Magna Scientia Advanced Research and Reviews

Cross Ref DOI: 10.30574/msarr

Journal homepage: https://magnascientiapub.com/journals/msarr/

(RESEARCH ARTICLE)

Evaluation of water quality index in some artificial aquatic environments in Port Harcourt, Rivers State, Nigeria

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Magna Scientia Advanced Research and Reviews, 2021, 01(03), 013–021

Publication history: Received on 10 January 2021; revised on 06 February 2021; accepted on 08 February 2021

Article DOI: https://doi.org/10.30574/msarr.2021.1.3.0015

Abstract

Background and Objective: This study aimed at using application of Water Quality Index (WQI) in evaluating the quality status of some artificial aquatic environments (concrete, earthen and plastic fish tanks/pond) in Roone Fish Farm, Port Harcourt, Rivers State, Nigeria were studied from October 2018 to September 2019.

Methodology: Nine water quality parameters were considered and some samples were measured in-situ (Temperature, pH, conductivity (EC), total dissolved solid (TDS), turbidity, dissolved oxygen (DO) while biological oxygen demand (BOD), nitrate (NO3) and phosphate (PO4) were analyzed in the laboratory following standard methods.

Results: The results obtained were subjected to Minitab version 16 and Tukey's comparison test was also employed to separate means. The water quality index (WQI) calculation used the mean values of the nine (9) parameters chosen using the standards recommended by the World Health Organization (WHO), Bureau of Indian Standards (BIS) and Indian Council for Medical Research (ICMR) for drinking water quality. The water quality indices for concrete fish tank, earthen fish pond and plastic fish tank were 60.24, 73.34 and 70.20 respectively. Though, earthen fish ponds had higher WQI value and would have considered very poor water with regard to WQI calculation. The values of the WQI revealed that all the three artificial aquatic environments (concrete, earthen and plastic pond/tanks) were considered to be poor water quality.

Conclusion and Recommendations: It was concluded that WQI is used as a tool for communicating information on the status of quality in different water bodies despite their medium and purpose of use. It was also recommended that the three artificial aquatic environments water should be monitored regularly and may be treated before use to avoid related public health issues.

Keywords: Water quality index; Artificial aquatic environments; Physico-chemical parameters; Niger Delta

1. Introduction

Water quality index is simple arithmetic methodologies using physico-chemical variables in estimating the level of fitness in any water body. Water quality index is one of the most effective tools to communicate information on the quality of water to the concerned citizens and policies makers [1]. It is also a useful factor in relating information on the overall quality of water [2], [3]. The different water quality parameters combine provide evidence of the water quality index status to which it will serve the purpose for man. According to Ajibade [4], reported the daily activities of man with regards to water application is a function of its quality or quantity. Furthermore, water quality index has been a global concern on the issue of public health attributed to water becoming worse with regard to its use. AL-Sabah[5],

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reported water is polluted artificially by nature or by human activities.In other to control the impact of human activities on water bodies safe, an environmental management plan has been put in place to gain economic and environmental protections [6].

Artificial aquatic habitat is an environment made by man not made by nature such as reservoirs, aquarium, lakes, ponds, tanks cages and canal. Artificial aquatic environment is generally associated with multiple objectives for human benefits such as water supply, fish culture, medicine, hydroelectric power and recreation. Artificial aquatic environments form a significant component of aquatic resources of any country [7].Ponds are generally small natural or artificial, shallow, confined bodies of standing water usually have a muddy or silty bottom that provide habitat and food for many species and they are too small for wave action and too shallow for major temperature differences from top to bottom[8]. Fish and other aquatic organisms are reared in manmade ponds, reservoirs, cages or other enclosures for aquaculture [9]. Reservoirs are artificial lentic water bodies, associated with multiple objectives for human benefits such as water supply, irrigation, hydroelectric power and recreation [10]. Thus, Radovan *et al.* [11] stated the economic value such as irrigation fish ponds, helpthe biodiversity for ornamental and recreational purposes of artificial pond of fresh water aquaculture.

Physico-chemical parameters can be divided into three main categories: physical (density, temperature); chemical (pH, conductivity, nutrients) and biological (bacteria, plankton and parasites) [12],[13].Physico-chemical parameters are used as an indicator for any perturbed aquatic environment [14]. The act of observing water quality in an aquatic system is an important activity in the approach of nature, control effectiveness of pollution measures. More so, it is a valuable factor in determining the water quality trends and recommending efforts on pollution control.

Water quality index tool has been used bysome researchers to determine water quality in Nigeria river[15], stream [16], creek[17], dam [18]and groundwater [19]. Besides this, the status of various water quality index has been much studied but little or no information on the water quality index on some artificial aquatic environments, Port Harcourt, Nigeria. Therefore, to bridge the gap in knowledge, the study aimed to evaluate the WQI of some artificial aquatic environments in Port Harcourt, Nigeria.

2. Material and methods

2.1. Study area

The study was carried out in Roone Fish Farm, Port Harcourt, Rivers State, Nigeria. The farm lies between latitudes 4.782^0N and longitudes 7.055^0E.The research was conducted for a period of twelve months (October 2018 to September 2019). The region appears to experience heavy rainfall and short dry season every year with relative temperatures with slight variation from 25^o C – 30^oC.

2.2. Sampling tanks/pond

Three artificial fish culture pond/tanks were used: plastic fish tank of 3m x 3m x 1.5, concrete tank of 2.5m x 5m x 1.5m and earthen pond of 4m x 5m x 1.5m one each.

2.3. Artificial aquatic environment (AAE)

AAE Pond 1: Concrete fish tank
AAE Pond 2: Earthen fish pond
AAE Pond 3: Plastic fish tank

2.4. Samples collection and analysis

Tank/pond water samples were collected monthly and analyzed following standard method [20], for some physico-chemical parameters such as temperature, pH, conductivity, total dissolved solids, turbidity, dissolved oxygen, biochemical oxygen demand, phosphate and nitrate.

2.5. Statistical Analysis

Data obtained were subjected to one-way analysis of variance (ANOVA) using Minitab version 16.0 package. Means were separate using Post hoc test Turkey's HSD @ 95% probability.

Nine (9) parameters were considered in the calculation of water quality index (WQI). The standards recommended by the World Health Organization [21], Bureau of Indian Standards [22] and Indian Council for Medical Research [23] for drinking water quality were followed in the calculation of water quality index.The weighted water arithmetic index method (WAWQI) Brown *et al*. [24] was used for the calculation of WQI of the water body while quality rating or sub index (qn) was calculated from the expression:

$$qn = 100 \quad {(Vn - Vio)}/{(Sn - Vio)}$$

Where;

Qn = Quality rating for the nth water quality parameters

Vn = Estimated value of the nth water quality parameters of collected sample

Sn = Standard permissible value of the nth water quality parameters

Vio = Ideal value of the nth water quality parameters in pure water

(i.e O for all other parameters except pH and Do which are 7.0 and 14.6mg/l respectively).

Unit weight (Wn) was calculated by a value inversely proportional to the recommended standard value Sn of the corresponding parameters.

$$Wn = {K}/{Sn}$$

Where;

Wn = Unit weight for the nth parameter

Sn = Standard value for nth parameters

K = Constant for proportionality

The overall WQI was therefore calculated by aggregating the quality rating with the unit weight linearly as follows:

$$WQI = {\sum qnWn}/{\sum Wn}$$

Table 1 shows the Water Quality Index and Status of Water Quality by Chaterjee and Raziuddin [25]and Table 2 indicates the adopted permissible limit of recommended agencies and unit weight.

Table 1 Water Quality Index and Status of Water Quality

Class	Water Quality Index	Water Quality Status
A	0 - 25	Excellent water quality
B	26 -50	Good water quality
C	51 -75	Poor water quality
D	76 – 100	Very poor water quality
E	>100	Unsuitable water quality

Source: Chaterjeeand Raziuddin [25]

Table 2 Adopted permissible limit of recommended agencies and unit weight (All values are in mg/L except pH, conductivity and turbidity).

S/No.	Parameter	Standard Permissible limits (Si)	Unit weight	Recommended Agencies References
1.	Temperature	25	0.00468	[26]
2.	pH	6.5 -8.5	0.0302	[27], [28]
3.	Conductivity	300	0.371	[23]
4.	Total dissolved solids	500	0.0037	[29]
5.	Turbidity	5	0.0234	[28]
6.	Dissolved oxygen	5.0	0.3723	[27]
7.	Biological oxygen demand	5.0	0.3723	[27]
8.	Phosphate	0.30	0.8566	[27],[28]
9.	Nitrate	45	0.0412	[27]

3. Results

The results of the physico-chemical parameters of the artificial aquatic environments are shown in Table 3. Higher mean value and standard deviation of temperature (28.68±1.92 °C), pH (7.26±0.41), conductivity (238.08±81.34 µs/cm) and turbidity (33.16±25.81 NTU) were recorded for earthen pond, TDS (135±58.10 mg/L), BOD (2.30±0.97 mg/L) and NO_3 (0.50±0.71 mg/L) were also recorded for plastic fish tank, while DO (7.09±3.16 mg/L) and PO_3 (0.27±0.29 mg/L) were recorded in concrete fish tank respectively. From Table 1, plastic tank recorded low temperature mean value (27.22±1.50 °C), pH (6.79±0.83) and PO_3 (0.19±0.24 mg/L).Concrete tank recorded low conductivity with mean value (208.33±67.89 µs/cm), TDS (103.53±39.11 mg/L), turbidity (15.22±6.37 NTU) and NO_3 (0.41±0.50 mg/L) while earthen pond had low DO value (3.96±1.67 mg/L) and BOD (0.65±0.66 mg/L). However, serial number 1-4, 8 and 9 among the artificial aquatic environment were not significantly different ($p>0.05$) (Table 1). While serial number 5,6 and 7 among these artificial environments were significantly different($p<0.05$) (Table 3). The water quality index of the artificial water bodies were 60.24 (concrete fish tank), 73.34 (earthen fish pond) and 60.68 (plastic fish pond) respectively (Tables 4-6). For all the environments earthen pond had the highest index value indicating that the water is poor (Tables 1).

Table 3 Physico-Chemical Parameters of the Different Artificial Aquatic Environments (Mean±SD)

S/No.	Parameter	Concrete tank	Earthen pond	Plastic tank
1.	Temp (°C)	28.30±1.76^{a}	28.68±1.92 ^{a}	27.22±1.50 ^{a}
2.	pH	7.08±1.41^{a}	7.26±0.41^{a}	6.79±0.83^{a}
3.	Conductivity(µs/cm)	208.33±67.89 ^{a}	238.08±81.34 ^{a}	234±56.55^{a}
4.	TDS (mg/L)	103.53±39.11^{a}	113.85±33.17 ^{a}	135±58.10 ^{a}
5.	Turbidity (NTU)	15.22±6.37^{a}	33.16±25.81^{b}	16.39±9.53^{a}
6.	DO (mg/L)	7.09±3.16 ^{a}	3.96±1.67 ^{b}	4.95±3.03^{ab}
7.	BOD (mg/L)	1.51±0.81 ^{a}	0.65±0.66^{b}	2.30±0.97^{a}
8.	PO_3 (mg/L)	0.27±0.29^{a}	0.22±0.24^{a}	0.19±0.24 ^{a}
9.	NO_3(mg/L)	0.41±0.50 ^{a}	0.42±0.54^{a}	0.50±0.71^{a}

Means with different superscripts within row are significant different ($p<0.05$); Temp-Temperature; pH-Hydrogen ion concentration; TDS-Total dissolved solids; DO-Dissolved oxygen; BOD- Biological oxygen demand; TOC- Total organic carbon.

Table 4 Calculated water quality index (WQI) for Concrete fish tank.

S/No.	Parameter	Observed values	Sn	Wn	qn	Wnqn
1	Temp (°C)	28.30	25	0.00468	113.2	0.530
2	pH	7.08	6.5 -8.5	0.0302	5.33	0.161
3	Conductivity(µs/cm)	208.33	300	0.371	69.44	25.752
4	TDS (mg/L)	103.52	500	0.0037	20.70	0.077
5	Turbidity (NTU)	15.22	5	0.0234	304.4	7.123
6	DO (mg/L)	7.09	5.0	0.3723	78.23	29.125
7	BOD (mg/L)	1.51	5.0	0.3723	30.2	11.243
8	PO_3 (mg/L)	0.27	0.30	0.8566	90	50.94
9	NO_3(mg/L)	0.41	45	0.0412	0.91	0.037
	Summation (∑)			**∑ 2.075**	**∑712.41**	**∑124.988**
	Water Quality Index (WQI) = $\sum qnWn / \sum Wn$ = **60.24**					

Table 5 Calculated water quality index (WQI) for Earthen fish pond.

S/No.	Parameter	Observed values	Sn	Wn	qn	Wnqn
1	Temp (°C)	28.30	25	0.00468	114.72	0.54
2	pH	7.26	6.5 -8.5	0.0302	17.33	0.52
3	Conductivity(µs/cm)	238.08	300	0.371	79.36	29.44
4	TDS (mg/L)	113.85	500	0.0037	22.77	0.08
5	Turbidity (NTU)	33.16	5	0.0234	563.2	13.17
6	DO (mg/L)	3.96	5.0	0.3723	110.83	41.26
7	BOD (mg/L)	0.65	5.0	0.3723	13.0	4.34
8	PO_3 (mg/L)	0.22	0.30	0.8566	73.33	62.81
9	NO_3(mg/L)	0.42	45	0.0412	0.93	0.03
	Summation (∑)			**∑ 2.075**	**∑ 995.46**	**∑152.19**
	Water Quality Index (WQI) = $\sum qnWn / \sum Wn$ = **73.34**					

Table 6 Calculated water quality index (WQI) for Plastic fish pond

S/N	Parameters	Observed values	Sn	Wn	qn	Wnqn
1	Temp (°C)	27.22	25	0.00468	108.88	0.51
2	pH	6.79	6.5 -8.5	0.0302	-14	-0.42
3	Conductivity(µs/cm)	234	300	0.371	78	28.94
4	TDS (mg/L)	135	500	0.0037	27	0.10
5	Turbidity (NTU)	16.39	5	0.0234	327.8	7.67
6	DO (mg/L)	4.95	5.0	0.3723	100.52	37.42
7	BOD (mg/L)	2.30	5.0	0.3723	46	17.13
8	PO_3 (mg/L)	0.19	0.30	0.8566	63.33	54.25
9	NO_3(mg/L)	0.50	45	0.0412	1.11	0.05
	Summation (∑)			**∑ 2.075**	**∑ 738.64**	**∑145.65**
	Water Quality Index (WQI) = $\sum qnWn / \sum Wn$ = **70.20**					

4. Discussion

Water quality index (WQI) bestow brief datum of large number of water quality variable into a single term such as; excellent, good, poor, very poor, unsuitable water quality. In this regard Hulya [30] reported WQI range level value is use for easy reporting to the concerned users. This will help in ensuring safety measures in any water bodies. For water quality management, the indices are the most effective means of information to the concerned authority [31].

Temperature the father to every life, determined the positive and negative status within each medium life exists. The temperature with the highest mean values (28.68±1.92) in this study were in line with the Niger Delta climate. Thus, all the artificial culture systems exhibited normal survival rangefor aquatic life. The result obtained is in agreement with Roberts *et al.* [32] 20 – 33°C is considered as maximum temperature range foraquatic life.However, the temperature of all artificial aquatic environments is higher than WHO [28] standard for water quality index (WQI). In the present study the increase of temperature of these artificial environments could be attributed to the holding structure of the different media.

Hydrogen ion concentration (pH) is an important factor in the lives of aquatic organism to survive. The pH of the artificial aquatic environments varied between media slightly from acidic to neutral. However, the water of the three artificial aquatic environments showed good neutral condition. Though, in different water bodies similar results were recorded by[33].The observed range for pH were found to be suitable for fish culture.

Electrical conductivity is the ability of the water to conduct electricity [34]. The total concentration of salts in a water body is a function of its electrical conductivity. Earthen pond had higher conductivity value, followed by plastic fish tank. The observed electrical conductivity (EC) in this study signified that the artificial aquatic environments were freshwater habitat with regard to low salinity vicinity. According to Egborge [35]opined that conductivity value below 1000 µs/cm indicated freshwater, above 1000 µs/cm is brackish water and above 40,000 µs/cm is marine water. Thus, the result obtained were below standard limit of 300 WQI [23].

Total dissolved solids (TDS) is regarded as the total load of dissolved substances in a water body. The presence of such solutes affects the physical and chemical properties of water bodies [14]. The observed total dissolved solids were within the acceptable range 500 recommended by [36]. The result obtained agreed with 22.11± 2.41mg/L in artificial concrete tank as reported by [34].

Turbidity prevents the direct penetration of sunlight in pond culture system making it difficult for aquatic organism like algae to photosynthesize positively [37]. The recorded turbidity values in this study of all the artificial aquatic environments were higher with values (15, 33 and 16NTU) respectively above WHO [26] permissible limit of 5NTU for water quality index (WQI). This could be attributed to suspended particulates matter, organic and inorganic matter and plankton biomass, except for earthen pond that is mixed with silt, sand and clay. This tie to the findings of Al-Janabi*et al.* [38] on WQI in surface water of Tigris.

Dissolved oxygen (DO) affects the growth and survival of aquatic life distribution. The result of dissolved oxygen concentration obtained in earthen and plastic tank/pond were3.96 mg/l and 4.95 mg/l respectively which were below permissible limit of DO 5mg/L as regard to Bureau of Indian Standards (BIS) for WQI, except for concrete tank that recorded higher DO value. However, the low level of oxygen concentration in earthen and plastic pond in this study might be attributed to high density of fish stock, microbial and photosynthetic plankton activities in the artificial aquatic systems. This result is in conformity with the finding of Islam*et al.*[39] reported high load of organic contaminant in the assessment of water quality index (WQI) in pond water.

Biological oxygen demand (BOD) values recorded in this study in the aquatic culture systems is within the acceptable limit of 1 mg/L to 3 mg/L for aquatic environments. Biological oxygen demand decreases with increased organic matter and fishes in a water body. Water body with Biological oxygen demand (BOD) levels less than 1.0 and 2.0mg/L are regarded as good water, 3.0 mg/L fairly good, 5.0 mg/L doubtful and 10 mg/L heavily polluted [40]. Therefore, the obtained result is below permissible limit of (BIS) for WQI which is an indication that the artificial aquatic environments were regarded as good water for aquatic organism.

Nitrate is relatively non harmful to aquatic life and cause no health hazard except at exceedingly high levels of 90 mg/ L and above [41]. The nitrate and phosphate value in this study is below permissible limit of 45 and 0.30 mg/L respectively as per WHO [28] in three artificial aquatic environments. Hence, absence of inorganic fertilizers and decrease in various forms of pollutants into the artificial aquatic environments could be reasons for the low value. The

obtained results agree with the work of Santhosh and Singh [42] who reported the range of 0.1 mg/L to 4.0 mg/L is favorable for fish culture water.

5. Conclusion

Some physico-chemical properties were used to evaluate the water quality status of some artificial aquatic environments using CCME/BIS/ICMR and WHO standards for water quality Index.The water quality index (WQI) for concrete tank, earthen pond and plastic tank artificial aquatic environments samples ranges from 60.24 to 73.34. The result of study revealed WQI of concrete tank, earthen pond and plastic tank had poor water quality status based on WQI classification (Table 1) which is not suitable for usage as drinking water but for culture of aquatic organisms like fish. Even though it is considered less polluted environment, the needs to be protected from the perils ofcontamination such bacteria and harmful algae are of concern to human health. Therefore, the study unveiled the application of Water Quality Index is auseful tool in evaluating the overall quality of the artificial aquatic environments.

Compliance with ethical standards

Acknowledgments

Disclosure of conflict of interest

The authors have no area of conflict of interest.

References

[1] Mishra PC, Patel RK. Study of the pollution load in the drinking water of Rairangpur, a small tribal dominated town of North Orissa. Indian J Environ Ecoplan. 2001; 5(2): 293-298.

[2] Asadi SS, Vuppala P, Anji RM. Remote sensing and GIS techniques for evaluation of groundwater quality in municipal corporation of Hyderabad (Zone-v), India. Int. J. Environ. Res. Public Health. 2007; 4: 45 – 52.

[3] Buchanan S, Triantafilis J. Mapping water table depth using geophysical and environmental variables. Groundwater. 2009; 47: 80.

[4] Ajibade LT. The Environmentalist. 2004; 24: 11-18.

[5] AL-Sabah BJJ. Application of Water Quality Index to Assessment of Tigris River. Int. J. Curr. Microbiol. App. Sci. 2016; 5(10): 397-407.

[6] Otene BB,Nnadi PC. Water Quality Index and Status of Minichinda Stream, Port Harcourt, Nigeria. IIARD International Journal of Geography and Environmental Management. 2019; 5(1): 1-9.

[7] Davies OA,Abolude DS. Polycyclic Aromatic Hydrocarbons (Pahs) of Surface Water from Oburun Lake, Niger Delta, Nigeria. App. Sci. Report. 2016; 13 (1): 20-24.

[8] Joseph Jiji. Diversity and distribution of phytoplankton in an artificial pond. Int. J. Adv. Res. Biol. Sci. 2017; 4(5): 114-122.

[9] Suleiman MA,Solomon RJ. Effect of stocking on the growth and survival of Clariasgariepinusgrown in plastic tanks. Direct Research Journal of Veterinary Medicine and Animal Science. 2017; 2(3): 82-92.

[10] Edna C, Paul JVB, Joa˜o AC, Rui C, Martinho LO,Miguel AP. Ecological relationships between phytoplankton communities and different spatial scales in European reservoirs: implications at catchment level monitoring programmes. Springer Science. 2009; 628:27–45.

[11] Radovan K, PavlaŘezničkova, LenkaHadašova, RadimPetrek,TomašBrabec. Water quality and phytoplankton communities in newly created fish ponds. Acta Universitatis Agriculturae et SilviculturaeMendelianaeBrunensis. 2016; 64(1): 71–80.

[12] Delince G. The ecology of the fish pond ecosystem with special reference to Africa. Kluwer Academic Publishers, London. 1992; 230.

[13] Mood YFO. An assessment of water quality in integrated poultry-cum-fish reservoir, NIFFRI New Bussa. In: P.A. Araoye(ed), Conference Proceeding of Fisheries Society of Nigeria (FISON), Ilorin, 29th November – 3rd December. 2004.

[14] Davies OA. Seasonal variation of the physico-chemistry quality of a tributary of the Bonny estuary, Rivers State, Nigeria. Journal of Advances in Biology. 2013; 2(1): 92 –107.

[15] Edwin AI,Murtala AI. Determination of water quality index of river Asa, Ilorin, Nigeria. Advances in Applied Science Research. 2013; 4(6):277-284.

[16] Otene BB,Nnadi PC. Water Quality Index and Status of Minichinda Stream, Port Harcourt, Nigeria. IIARD International Journal of Geography and Environmental Management. 2019; 5(1): 1-9.

[17] Aigberua A,Tarawou T. Water Quality Index (WQI) Assessment along Inland Fresh Waters of Taylor Creek in Bayelsa State, Nigeria. Journal of Environmental Treatment Techniques. 2019;7(3): 260-269.

[18] Odesanya BO, Bakare TE,Adeyemi MM. Critical Analysis and Evaluation of the Surface Water Quality Index: A Case Study of Asejire Dam, Ibadan, Oyo State Nigeria. Journal of Scientific and Engineering Research. 2018; 5(7): 182-192.

[19] Oni O,Fasakin O. 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. American Journal of Engineering Research (AJER). 2016; 5(10): 96-101.

[20] America Public Health Association (APHA). Standard method for the examination of water and wastewater, 23th edition, Washington DC. 2017.

[21] WHO. International Standards for Drinking water. World Health Organization, Geneva, Switzerland. 1992.

[22] BIS. Standards for Water for Drinking and other purposes, Bureau of Indian Standards, New Delhi. 1983.

[23] ICMR. Manual of standards of quality for drinking water supplies, Indian Council of Medical Research Rep. 1975; 44: 27.

[24] Brown RM, McClelland NI, Deininger RA,Tozer RG. Water quality index- do wedare?,Water Sewage Works. 1970; 117(10): 339-343.

[25] Chaterjee C,Raziuddin M. Determination of water quality index (WQI) of a degraded river in Asanol Industrial area, Raniganj, Burdwan, West Bengal. Nature, Environ. Pollu. Technol. 2002; 1(2): 181- 189.

[26] WHO. Guidelines for drinking water quality. Vol. 1:3rd ed., Geneva, World Health Organization. 2004.

[27] BIS.BIS10500: Analysis of Water and Waste water, Bureau of Indian Standards, New Delhi. 2012.

[28] WHO. Guidelines for drinking water quality. Recommendations, vol. 1, 2nd ed., Geneva. 1993.

[29] CCME. Canadian environmental sustainability indicators. Freshwater quality indicator: Data sources and methods. Catalogue no. 16-256-XIE. 2005.

[30] Hulya B. Utilization of the water quality index method as a classification tool. Environmental Monitoring and Assessment. 2009; 167: 115-124.

[31] Jagadeeswari PB,Ramesh K. Water quality index for assessment of water quality in South Chennai Coastal Aquifer, Tamil Nadu, India. International Journal of Chem. Tech Research. 2012; 4(4): 1582-1588.

[32] Roberts R, Kawamura T, Nicholson C. Overview of larval settlement and post-larval growth/survival in abalone. In: Hone, P (Ed). Proceedings of the 5th Annual Abalone Aquaculture Workshop, July, 1998, Hobart, Tasmania. Fisheries Research and Development Corporation. 1997; 1-8.

[33] Davies AO,Ansa E. Comparative Assessment of water quality parameters of Freshwater Tidal Earthen ponds and Stagnant Concrete Tanks for Fish Production in Port Harcourt, Nigeria. Intl. J. Sci. and Nat. 2010; 1(1):34-37.

[34] Agbaire PO, Akporido SO, Emoyan OO. Determination of some physicochemical parameters of water from artificial concrete fish ponds in abraka and its environs, delta state, Nigeria. International journal of plants, animal and environmental sciences. 2015; 5(3): 70 -76.

[35] Egborge AMB. Salinity and the Distribution of Rotifers in the Lagos Harbour Badagry Creek System, Nigeria. Hydrobio. 1994; 272: 95 – 104.

[36] CCME. Canadian Sediment Quality Guidelines for the protection of aquatic life. Summary Tables. Updated. In: Canadian Environmental Quality Guidelines. 2001; 1999. Excerpt from Publication No. 1299; ISBN 1-896997-34-1

[37] Ali FM, Abdus–Salam BA, Ahmad KS, Qamar M, Umer K. Seasonalvariations of physico – chemical characteristics ofRiverSoan water at Dhoak Pathan bridge (Chakwal),Pak. 2004; 1: 89 – 92.

[38] Al-Janabi ZZ, Al-kubaisi A,Al-obaidy AHMJ. Assessment of water quality of Tigris river by using water quality index (CCME WQI). Journal of Al-Nahrain University. 2012; 15(1):119-126.

[39] Islam MS, Azadi MA,Nasiruddin M. Water quality of three ponds of Chittagong university campus using water quality index. 2019; 7(12): 1229-1251.

[40] Ekubo AA, Abowei JFN. Review of some water quality management principles in culture fisheries, Research Journal of Applied Sciences, Engineering and Technology. 2011; 3(2):1342-1357.

[41] Bhatnagar A,Devi P. Water quality guidelines for the management of pond fish culture. International Journal of Environmental Sciences. 2013; 3(6): 1980 -2009.

[42] Santhosh B,Singh NP. Guidelines for water quality management for fish culture in Tripura, ICAR Research Complex for NEH Region, Tripura Center, Publication. 2007; 29.