American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-5, Issue-10, pp-96-101
www.ajer.org
Research Paper Open Access

The Use of Water Quality Index Method to Determine the Potability of Surface Water and Groundwater in the Vicinity of a Municipal Solid Waste Dumpsite in Nigeria.

Olayiwola Oni[1] and Olubunmi Fasakin[2]
[1]*Department of Civil Engineering, Ekiti State University, Ado Ekiti, Nigeria*
[2]*Department of Chemistry, Ekiti State University, Ado Ekiti, Nigeria*

ABSTRACT: *The quality of the groundwater and surface water bodies close to the location of the major dumpsite being used for disposing the municipal solid waste produced by residents of Ado Ekiti, Nigeria was determined. In contrast to the common method of comparing measured values of the physico-chemical and biological properties of water with standard values, a water quality index (WQI) method was used to classify the water. Analysis of the water samples using the WQI method indicated that the quality of both the groundwater and surface water poor owing to the high content of lead in them. It was concluded that the WQI method is a very effective tool for determining the quality of water susceptible to leachate pollution and communicating it in an unambiguous manner to the stakeholders in the water industry.*

Keywords: *water quality index, municipal solid waste, dumpsite, parameters, leachate*

I. INTRODUCTION

"Water is life", "Health is Wealth' and "Waste to Wealth" are popular sayings relating to life and wealth. However, waste that is not properly managed in the vicinity of surface water and groundwater can be detrimental to life, health and wealth. Ever since the 'Earth Summit' in Rio de Janeiro in June 1992, awareness on the environment and sustainable development has increased tremendously all over the world. More importantly, is the greater awareness of and concern over the growing scarcity of potable water [1]. This is not surprising as clean water supplies and sanitation remain persistent problems in many parts of the world, with approximately a fifth of the global population lacking access to potable water [2]. Today, approximately 1.1 billion people worldwide do not have access to improved water supply sources and 450 million people in 29 countries have critical water shortages. In fact, it is projected that two-thirds of the people will live in water-stressed areas by the year 2025. In Africa alone, it is projected that 25 countries will be experiencing water stress (below 1,700 m^3per capita per year) by 2025[2]. Currently, approximately 18 million (43%) out of the over 44 million people living in Kenya do not have access to clean water [3]. Over 3,100 children die yearly from diarrhoea caused by unsafe water and poor sanitation in Kenya. In Nigeria, approximately 130 million people do not have access to adequate sanitation and approximately 57million people do not have direct access to potable water. Consequently, approximately 45,000 children under five years old die yearly from diarrhoea, which is caused by unsafe water and poor sanitation [4]. This is quite significant, considering a projected 2016 population of 187million [5].

The continued disposal of solid waste at open dumpsites constitutes an ever-present problem to the health of people living in the developing countries [6-9]. This is owing to the burning of the waste and runoff of leached contaminants from these sites to the adjoining ground and surface water-bodies. There have been many studies on the effect of dumping solid waste indiscriminately at open dumpsites in the developing countries. In some cases, water quality data of boreholes close to a refuse dump have been compared with the data of a control borehole, which is very far from the refuse dump [10]. In many cases, the values of measured parameters in the ground and surface water-bodies have been compared with international and national standards to determine their adequacy [11-19].

The use of water quality index (WQI) in determining the quality of both surface and ground water-bodies have increased tremendously since the initial WQI developed by Horton in 1965, and improved version by Brown et al. in 1970 [20, 21]. This is owing to the ability of WQI to provide a number, simple enough for the public to understand, that states the overall water quality at a certain location and time using the measured values of selected water quality parameters. In most cases, it is used to determine the potability of surface water and groundwater. Over the years, several WQIs have been proposed and used appropriately by governmental agencies and researchers. These include: (a) The Scatterscore index [22]; (b) Index of River Water Quality [23]; (c) Overall Index of Pollution [24]; (d) Chemical Water Quality Index [25]; (e) Iowa Water Quality Index [26]; (f) Universal Water Quality Index-UWQI [27]; (g) Canadian Council of Ministers of Environment Water Quality Index-CCMEWQI [28-30]; (h) National Sanitation Foundation Water Quality Index – NSFWQI [21, 31]; (i) Oregon Water Quality Index-OWQI [32, 33]; (j) Weighted Arithmetic Water Quality Index Method-WAWQIM [34-36].Out of these, the CCMEWQI, NSFWQI, OWQI, and WAWQIM are the commonly used [37, 38].

The WQI, which is calculated using the weighted arithmetic index method (WAWQIM)is commonly used among researchers in developing countries where data collection infrastructure is not extensive for the database of the water quality parameters to be vast, and reliable rating curves are rare [39-44]. It is especially useful for determining the water quality at a place where data have been collected over a period of time for the specific purpose of determining the water quality. It is also simple and easy to use by any researcher or assessor. It has been observed that most researchers have employed the WQI to determine the water quality in surface waters (rivers and lakes) and groundwater individually without any reference to the perennial curse of the contamination or pollution. In this study, however, the WQI has been used as a tool to determine the impact of the practice of dumping municipal solid waste at open dumpsites on the ground and surface water-bodies in the immediate environment. This is important as the study area has a tropical climate and therefore susceptible to enormous leachate runoff from the waste fill, as the dumpsite is not engineered.

II. STUDY AREA

The study area comprises a stream and groundwater in the dug wells in the vicinity of the major dumpsite being used for the disposal of municipal solid waste (MSW) produced in Ado Ekiti, Nigeria (Figure 1) by Ekiti State Waste Disposal Board. Ado Ekiti is a city located between latitude 7^{o}25’ and 7^{o}47’north of the equator, and between longitude 5^{o}5’ and 5^{o}30’ east of the Greenwich Meridian. The city experiences the wet and dry seasons. The wet season runs from April through October while the dry season runs from November through March. The main rock type found in the study area is charnockitic rock which has undergone an intense weathering into reddish to dark brown medium grained lateritic layer of considerable thickness [45, 46]. The groundwater in the wells is used by the residents of Aba Igbira as potable water while the stream adjacent to the dumpsite is being used for washing and occasionally drinking purposes by the farmers that have farms in the vicinity of the stream.

III. MATERIALS AND METHODS

Data: The water samples were collected from four different locations-two each from the stream (SW1, SW2) and dug wells(GW1, GW2),in the vicinity of the MSW dumpsite. The samples were collected at the peak wet season in June, through August 2016. The samples were collected in clean 2litre plastic bottles that were rinsed three times with the well water and stream water respectively, prior to eventual sampling. The pH and temperature were done in-situ while the other physicochemical and bacteriological parameters were measured in the laboratory using standard procedures and precautions [47]. Each sample was divided into three subsamples to enable representative value of the parameters to be obtained. Distance of well water to ground level was 5m.

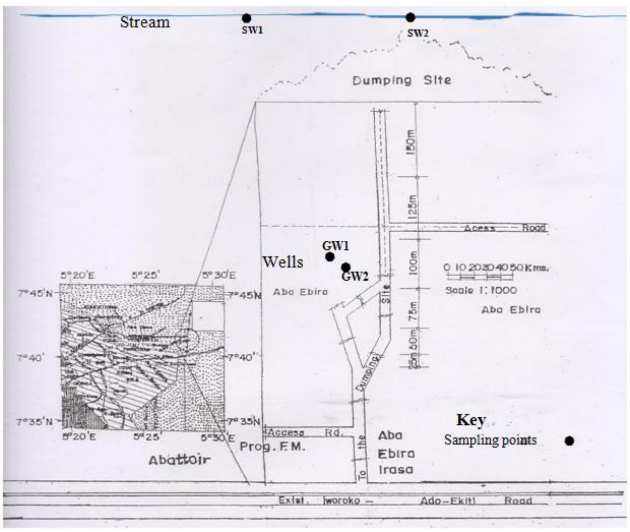

Figure 1: Map of the study area.

Model Selection: The WQI method is a powerful tool that enables easy communication of the quality of water to the public especially the policy makers. It is an unambiguous tool that enables the integration of the water parameters, which are deemed important to the quality of the water accordingly. In this study, the WQI, which is calculated using the weighted arithmetic index method [21] is used to determine the effect of waste dumping on the immediate ground and surface water- bodies to the dumpsite, as it is deemed the most appropriate, based on the prevailing conditions.
The WQI is given as:

$$WQI = \frac{\sum_{i=1}^{n} q_i w_i}{\sum_{i=1}^{n} w_i} \quad (1)$$

where
q_i=quality rating (sub index) of i^{th} water quality parameter
w_i= unit weight of i^{th} water quality parameter; $\sum_{i=1}^{n} w_i = 1$
Also, q_i , which relates the value of the parameter in polluted water to the standard permissible value is obtained as follows:

$$q_i = 100\left(\frac{v_i - v_{io}}{s_i - v_{io}}\right) \quad (2)$$

where
v_i= estimated value of the i^{th} parameter
v_{io}= ideal value of the i^{th} parameter
s_i= standard permissible value of the ith parameter
In most cases, v_{io}=0 except for pH and DO
For pH, v_{io}=7; For DO, v_{io}=14.6mg/l
The unit weight (w_i), which is inversely proportional to the values of the recommended standards is obtained as:

$$w_i = \frac{K}{s_i} \quad (3)$$

Where $k = \frac{1}{\sum_{i=1}^{n} \frac{1}{s_i}}$

The rating of the water quality using the above method is shown in Table 1.

Table 1: Rating of Water Quality for various WQI

WQI	Rating of Water Quality
0-25	Excellent
26-50	Good
51-75	Poor
76-100	Very Poor
Above 100	Unsuitable for Drinking

Parameter Selection: The parameters used for the indices of water quality in this study are those used for the Global Drinking Water Index Development and Sensitivity Analysis [48]. These parameters have been carefully selected to accurately reflect the major acceptability and health issues relating to water quality. In addition, factors including detection level and general ability for researchers and stakeholders to accurately measure the parameters in most parts of the world have been considered. The parameters are presented in Table 2.

Table 2: Parameters used in WQI [48]

Acceptability	Health	Microbes
Ammonia	Arsenic	Faecal Coliform bacteria
Chloride	Boron	
Iron	Cadmium	
pH	Chromium	
Sodium	Copper	
Sulphate	Fluoride	
Zinc	Lead	
	Manganese	
	Mercury	
	Nitrate	
	Nitrite	

IV. RESULTS AND DISCUSSION

The measured values of the water-quality parameters of the surface water and groundwater at the study area are presented in Table 3. The WHO guidelines, which are universally accepted as the permissible values for the water-quality parameters, have been categorized and presented in Table 3. In order to include the impact of microbes on the WQI, a non-zero value was specified for faecal coliform bacteria count [48]. There is no specified value for dissolved oxygen (DO) in the WHO guidelines and is thus excluded from the selected parameter used for the calculation of WQI.

The computed WQIs for the steam points and groundwater points SW1, SW2, GW1 and GW2 respectively indicate a very poor quality of water. This has been caused principally by the high content of lead in relative to the WHO permissible level, which has been based on health issues. Sometimes, there are concerns on the accuracy of values of the parameters used for calculating WQI in the developing countries, owing to the integrity of the obsolete equipment often used for the measurements. In addition, contamination of the water in the dug wells often used as samples for groundwater occurs due to the contaminated and rusty metallic containers commonly used for drawing water from such wells by the peasants living in the vicinity of the study area. This would have probably affected the high values of parameters such as lead and iron in the groundwater in wells used in this study.

Table 3: The Measured Values of the Water Quality Parameters and WHO Guidelines

Parameter	Measured Values				WHO Guidelines –Permissible value [49]	
	GW1	GW2	SW1	SW2	Acceptability (Taste, Colour and Appearance)	Health issues
Temperature	24.0	25.8	26.0	25.3	-	-
Odour	odourless	odourless	odourless	odourless		
Colour (TCU)	5	5	15	15	15	nhgv
Turbidity (NTU)	3.4	2.9	6.4	6.6	5	nhgv
Total Dissolved Solids (mg/l)	410	418.5	550.5	647.5	600 is used for palatability	nhgv
Appearance	fairly clear	fairly clear	Not clear	Not clear	-	-
pH	5.6	6.0	5.6	6.2	6.5-8	nhgv
Sulphate (mg/l)	10.0	10.1	8.0	8.0	250	nhgv
Dissolved Oxygen mg/l	2.4	3.3	2.1	2.8	-	-
Calcium (mg/l)	29.9	24.7	57.9	70.2	Expressed as hardness	-
Magnesium (mg/l)	31.2	44.7	103.9	159.9	Expressed as hardness	-
Iron (mg/l)	0.45	0.45	0.45	0.45	0.3	nhgv
Nitrite (mg/l)	0.17	0.10	0.24	0.22	-	3mg/l
Alkanity	36.6	40.2	44.6	27.4	-	-
Chloride (mg/l)	125.0	136.6	223.5	371.0	250	nhgv
Hardness (mg/l)	33.2	35.9	36.8	42.0	200	nhgv
Nitrate (mg/l)	0.35	0.25	0.50	0.48	-	50
Lead (mg/l)	0.02	0.05	0.08	0.05	-	0.01
Zinc (mg/l)	0.09	0.07	0.02	0.03	3	nhgv
Copper (mg/l)	0.012	0.005	0.008	0.002	Staining may occur at lesser values	2
E-coli (counts/100ml)	14	15	26	25	-	0
Total Coliform (counts/100ml)	15	15	23	25		0
BOD (mg/l)	73.1	64.2	62.5	68.1	-	-
COD (mg/l)	160.0	182.5	227.5	220.0	-	-

SW1and SW2- Surface water samples 1 and 2 respectively; GW1 and GW2- Groundwater samples 1 and 2 respectively; nhgv- No health guideline values; - Not specified.

Table 4: Calculated Values of WQI

S/N	Parameter	s_i	$1/s_i$	Unit weight ($w_i=k/s_i$)	GW1 q_i	GW2 q_i	SW1 q_i	SW2 q_i	GW1 q_iw_i	GW2 q_iw_i	SW1 q_iw_i	SW2 q_iw_i
1	pH	8	0.13	0.001	140.0	100.0	145.0	80.0	0.17	0.12	0.17	0.10
2	Sulphate (mg/l)	250	0.004	0.00004	4.0	4.0	3.2	3.2	0.0002	0.0002	0.0001	0.0001
3	Iron (mg/l)	0.3	3.3	0.03	149.7	146.3	136.7	120.0	4.8	4.7	4.3	3.8
4	Nitrite (mg/l)	3	0.3	0.003	5.7	3.4	8.0	7.2	0.018	0.011	0.025	0.023
5	Cloride (mg/l)	250	0.004	0.00004	50.0	54.6	89.4	148.4	0.002	0.002	0.003	0.006
6	Nitrate (mg/l)	50	0.02	0.0002	0.70	0.50	1.0	0.95	0.0001	0.0001	0.0002	0.0002
7	Lead (mg/l)	0.01	100	0.95	225.0	470.0	845.0	515.0	214.8	448.7	806.7	491.6
8	Zinc (mg/l)	3	0.33	0.003	3.0	2.3	0.53	0.87	0.009	0.007	0.002	0.003
9	Copper (mg/l)	2	0.50	0.005	0.58	0.25	0.38	0.08	0.003	0.001	0.002	0.0004
10	Total Coliform (counts/100ml)	10	0.10	0.001	150	150	230	250	0.14	0.14	0.22	0.24
		$\Sigma(1/s_i)$ =	104.8	Σwi=1				WQI=	220	454	811	496
		$k = 1/(\Sigma(1/s_i))$ =	0.01					Average. WQI=	337		654	

Ordinarily, natural attenuation of any infiltrating pollutant in the study area is expected to occur within the 5m vadose zone above the water level in the wells as the soil formation between the ground surface level and the water level is lateritic soil; which is expected to act a natural filter for infiltrating contaminated water in the area. The poor quality of water in the surface stream is expected as the refuse dumpsite is uncontrolled. Moreover, the solid waste being deposited at the dumpsite consists of all types of solid waste produced by residents in Ado Ekiti-both hazardous and non-hazardous. Even with these influencing factors, the calcaulated WQI for the groundwater is relatively lower than the surface stream, which would have been affected by the direct runoff of leachate from the nearby refuse-dump. In general, the magnitude of non-drinkability of the waters near the dumpsite has been undoubtedly shown with the WQI method.

V. CONCLUSION

This study has shown that WQI is a powerful, yet a simple tool, that can be used to accurately determine the impact of unabated placement of solid waste at open dumpsites on the immediate groundwater and surface water. Whereas the quality of groundwater and surface water in the vicinity of the major waste dump at Ado Ekiti has been found to be very poor owing to the high content of principally lead in the waters, the significance of WQI in determining the impact of uncontrolled dumping of solid waste in the vicinity of surface and ground water bodies cannot be overemphasised. The water in both groundwater and surface water in the vicinity of the dumpsite has been simply shown to be not suitable for drinking and other daily uses of the peasants living there.

ACKNOWLEDGEMENT

The authors are grateful to Kehinde George, Yusuf Oteniara and Ayo Oluwatugbo for their contributions to the success of this paper.

REFERENCES

[1]. UN, (1997).*United Nations Conference on Environment and Development (1992)* [online]. Available at: http://www.un.org/geninfo/bp/enviro.html [Accessed December 22 2014]/

[2]. UNEP, (2008). *An Overview of the State of the World's Fresh and Marine Waters - 2nd Edition – 2008* [online]. Available at: http://www.unep.org/dewa/vitalwater/article186.html [Accessed April 15 2015].

[3]. Just One Africa, (2016).*Clean Water: The Problem* [online]. Available at: https://www.justoneafrica.org/clean-water/?gclid=CPnrtrfhh88CFcQV0wod3K8DYQ [Accessed January 29 2016].

[4]. Water Aid, (2016).*Nigeria* [online]. Available at: http://www.wateraid.org/ng. [Accessed January 21 2016]

[5]. UN, (2016). *World Statistics Pocketbook-Nigeria* [online]. Available at: http://data.un.org/CountryProfile.aspx?crName=NIGERIA [Accessed February 16 2016]

[6]. Nabegu, A. B. (2010). An Analysis of Municipal Solid Waste in Kano Metropolis, Nigeria. *Journal of Human Ecology*, 31(2), pp111-119.

[7]. Aderemi, A. O. and Falade, T. C. (2012). Environmental and Health Concerns Associated with the Open Dumping of Municipal Solid Waste: A Lagos, Nigeria Experience. *American Journal of Environmental Engineering*, 2(6), pp 160-165.

[8]. Ogunrinola, I. O. and Adepegba, E. O. (2012). Health and Economic Implications of Waste Dumpsites in Cities: The Case of Lagos, Nigeria. *International Journal of Economics and Finance*, 4(4), pp239-251.

[9]. Obeta, M. C. and Ochege, F. U. (2014). Effects of Waste Dumps on Stream Water Quality in Rural Areas of Southern Nigeria. *IOSR Journal of Environmental Science, Toxicology and Food Technology*, 8(2), pp 82-88.

[10]. Ogbeibu, A. E., Chukwurah, N. A. and Oboh, I. P. (2012). Effects of an open Waste dump-site on groundwater quality in Ekurede-Urhobo, Warri, Delta State, Nigeria. *Tropical Freshwater Biology*, 21(2): 81-98.

[11]. Omofonmwan, S. I. And Eseigbe, J. O. (2009), Effects of Solid Waste on the Quality of Underground Water in Benin Metropolis, Nigeria. *Journal of Human Ecology*, 26(2), pp 99-105.

[12]. Akudo, E. O., Ozulu, G. U. and Osogbue, L. C. (2010). Quality Assessment of Groundwater in Selected Waste Dumpsites Areas in Warri, Nigeria. *Environmental Research Journal*, 4(4), pp281-285.

[13]. Abdus-Salam, N., Ibrahim, M. S. and Fatoyinbo, F. T. (2011). Dumpsites in Lokoja, Nigeria: A Silent Pollution Zone for Under-groundwater.*Waste Management and Bioresource Technology*, 21-30.

[14]. Saidu, M. (2011).Effect of Refuse Dumps on Groundwater Quality.*Advances in Applied Science Research*, 2(6), pp 595-599.

[15]. Afolayan, O. S. and Ogundele, F. O. (2012). Comparative Analysis of the Effect of Closed and Operational Landfills on groundwater Quality in Solous, Lagos, Nigeria. *Journal of Environmental Science and Water Resources*, 1(3), pp52-58.

[16]. Butt, I. and Ghaffar, A. (2012). Ground Water Quality Assessment near MehmoodBoti Landfill, Lahore, Pakistan. *Asian Journal of Social Sciences and Humanities*, 1(2), pp 13-24.

[17]. Oyelami, A. C., Ojo, A. O., Aladejana, J. A. and Agbede, O. O. (2013). Assessing the Effect of a Dumpsite on Groundwater Quality: A Case Study of Aduramigba Estate within Osogbo Metropolis. *Journal of Environment and Earth Science*, 3(1), pp 120-130.

[18]. Salami L., Fadayini, M.O. and Madu C. (2014). Assessment of a Closed Dumpsite and Its Impact on Surface and Groundwater Integrity: A Case of OkeAfa Dumpsite, Lagos, Nigeria. *IJRRAS*, 18(3), pp 222-230.

[19]. Anilkumar, A., Sukumaran, D. and Vincent, S. G. T. (2015). Effect of Municipal Solid Waste Leachate on Ground Water Quality of Thiruvananthapuram District, Kerala, India. *Applied Ecology and Environmental Sciences*, 3(5), pp 151-157.

[20]. Horton, R. K. (1965).An Index number system for rating water Quality. *J. Water Pollu. Contd. Fed*., 37(3), pp 300-305.

[21]. Brown, R. K., McClelland, N. I., Deininger, R. A. and Tozer, R. G. (1970). Water Quality Index-do we care? *Water Sewage Works*, 117(10), pp 339-343.

[22]. Kim, A. G. and Cardone, C. R. (2005).Scatterscore: a reconnaissance method to evaluate changes in water quality. *Environmental Monitoring and Assessment*, 11, pp 227-295.

[23]. Liou, S. M., Lo, S. L. and Wang, S.H. (2004). A generalized water quality Index for Taiwan. *Environmental Monitoring and Assessment*, 96, pp 25-32

[24]. Sargonkar, A. and Deshpande, V. (2003). Development of an Overall index of Pollution for Surface water based on a General Classification Sheme in India Context. *Environmental Monitoring and Assessment*, 89, pp 43-67.

[25]. Tsegaye, T., Sheppard, D., Islam, K.R., Johnson, A., Tadesse, W., Atalay, A. and Marzen, L. (2006). Development of Chemical Index as a Measure of In-Stream Water Quality in Response to Land-use and Land Cover Changes. *Water, Air, and Soil Pollution*, 174, pp 161-179.

[26]. IDNR, (2006). Why a Water Quality Index? Iowa Department of Natural Resources, *Geological Survey*, Iowa City.

[27]. Boyaciogiu, H. (2007). Development of a Water Quality Index based on a European Classification Scheme. *Water SA*, 33(1), pp 101-106.

[28]. CCME, (2001).*Canadian Environmental Quality Guidelines for the Protection of Aquatic Life*, CCME Water Quality Index: technical report, 1.0

[29]. Lumb, A., Halliwell, D. and Sharma, T. (2006). Application of CCME Water Quality Index to Monitor Water Quality: a case of Mackenzie River Basin, *Canada. Environ. Monit. Assess.*, 113, pp 411-429.

[30]. Damo, R. And Icka, P. (2013). Evaluation of Water Quality Index for Drinking Water.*Pol. J. Environmental Studies*, 22(4), pp 1045-1051.

[31]. Kumar, A. A. and Alappat, B. (2009). NSF-Water Quality Index: Does it represent the Experts' Opinion? *Pract. Period. Hazard. Toxic. Radioact. Waste Manage*. 13(1), pp 75-79.

[32]. Dunnette, (1979).A geographically variable water Quality Index used in Oregon. *J. Water Pollu. Contd. Fed.*, 51(1), pp 53-61.

[33]. Dinius, S. H. (1987).Design of an Index of Water Quality.*Water Resources Bulletin*, 23(5), pp 833-843.

[34]. Chauhan, A. and Singh, S. (2010). Evaluation of Ganga Water for Drinking Purpose by Water Quality Index at Rishikesh, Uttarakhand, India, *Report Opinion*, 2(9), pp 53-61.

[35]. Rao, C. S., Rao, B. S., Hariharan, A. V. L. and Bharathi, N. M. (2010). Determination of Water Quality Index of some areas in Guntur District Andra Pradesh.*Int. J. Appl. Bio. Pharm. Tech*., 1(1), pp 79-86.

[36]. Manju, E. K., George, A. V. And Rekha, V. B. (2014). A Comparative Study of Water Quality Index (Wqi) of Vagamon and Peermade Sub-Watersheds of Meenachil and Pamba River Basins of Western Ghats, Kerala, South India. *IOSR Journal of Environmental Science, Toxilogy and Food Technology*, 8(1), pp 53-58.

[37]. Bharti, N. And Katyal, D. (2011). Water Quality Indices Used for Surface Water Vulnerability Assessment. *International Journal of Environmental Sciences*, 2(1), pp 154-164.

[38]. 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.

[39]. Yogendra, K. and Puttaiah, E. T. (2008).*Determination of Water Quality Index and Suitability of an Urban Water body in Shimoga Town, Karnataka*. In Proceedings of Taa2007: The 12th World Lake Conference. pp342-346.

[40]. Amadi, A. N., Olasehinde, P. I., Okosun, E. A. and Yisa, J. (2010). Assessment of the Water Quality Index of Otamiri and Oramiriukwa Rivers. *Physics International*, 1(2), pp 116-123.

[41]. Yisa, J. And Jimoh, T. (2010).Analytical Studies on Water Quality Index of River Landzu. American *Journal of Applied Sciences*, 7(4), pp 453-458.

[42]. Akoteyon, I. S., Omotayo, A. O., Soladoye, O. and Olaoye, H. O. (2011). Determination of Water Quality Index and Suitability of Urban River for Municipal Water Supply in Lagos, Nigeria. *European Journal of Scientific Research*, 54(2), pp 263-271.

[43]. Boah, D. K., Twum, S. T. And Pelig-Ba, K. B. (2015). Mathematical Computation of Water Quality Index ofVea Dam in Upper East Region of Ghana. *Environmental Sciences*, 3(1), pp 11-16.

[44]. Akter, T., Jhohura, F. T., Akter, F., Chowdhury, T. R., Mistry, S. K., Dey, D., Barua, M. K., Islam, M. A. and Rahman, M. (2016). Water Quality Index for Measuring Drinking Water Quality in Rural Bangladesh: a cross sectional study. *Journal of Health, Population and Nutrition*, 35(4), pp 1-12.

[45]. Ogundana, A.K., and Talabi, A. O. (2014). Groundwater Potential Evaluation of College of Engineering, Afe Babalola University, Ado-Ekiti, Southwestern Nigeria, *American Journal of Water Resources*, 2(1), pp 25-30.

[46]. Okwoli, E., Onoja, O.S. and Udoeyop, U. E. (2014). Ground Magnetic and Electrical Resistivity Mapping for Basement Structurs over Charnokitic Terrain in Ado-Ekiti Area, South western Nigeria. *International Journal of Science and Technology*, 3 (10), pp683-689.

[47]. Eaton, A. D., Clesceri, L. S., Greenberg, A. E. and Federation, W. E. (1995).*Standard Method for Examination of Water and Wastewater*. 19thEdn., Published by E. and F. N. Spon, Washington D. C.

[48]. UNEP, (2007).*Global Drinking Water Quality Index Development and Sensitivity Analysis Report*. United Nations Environment Programme Global Environment Monitoring System/Water Programme.

[49]. WHO, (2011), *Guidelines for Drinking-water Quality*, Fourth Edition, World Health Organisation.