement area of the Federal Capital Territory, Nigeria. The Apo resettlement area, a semi-urban residential settlement has since seen a rapid urbanization following the creation of Abuja as the new administrative capital of Nigeria on 3rd Feb 1976. This is through the promulgated Federal Capital Territory decree No. 6, 1976 resulting from the growing unsuitability of Lagos as Nigeria's Federal Capital City. Water quality index (WQI) provides a single number that expresses the overall water quality, at a certain location and time, based on several water quality parameters. The water sourced from the Apo resettlement area was rated as a good water type with index of 76.0% by World Health Organization permissible limits, whilst the Federal Ministry of Environment (FMEnv Limit) rates it at 45.6%. The study outlined that the surface water of the area is impaired due to the rapid urbanization and is not suitable for domestic consumption without treatment. However, the water body is suitable to support ecosystem functioning. This can be improved, or level of pollution reduced if proper measures are put in place to discourage the users from polluting the water in order to bring about improved health.*



## 1. INTRODUCTION

The increase in pollution of water sources like lakes and rivers is a major concern for the global scenario as most of the water bodies around the world are the source for water supply including human consumption and domestic purposes (Kazi *et al.,* 2009). Accordingly, the quality of water depends on the composition of recharging source, the interaction between the water and the environment (Oseke *et al.,* 2021). As such, the quality objective in water resources management is an important contributor touching on all aspects of ecosystems and a significant tool in determining the human poverty, wealth, and education levels.

The optimal functionality of the aquatic ecosystem is determined by the parameters of water quality objective which includes the physical, chemical, and biological characteristics (Oseke *et al.,* 2021). Therefore, a particular problem with water quality monitoring is a complex issue associated with analyzing a large number of associate measures of variables (Boyacioglu 2007) and the high variability among the variables is due to increase in man-induced activities including natural influences (Simeonov *et al.,* 2002).

The man-induced discharges constitute a constant polluting source, thereby reducing the quality object of water. Man-induced activities are the major factor determining the quality of water (Global Risks 2015). Environmental pollution leading to decrease in the quality object of water resources has become a major global issue, including developing countries which have been suffering from the impact of pollution due to poor socio-economic growth associated with the exploitation of natural resources. In this regard, water is considered as the highest risk to the world for future due to increase in demand as well as increase in global pollution (Global Risks 2015).

Various geostatistical concepts were used to better understand complex data sets of water quality parameters (Joshi *et al.,* 2009). The use of indices is one of the most effective approaches to communicate information on the quality objective of any water to decision makers (APHA 2012). Indices are measure of changes in a representative group of individual data points of various physicochemical and biological parameters in a given sample. The advantage of indices is that it has the potential to inform the general public and decision makers about the status of the ecosystem (Simoes *et al.,* 2008). The benefit of this approach is the provision to evaluate the success and failure of any management plan for improving the water quality.

A number of studies have reported the importance of water quality indices (WQI), which is a mathematical equation used to transform large numbers of water quality data into a single number (Oseke *et al.,* 2021). According to Oseke *et al.* (2021), WQI promotes understanding of water quality issues by integrating complex data and generating a score that describes water quality status. The WQI serve as an indicator for assessment of water quality as proposed for the first time by Horton (1965). Later, numerous researchers have carried out studies on water quality assessment using WQIs around the world in various water bodies (Hector *et al.,* 2012; Mohamed *et al.*, 2014; Will *et al.,* 2015; Lobato *et al.,* 2015). Similarly, a number of studies have been carried out in Nigeria (Emmanuel *et al.*, 2013; Ahaneku and Animashaun, 2013; Agidi *et al.,* 2022; Oseke *et al.,* 2021). Nevertheless, a substantive amount of works has been done on the water quality parameters of water bodies stretching in and out of the city (Abuja City Report 2016). However, there was no literature which reveals scientific study carried out with respect to WQI in urbanized city of the Abuja, a mega biodiversity region.

The rationale of the present study is to identify the water quality status of the Apo resettlement area following the establishment of an open market using the physicochemical parameters as there is exposure from riparian population on a daily basis. This study will also help in assessment and periodic monitoring of water quality and turn the complex water quality data into information that is understandable and usable by the public for proper management strategies to minimize the further decrease of the water quality objective due to pollution in spite of increasing urbanization.

## 2. MATERIALS AND METHODS

### 2.1. Study Area

The Apo resettlement area is located in Abuja Municipal Area Council. The area is along the Outer Southern Express Way around the Phase II of Abuja. It is bounded to the North by Guzape District and to the West by Dutse and Wumba Districts respectively. Notable features within the study area include: shopping mall, Apo round about, Apo bridge, Apo main village, Federal Housing Authority, Apo resettlement towns among others. The Abuja Municipal Area Council is the administrative body of Abuja City, which is Nigeria's Federal Capital Territory. Abuja is located in the middle of the country with a land area of about 8,000 km$^2$ (See Figure 1). Similarly, Abuja is bounded on the north by Kaduna state, on the west by Niger state on the east and southeast by plateau state, and on the south-west by Kogi state (Abuja City Report, 2016). According to the Abuja City Report, (2016), Abuja lies within latitude 90 25'N and 90 20'N of the equator and longitude 50 45'E and 70 39'E (Ade and Afolabi 2013).

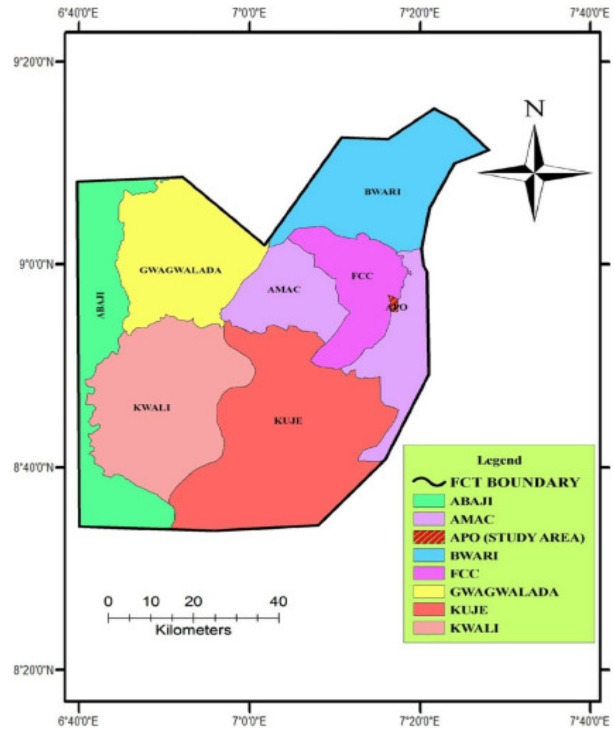


Figure 1: Map of FCT showing the study area and area councils (Adapted from Musa *et al.,* 2017)

## 2.2. Water Quality Sampling

### 2.2.1. Field work

The sampling was performed to obtain the water quality status within the Apo resettlement area. The sampling involved collecting 33 water samples for laboratory analysis to determine the water quality status. The samples were taken at upstream, midstream and downstream locations from the river channels within the study area. The field work was designed to individually accommodate three samples per sampling points on the three locations. The collected water sample from each sample points was carefully kept in bottles made from plastic polythene materials to avoid contamination and reduce possible reaction with the plastic container. The samples were transported in their preserved state (storage coolers) using the project vehicle.

### 2.2.2. Water quality sampling locations

The locations for sampling the water quality involved equidistance points of varying distances ranging from 500 m to 1 km between points. The sampling point was determined by use of Global Positioning System (GPS). The water quality sampling locations within Apo resettlement area is shown in Table 1.

Table 1: Water quality sampling locations within Apo resettlement area

| Sampling locations | Sampling locations | Northing | Easting | Elevation (m) |
|---|---|---|---|---|
| 1 | Upstream surface source | 09°38'69.7 | 007°44'77.0' | 629.9 |
| 2 | Midstream surface source | 09°39'14.5 | 007°43'21.4 | 635.1 |
| 3 | Downstream surface source | 09°11'37.2 | 007°22'36.9 | 569.1 |

### 2.2.3. Laboratory analysis

The collection, transportation, preservation, and measurement of concentration levels were carried out in accordance with national standard methods. The analysis of the physicochemical water quality parameters (pH, $CL^-$, TDS, TH, Fe, Cu, Cr, DO, BOD, COD, and Turbidity) was done based on the standard method of measurements described by APHA (2012). In the same manner, selected physical parameters were measured in-situ. The basic information of 11 parameters for water quality analysis results were reported in accordance with global best practice system.

### 2.3. Determination of Water Quality Index

The data analysis for WQI is achieved by evaluating the cumulative influence of urbanization on selected parameters of the water sample. A weight value ranging from 1 to 5 is assigned to the selected water quality parameters for estimating water quality index, depending on the relative significance of the parameters in water quality status assessment (Equation 1).

$$W_i = \frac{wi}{\sum_{i=1}^{n} wi,} \quad (1)$$

Where $W_i$ is the relative weight, $w_i$ is the weight of each parameter and $n$ is the number of parameters.

The quality rating scale for each determinant was obtained by dividing its concentration in each water sample by its respective standards according to the WHO (2012) and multiplied the results by 100 as shown in Equation 2.

$$qi = \frac{C_i}{S_i} x\ 100 \quad (2)$$

Where $q_i$ is the quality rating, $C_i$ is the concentration of each chemical parameters in each sample in milligrams per litre, $S_i$ *is* the World Health Organization standard for each chemical determinant in milligrams per litre according to the guidelines of the (WHO, 2012).

Finally, the sub index (SI) was first determined for each parameter. The sum of SI values gave the water quality index for each sample, as shown in Equation 3 and 4 respectively.

$$SI_i = W_i\ x\ qi \quad (3)$$

$$\text{WQI} = \sum SI_i \quad (4)$$

Where $SI_i$ is the sub-index of $i^{th}$ parameters; $qi$ is the rating based on the concentration of $i$th parameter, $n$ is the number of parameters.

The water quality classification ranges and types of water based on WQI values are listed in Table 2. The determination of water quality index was achieved by evaluating the cumulative influence of man induced and the naturally occurring activities based on certain determinants in the hydro-geometry characteristics of the water sample. The average concentration of determinants (pH, Cl,TDS, TH, Fe, Cu, Cr, DO, BOD, COD, Turbidity) were used in calculating the WQI values for each sampling location.

Table 2: Water quality index and status of water quality

| Range | Type of water |
|---|---|
| <50 | Excellent water |
| 50 - 100 | Good water |
| 100 - 200 | Poor water |
| 200 - 300 | Very poor water |
| >300 | Water unsuitable for drinking purposes |

The results from the laboratory analysis belonging to all samples obtained were used for quality assessment. Furthermore, the World Health Organization (WHO) and the Federal Ministry of environment (FMEnv limit) limits were utilized for calculations. To calculate the WQI, A weight has been assigned for the physicochemical parameters, according to the parameter's relative importance in the overall quality of water for the purpose of water supply and ecosystem functioning.

## 3. RESULTS AND DISCUSSIONS

### 3.1. Analytical Description of Selected Quality Objective Parameters

The summarized water quality rating of selected quality objective parameters by the analytical results of the physicochemical parameters is shown in Table 3 for water sourced from the Apo resettlement area.

The pH value is a very significant indicator which determines the suitability of water for various purposes (Oseke *et al.,* 2021). The recorded pH value within the study area falls within the threshold of 6.5-8.5 with an average value of 6.77 which tend to be slightly alkaline. This could be due to discharge of effluent in alkaline due to the rapid urbanized population form as reported by Inam *et al.,* (2016)

Turbidity is an important parameter when considering water for drinking purpose (Inam *et al.,* 2016). It was observed that the turbidity values within the Apo resettlement area were higher than the allowable level recommended by the WHO and FMEnv limit for drinking and environmental water use purposes. The turbidity of the river increased downstream, with an average of 19 NTU. Turbidity rate of river is a product of suspended particles such as clay, silt, finely divided organic and inorganic matter, plankton and other microorganisms (Oseke *et al.,* 2021). It is however not surprising that the highest value of turbidity was recorded at downstream location which serves as collection point.

Total dissolved solid is a vital parameter which imparts an unusual taste to water and lessen its usage as potable water. In natural water, it is composed of the sulfate, bicarbonate and chloride of calcium, magnesium and sodium (Inam *et al.,* 2016). TDS which can be referred to as trace metals: when present in water, have major effect on the quality especially for drinking purpose. Similarly trace metals accumulations determined in waters indicate the presence of natural or anthropogenic sources. The occurrence of trace metal may affect human health if they reach levels such that they constitute toxic pollutants (Bibi *et al.,* 2007). The highest value (55.01 mg/l) was observed at the downstream location within the Apo resettlement area. However, all the observed values were within the permissible level recommended by WHO and FMEnv Limit for drinking and environmental water use.

The concentration of the heavy metals (Iron and Chromium) exceeded the permissible level recommended by WHO and FMEnv Limit for domestic and environmental water uses purposes. The average concentration of the metals (0.02 mg/l for Fe and 0.004 mg/l for Cr) were recorded within the Apo resettlement area. The slightly elevated values recorded for the heavy metals within the study area can be attributed to the ongoing rapid urbanization within the Apo resettlement area, resulting in discharge of industrial effluent, indiscriminate disposal of domestic waste, runoffs, and atmospheric deposition (Inam, *et al.,* 2016). This observation is supported by the findings of Oseke *et al.* (2021).

Table 3: Statistical summary of physico-chemical data of surface water sources in the study area

| Parameters | Sampling location | | | Average | Standard deviation | WHO limit | FMEnv limit |
|---|---|---|---|---|---|---|---|
| | Upstream river | midstream river | Downstream river | | | | |
| pH | 6.74 | 6.77 | 6.80 | 6.77 | 0.03 | 6.5-9.2 | 6-9 |
| Chloride (mg/l) | 10.63 | 10.00 | 11. 23 | 10.32 | 0.45 | 250 | 250 |
| Total dissolved solids (mg/l) | 48.00 | 52.00 | 55.00 | 51.67 | 3.51 | 500 | 2000 |
| Total Hardness (mg/l) | 136.96 | 139.10 | 143.01 | 139.69 | 3.07 | 300 | 200 |
| Iron (mg/l) | 0.02 | 0.02 | 0.03 | 0.02 | 0.01 | 0.3 | 0.3 |
| Copper (mg/l) | 0.07 | 0.06 | 0.07 | 0.07 | 0.00 | 2 | 2 |
| Chromium (mg/l) | 0.004 | 0.005 | 0.004 | 0.004 | 0.00 | 0.05 | 0.05 |
| Dissolved oxygen (mg/l) | 8.81 | 7.54 | 8.68 | 8.34 | 0.70 | 10 | 10 |
| Biochemical oxygen demand (mg/l) | 4.20 | 4.00 | 3.22 | 3.81 | 0.52 | 4 | 4 |
| Chemical oxygen demand (mg/l) | 8.40 | 10.25 | 12.10 | 10.25 | 1.85 | 10 | 10 |
| Turbidity (NTU) | 13.00 | 19.00 | 25.00 | 19.00 | 6.00 | 15 | 15 |

### 3.2. Water Quality Index

Water quality index for each of the four stations along the water body was determined for the surface water using the physicochemical parameters listed in Table 4. The results in Table 4 show the average concentration of the water quality determinants (pH, $CL^-$, TDS, TH, Fe, Cu, Cr, DO, BOD, COD, Turbidity) from the Apo resettlement area for the purpose of assessing the water quality status, for the calculation of WQI.

Table 4: Statistical summary, weight and relative weight for of selected physico-chemical data of surface water

| Parameters | River sample | | | WHO limit | FMEnv limit | Weight ($wi$) | Relative weight $Wi = (wi\sum_{i=1}^{n} wi)$ |
|---|---|---|---|---|---|---|---|
| | Upstream river | midstream river | Downstream river | | | | |
| pH | 6.74 | 6.77 | 6.80 | 6.5-9.2 | 6-9 | 4 | 0.10 |
| Chloride (mg/l) | 10.63 | 10.00 | 11. 23 | 250 | 250 | 1 | 0.02 |
| Total dissolved solids (mg/l) | 48.00 | 52.00 | 55.00 | 500 | 2000 | 5 | 0.12 |
| Total Hardness (mg/l) | 136.96 | 139.10 | 143.01 | 300 | 200 | 3 | 0.07 |
| Iron (mg/l) | 0.02 | 0.02 | 0.03 | 0.3 | 0.3 | 2 | 0.05 |
| Copper (mg/l) | 0.07 | 0.06 | 0.07 | 2 | 2 | 2 | 0.10 |
| Chromium (mg/l) | 0.004 | 0.005 | 0.004 | 0.05 | 0.05 | 4 | 0.12 |
| Dissolved oxygen (mg/l) | 8.81 | 7.54 | 8.68 | 10 | 10 | 5 | 0.10 |
| Biochemical oxygen demand (mg/l) | 4.20 | 4.00 | 3.22 | 4 | 4 | 5 | 0.12 |
| Chemical oxygen demand (mg/l) | 8.40 | 10.25 | 12.10 | 10 | 10 | 5 | 0.12 |
| Turbidity (NTU) | 13.00 | 19.00 | 25.00 | 15 | 15 | 3 | 0.12 |
| | | | | | | $\sum wi = 42$ | $\sum W_i = 1.00$ |

The WQI classifications are presented in Table 5. The computed WQI values were between 45.6% and 76.0 % for the surface water source within Apo resettlement area. In addition, 45.6 % (excellent water type) was recorded for the water sources within Apo resettlement area when compared with Federal Ministry of Environment (FMEnv) Limit. However, the surface water source within Apo resettlement area recorded 76.0% water quality index when compared with the World Health Organization (WHO) limits. Both recommended limits indicate good water type for domestics use and ecosystem functioning. The water quality at the Apo resettlement area in the ‘‘excellent” for FMEnv Limit to ‘‘good” for WHO limits water type from the establishment of the urban and fish market within Apo resettlement area can be due to the rapid urbanization and input of municipal and industrial wastes and/or runoffs from agricultural activities.

Table 5: Water quality index classification for the sampled locations

| Location | WHO Limit | Remark | FMEnv Limit | Remark |
|---|---|---|---|---|
| Water sourced from the Apo resettlement area | 76.0% | Good water type | 45.6% | Excellent water type |

## 4. CONCLUSION

The quality objective of some physicochemical properties of the water body within the Apo resettlement area was assessed and the water quality status was evaluated using water quality Index. The result of study revealed that the river is not suitable for usage as drinking water without treatment, however, the water body can serve excellently for environmental usage especially to support ecosystem functioning. However, the upstream location at the Apo resettlement area has been considered as less polluted site because it is upstream of the Industrial Estate from where a lot of the pollutants are being released into the water bodies due to urbanization. The presence of commercial activities such as the urban and fish markets, industries such as Soap and Detergent Industries Limited, Butterfield Bakery, and agricultural activities around the surrounding catchment impacted negatively on the water body. Other source of pollution of these water bodies within the Apo resettlement area as observed includes human activities as defecation and dumping of untreated waste. In this regard, there should be caution in using the surface water sourced within Apo resettlement area for drinking. More so, the study showed that application of Water Quality Index is a useful tool in assessing the overall quality of the surface water within Apo resettlement area.

## 5. ACKNOWLEDGMENT

The authors wish to acknowledge the assistance and contributions of the laboratory staff of National Water Resources Institute, Kaduna and Nigerian Defense Academy, Kaduna toward the success of this work.

## 6. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

## REFERENCES

Abuja City Report, (2016). The evolution of Abuja as a 'smart city' a prognosis, available online at https://oxfordbusinessgroup.com/ (Date Accessed: (04/28/2023)

APHA, (2012). American Public Health Association American. *Standard Methods for the Examination of Water and Wastewater*, 21st Edition. Washington, pp. 1–467.

Ahaneku, I. E. and Animashaun, I. M. (2013). Determination of water quality index of river Asa, Ilorin, Nigeria *Advances in Applied Science Research,* 4(6), pp. 277-284

Ade, M.A. and Afolabi, Y.D. (2013). Monitoring urban sprawl in the Federal Capital Territory of Nigeria using remote sensing and GIS techniques. *Ethiopian Journal of Environmental Studies and Management*, 6 (1), pp. 82-95.

Agidi, B. M., Akakuru, O.C., Aigbadon, G.O., Schoeneich, K., Isreal, H., Ofoh, I., Joy, N. and Esomonu, I. (2022). Water quality index, hydrogeochemical facies and pollution index of groundwater around Middle Benue Trough, Nigeria. *International Journal of Energy and Water Resources*, 13, pp. 10–16.

Boyacioglu, H. (2007). Development of a water quality index based on a European classification scheme. *Water South African*, 33, pp. 101–106.

Bibi, M.H., Ahmed, F. and Ishiga, H. (2007). Assessment of metal concentrations in lake sediments of southwest Japan based on sediment quality guidelines. *Environmental Geology*, 52 (4), pp. 625–639.

Emmanuel, E.E., Odoh, R., Itodo, A.U., Umoh, S.D. and Lawal, U. (2013). Water quality index for the assessment of water quality from different sources in the Niger delta region of Nigeria. *Frontiers in Science*, 3(3), pp. 89-95.

Global Risks, (2015). World Economic Forum. Available online at http://reports.weforum.org/global-risks-2015/part-1-global-risks-2015/introduction/, Accessed 1st May 2023

Hector, R. A., Manuel, C.C., Rey, M.Q., Ruben, A.S.T. and Adan, P.M. (2012). An overall water quality index for a man-made aquatic reservoir in Mexico. *International Journal of Environmental Resources and Public Health,* 9, pp. 1687–1698.

Horton, R. (1965). An index number system for rating water quality. *Journal of Water Pollution and Control*, 37, pp. 300–306.

Inam, E., Offiong, N., Essien, J., Kang, S., Kang, S. and Antia, B. (2016). Polycyclic aromatic hydrocarbons loads and potential risks in freshwater ecosystem of the Ikpa River Basin, Niger Delta – Nigeria. *Environmental Monitoring and Assessment*, p. 188.

Joshi, D. M., Kumar, A. and Agrawal, N. (2009). Studies on physicochemical parameters to assess the water quality of river Ganga for drinking purpose in Haridwar district. *Rasayan Journal of Chemistry,* 2, pp 195–203.

Kazi, T. G., Arain, M. B., Jamali, M. K., Jalbani, N., Afridi, H.I., Sarfraz, R.A., Baig, J. A. and Shah, A. Q. (2009). Assessment of water quality of polluted lake using multivariate statistical techniques: A case study, *Ecotoxicology and Environmental Safety,* 72, pp. 301–309.

Lobato, T. C., Hauser-Davis, R. A., Oliveira, T. F., Silveira, A. M., Silva, H.A.N., Tavares, M.R.M, and Saraiva, A.C.F (2015). Construction of a novel water quality index and quality indicator for reservoir water quality evaluation: a case study in the Amazon region. *Journal of Hydrology*, 522, pp. 674–683.

Mohamed, E.G., Ali, M.H., Ibrahim, A.A.M., Ayman, H.F. and Seliem, M.E. (2014). Evaluation of surface water quality and heavy metal indices of Ismailia Canal, Nile River, Egypt. *Egypt Journal of Aquatic Resources,* 40, pp. 225–233

Musa, S. D., Ismail, N.A. and Akoji, P. U. (2017). An Assessment of the sustainability of resettlers livelihood assets in the Apo resettlement scheme of Abuja, Nigeria. *Asian Research Journal of Arts & Social Sciences,* 4(3), pp. 1-16.

Oseke, F. I., Anornu, G. K., Adjei, K. A. and Eduvie, M. O. (2021). Assessment of water quality using GIS techniques and water quality index in reservoirs affected by water diversion, *Water-Energy Nexus*, 4, pp. 25-34.

Simeonov, V., Einax, J. W., Stanimirova, I. and Kraft, J. (2002). Environmetric modeling and interpretation of river water monitoring data. *Analytical and Bioanalytical Chemistry*, 374: pp. 898–905

Simoes, F. S., Moreira, A. B., Bisinoti, M. C., Gimenez, S. M. N. and Yabe, M. J. S. (2008). Water Quality index as a simple indicator of aquaculture effects on aquatic bodies. *Ecological Indicators*, 8, pp. 476–484

Will, M. B., Richard, P. A. and George, E. (2015). Host evaluating a great lakes scale landscape stressor index to assess water quality in the St. Louis River Area of Concern. *Journal of Great Lakes Research,* 41, pp. 99–110

World Health Organization (WHO) (2012). Guidelines for Drinking Water-Quality (*4th Edition*), Geneva, Switzerland.