WATER QUALITY INDEX MODEL USING AHP-NSF METHODS; A CASE STUDY OF USUMA DAM RIVER, ABUJA, NIGERIA

Abatan, O. A [a, b*], Animashaun I. M. [b], Muhammad, A. S[b],

[a] National Biotechnology Agency, Abuja
[b] Department of Agricultural and Bioresources Engineering, Federal University of Technology Minna, Nigeria.
[*]Corresponding Author: oluwatoyinabatan@yahoo.com

ABSTRACT
Understanding physicochemical properties and identifying potential contaminants such as heavy pathogens in freshwater systems is crucial for monitoring environmental health and detection of any signs of pollution or change in water quality overtime. This research aimed at assessing the spatiotemporal variation in the water quality of Usuma Dam River, Abuja, Nigeria. Water samples were obtained at predetermined locations along the River and analysed for physicochemical parameters using APHA standard methods. The analysis was done for both the wet and dry seasons. National Sanitation Foundation Water Quality Index (NSFWQI) in combination with Analytic hierarchy process (AHP) models were employed to assess water quality variation for various uses. The results of the analyses shows that while some of the parameters are within the established limits, others are not. The results of the index also showed that the water fall into the medium class during the wet and dry seasons. This indicated that the Usuma Dam River has probably been polluted. Hence, the water is not suitable for domestic uses. Though the river could be used for irrigation, there is need for caution. The study showed that WQI is a useful for proper water treatment plan.

Keywords: Analytic hierarchy process, Physicochemical parameters, Water Quality Index.

1. INTRODUCTION

Water is a vital natural resource that is needed for the proper functioning of every sector of the economy- agriculture, power generation, processing industries, tourism- and for the survival and sustainability of life (Ahaneku and Animashaun, 2013). Conversely, the integrity of the freshwater system has been under continuous threat due to the activities of same sectors that have been the major beneficiaries of water of good health status. Though human - caused activities seems to be the major source of pollution, natural factors such hydrological, atmospheric, climatic, topographical, and lithological elements are all contributors (Uddin *et al.,* 2018).

The rate at which freshwater bodies are polluted in recent time is alarming and the trend is likely to continue due to increasing urbanisation, industrialisation and geometric increase in the world population. The complex and varied water quality is not a challenge faced by only the developing nations, even developed ones are in constant struggle to maintain or improve the quality of their water in the face of issues such as eutrophication of water resources (Uddin *et al.,* 2021).

Hence, for immediate attention and appropriate action, there is a need for monitoring and gathering of accurate and timely information about the water quality of freshwater system of every locality and the world at large.

Water quality refers to the overall status of water as relate to its physicochemical and biological characteristics, and its suitability for designated use such as domestic, industrial and agricultural purpose. The quality of surface water is a reflection of the surrounding environment just as the health status of the people around a particular area depends largely on the quality of their freshwater system (Roopshah, 2016). Assessment and management of water quality requires analysis of several water quality parameters which can be difficult to evaluate or cost and time-consuming. To this end, a number of approaches have been adopted recently among which is the use of indices. Water Quality Index (WQI) is a numerical scale used to classify a single metric arrived at based on computation and use of certain water parameters to express the overall quality of water of a particular source at a specific time (Ahaneku and Animashaun, 2013).

WQI is an effective tool for assessing water quality. It has acceptance worldwide due to its simplicity, consistency, and easiness to compute and use to convey important information about water quality to both non-technical personnel and policymakers. Though several indices have been developed, National Sanitation Foundation Water Quality Index (NSF-WQI), is among the widely used. It is a more rigorous version of Horton's WQI model and about 142 water quality experts informed decided on its parameter selection and weighting (Abbasi and Abbasi, 2012). However, due to its subjective nature during parameter weighting, analytic hierarchy process (AHP) method has been proposed. AHP is a decision-making technique and it is used in the context of WQI parameter weightings to allow for the determination of the most appropriate weightings for given parameters that are reflective of their influence on overall water quality (Uddin *et al.,* 2021).

A number of literatures as reported the use of water quality indices on surface water in Nigeria, only few reported the use of NSF. To our knowledge, no work has been reported on the use of AHP to reduce the bias introduce during the weighting process in NSF. To this end, this research work aimed at assessing the spatiotemporal variation in the water quality of Usuma Dam River to determine its suitability for drinking among other uses.

2. MATERIALS AND METHODS

2.1 Study Area

The area of study is Usuma Dam River, which is situated in Bwari, Federal Capital Territory (FCT), Abuja, Nigeria (Figure 1). Usuma Dam River is a perennial river and stands as the largest among the six drainage basins in Abuja. However, its flow rate significantly decreases during the long dry season, while in the wet seasons, it experiences high run-off and low infiltration capacity due to flash floods. These floods lead to swift transportation of large volumes of sediments downstream (Balogun, 2020). The dam receives inflow of water from Usuma and Gyedna Rivers

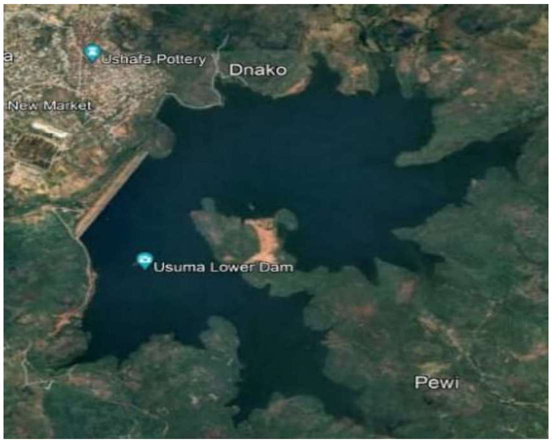

Figure 1: Usama dam

2.2 Sample collection and Analysis

In this study, water samples were collected at various sampling points (i.e., on Usuma river, Gyedna River and at the mid-station) in the study area during dry and wet season. The collected water samples were immediately taken to the laboratory for analyses. The analyses were done using the methods specified by the American Public Health Association (APHA) standard method as documented in the APHA's guidelines (APHA, 2012). The measured parameters measured are pH, Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Dissolved Solids (TDS), Temperature, Turbidity (Tur) and Nitrates (NO_3).

2.3 National Sanitation Foundation (NSF) Water Quality Index

The Water Quality Index(WQI) for the Usuma Dam River was calculated from the above-mentioned parameters to assess its suitability for drinking purposes among other uses. The WQI employed in this study, is a modified version of the National Sanitation Foundation (NSF) method. The modification involved the use of AHP as against the traditional way of assigning weight. The process for computing the NSF water quality index consists of four key stages.

2.3.1 Selection of water quality index parameters

Though about twenty parameters were measured, the eight mentioned in this article are those considered for calculating the water quality index. The choice of parameters is based on their significance for drinking water, as indicated by experts in water resources and engineering. (Uddin *et al* 2021)

2.3.2 Calculation of parameter sub-Index weights using rating curves (q):

Rating curves are employed to establish sub-index ratings for each parameter. Each parameter possesses its own rating curve. These rating curves transform measurements of the chosen water quality parameters into dimensionless sub-index curves, represented as a percentage.

2.3.3 Allocation of weights (w):

In this step, certain parameters are deemed more critical than others based on the extent of harm they can cause when present in water. Parameters with higher potential hazards are assigned greater values, whereas those with lesser potential harm are assigned lower. The assignment of weights is accomplished using the analytical hierarchy approach (AHP). AD Sutadian *et al* 2017. This method helps to reduce uncertainty resulting from inappropriate weighting of parameters. The respective weight assigned to each parameter is presented in Table 1 below.

Table 1: Weight Assigned to water quality parameter based on AHP Approach

Parameter	DO	BOD	COD	pH	NO_3^-	TDS	Turbidity	Temperature
AHP Weight	0.16	0.13	0.15	0.13	0.10	0.12	0.10	0.11

2.3.4 Generation of the ultimate index value

This step involves a mathematical formula that adds together the results of multiplying the weights of various parameters with their respective sub-index values. The equation is below is used to generate water quality index;

Water Quality Index (WQI) $=\sum_{i=1}^{n} Qi\ wi$ (1)

where Qi represents the sub-index corresponding to the i^{th} water quality parameter,
wi stands for the weight linked to the i^{th} water quality parameter, and
n denotes the count of water quality parameters.

The Water Quality Index (WQI) was computed using the accepted Q-value for each parameter along with the assigned weight, and then compared against the NSF's recognized water quality rating. Water quality rating for NSF is selected from the Table 2

Table 2: **Water Quality Index Scoring System**

S/No	WQI range	Class
1	90-100	Excellent
2	70-89	Good
3	50-69	Medium
4	25-59	Bad
5	0-24	Unsuitable for drinking

Uddin *et al* 2021

3. RESULTS AND DISCUSSION

3.1 NSF-WQI Classification of Usuma Dam River during the Dry Season

The National Sanitation Foundation (NSF) Water Quality Index outcomes of dry season water quality assessment for Gyedna River, Mid-section and Usuma river are 55.22, 55.17, and 53.92 respectively (Table 3-5). Using the NSF-WQI approach for classification, the findings for these three stations reveal that the water quality is medium during the dry season.

Table 3 NSF- AHP WQI for Gyedna River during Dry season

S/N	Parameter	Measured value	Rating Qi	Weight factor wi	QixWi
1	DO	6.98	6.4	0.16	1.02
2	BOD	3.60	60	0.13	7.80
3	COD	10.60	30	0.15	4.50
4	pH	7.20	89	0.13	11.57
5	NO_3^-	1.80	97	0.1	9.70
6	TDS	38.63	82	0.12	9.84
7	Turbidity	1.91	98	0.1	9.80
8	Temperature	29.97	9	0.11	0.99
				WQI	**55.22**

Table 4 NSF-AHP WQI for Mid-section during Dry season

S/N	Parameter	Measured value	Rating Qi	Weight factor wi	QixWi
1	DO	8.30	8.5	0.16	1.36
2	BOD	4.00	57	0.13	7.41
3	COD	12.10	24	0.15	3.60
4	pH	7.10	88	0.13	11.44
5	NO_3^-	1.90	97	0.1	9.70
6	TDS	44.40	86	0.12	10.32
7	TURB	3.60	91	0.1	9.10
8	TEMP	29.73	9	0.11	0.99
				WQI	**53.92**

Table 5: NSF-AHP WQI for Usuma Dam River during the Dry season

S/N	Parameter	Measured value	Rating Qi	Weight factor wi	QixWi
	DO	6.90	6.3	0.16	1.01
1	BOD	9.20	33	0.15	4.95
2	COD	7.20	89	0.13	11.57
3	pH	2.13	90	0.1	9.00
4	NO_3^-	37.73	81	0.12	9.72
5	TDS	37.73	81	0.12	9.72
6	TURB	2.39	92	0.1	9.20
7	TEMP	30.03	9	0.11	0.99
				WQI	**55.17**

3.2 NSF-WQI Classification of Usuma Dam River during the Wet Season

In the wet season, the Water Quality Index for the Gyedna River, Mid-section and Usuma river are 53.69, 50.91, and 50.95 respectively (Tables 6-8). The obtained index values for the three stations also indicate a medium level of water quality during the wet season.

Table 6: NSF- WQI for Gyedna River during Wet Season

S/N	Parameter	Measured value	Rating Qi	Weight factor wi	QixWi
1	DO	8.47	8.5	0.16	1.36
2	BOD	3.97	64	0.13	8.32
3	COD	11.60	31	0.15	4.65
4	pH	7.20	89	0.13	11.57
5	NO_3^-	4.80	76	0.1	7.60
6	TDS	46.47	86	0.12	10.32
7	TURB	6.05	80	0.1	8.00
8	TEMP	26.13	17	0.11	1.87
				WQI	**53.69**

Table 7: NSF-WQI for the Mid-Section during the Wet Season

S/N	Parameter	Measured value	Rating Qi	Weight factor wi	QixWi
1	DO	8.08	8.1	0.16	1.30
2	BOD	4.23	55	0.13	7.15
3	COD	12.57	26	0.15	3.90
4	pH	7.20	89	0.13	11.57
5	NO_3^-	5.23	68	0.1	6.80
6	TDS	45.97	86	0.12	10.32
7	TURB	5.92	80	0.1	8.00
8	TEMP	26.27	17	0.11	1.87
				WQI	**50.91**

Table 8: NSF-AHP WQI for Usuma Dam River during Wet Season

S/N	Parameter	Measured value	Rating Qi	Weight factor wi	QixWi
1	DO	7.93	7.3	0.16	1.17

2	BOD	3.97	57	0.13	7.41
3	COD	12.13	27	0.15	4.05
4	pH	7.20	89	0.13	11.57
5	NO_3^-	4.60	75	0.1	7.50
6	TDS	26.23	84	0.12	10.08
7	TURB	9.71	73	0.1	7.30
8	TEMP	26.37	17	0.11	1.87
				WQI	**50.95**

The river's water quality was computed using the NFS-AHP WQI using eight parameters. The obtained index values fall within the range of 50-55 across the three stations during dry and wet season which suggested a medium water quality (Ewaid, 2016). The results of the physicochemical parameters used for WQI calculation reflected the medium water quality class of the three stations. For instance, while the pH values mostly fall within the established limit of WHO and NSDWQ (6.5-8.5), the high COD values suggest the presence of the biological active and inorganic matter in the soil (Mahi and Isah, 2016). The result is in agreement with the finding of Okunlola et al. (2014) which ranked Usuma dam rivers low and concluded that the river water quality has been compromised.

4. Conclusion

Physicochemical parameters of Usuma River were assessed during the wet and dry seasons. The obtained results of the analysis were used to establish the river water quality status using NSF-AHP WQI. The result of study indicated medium class of the river water and hence not suitable for domestic purposes in any of the three stations. The high values of some of the parameters suggest probable influence of man activities on the rivers. There is therefore a need in using the water without treatment. The study showed the effectiveness of the WQI in assessing the overall quality of river

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