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ASSESSMENT OF THE PHYSICO-CHEMICAL PARAMETERS OF ITAPAJI RESERVOIR, ITAPAJI, SOUTH-WESTERN NIGERIA

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Abstract
Itapaji Reservoir serves for municipal water use, artisanal fishing, agricultural uses, and domestic activities. This study was carried out to investigate physico-chemical parameters of the reservoir to provide information for its sustainable management. Surface water samples were collected monthly from April, 2013 to March, 2015 at five purposively selected stations along the reservoir. Water temperature and transparency were measured in situ.Total Suspended Solid (TSS), Total Solid (TS), Phosphate and heavy metals were determined according to APHA methods. Data were analyzed using descriptive statistics, student's t-test, ANOVA, and Principal Component Analysis (PCA) at $\alpha_{0.05}$. Water temperature was 27.5±0.1 ºC; Transparency, 1.5±0.1 m; TSS, 16.6± 0.7 mg/L; TS, 59.7±2.6 mg/L; phosphate, 7.2±0.5 mg/L; zinc, 1.3±0.1 mg/L; copper, 0.9±0.8mg/L; iron, 10.9±0.6 mg/L; lead, 0.1±0.007mg/L and chromium, 0.2±0.02 mg/L. phosphate, TSS, zinc, copper, iron, lead, and chromium exceeded NESREA limits for aquatic life (3.5, 0.25, 0.01, 0.001, 0.05, 0.01, and 0.001 mg/L, respectively), while copper and iron exceeded the WHO standard limit for drinking water (≤0.50, and 0.3 respectively). Transparency, TSS, zinc, copper, iron, lead and chromium had significant seasonal variations while Sodium, magnesium and chromium showed significant spatial variation. The PCA showed high positive loadings for phosphate (0.9), transparency (0.9), TS (0.882), and high negative loading for potassium(-0.730). The total suspended solid, phosphate, and some heavy metals that exceeded the recommended standard for aquatic life and drinking water revealed that Itapaji Reservoir is under pollution stress; hence the need for adequate management.

Key Words: *Physico-chemical parameters, Spatial variation, Itapaji Reservoir, Pollution stress*

Introduction
Water is an essential and valuable natural resource vital to the existence of any form of life (Olajuyigbe and Fasakin, 2010), the ubiquity of water in biota as the fulcrum of bio-chemical metabolism rests on its unique physical and chemical properties (Adeyemo *et al.*, 2008 and Iscen *et al.,* 2008). The scarcity of clean water and pollution of fresh water has led to a situation in which one-fifth of the urban dwellers in developing countries

and three quarters of their rural dwelling population do not have access to reasonably safe water supplies (Lloyd and Helmer, 1992). Likewise, the inhabited biota equally suffers the impacts of this limited resource due to the vital roles that its quality plays in their abundance, distributions, and diversity (Prat and Munne, 2000). Meanwhile, the deterioration in water quality has been earlier attributed to man's expanding population, industrialization, intensive agricultural practices, discharge of massive amount of wastewater into the rivers and streams and poor management (Adakole and Annune, 2003 and Galadima *et al.,* 2011). The impacts of these anthropogenic activities have been so extensive that the water bodies have lost their self-purification capacity to a large extent (FAO, 1994; Oben, 2000; Tyokumbor *et al.,* 2002; and Sood *et al.,* 2008).

Despite the other usage ranging from agricultural and domestic use, the herdsmen solely depend on this reservoir to source water for their cattle. The perturbation effect of the activities around the reservoir, couple with the erosional run-off from the adjourning cassava processing might pose a threat on the water quality of the reservoir; hence the aim of this research is to determine the impacts of these various activities on the water quality by assessment of the physico-chemical parameters of the Itapaji Reservoir.

Materials and Methods

Study Area

Itapaji Reservoir; the second largest reservoir in Ekiti State, is located in Itapaji, Ikole Local Government Area of Ekiti State, south western Nigeria, and lies between latitude 07° 56' and 07° 57'N, and longitude 05° 27' and 05° 28'E at an elevation of 445 m above the sea level (Figure 1). The reservoir, that has a total catchment area of 647,250.6m^2 was formed by impounding River Ele in 1972 and commissioned in 1975, with a designed capacity of 5,175m^3/day for the supply of water to 13 towns and villages in 3 local government areas of Ekiti State.

The area surrounding the reservoir is hilly and lies within the northern fringes of the rain forest belt with heavy rainfall pattern year round, and characterized by two major seasons, the rainy season occurring between April and October and dry season between the month of November and March. Total annual rainfall ranges between 1350 – 1400mm while temperature varies between 28° – 30°C in dry and 22°-25°C in wet season. The hydrographs derived from the data collected at the gauging station downstream of the dam shows that the dam does not spill any water for a period spanning 4 - 6 months (January - June) annually (Fagbohun, 2016).

Vegetation

The surrounding vegetation of the area is made up of trees like *Chlorophora excels, Terminalia superba*, *Elaeis guineensis*, *Borassus* sp. Traditional farmlands has however transformed some sections of the area into secondary grass land, consisting primarily of cultivated and fallow agricultural fields with some secondary growth and occasional evergreen plant such as; *Talinium triangularis, Eupatorium odorantum, Amaranthus spinosus*. Floating plants include *Echinochloa pyramidalis, Sacciolepsis africana, Rhynchospora* *coryinbsa, Salvina nymphellula, Nymphaea lotus, Ludwigia decurrents, Ceratophyllum submersum, Mormodica balsamina, Commelina diffusa, Cyperus articulates, Pistia stratioles* and *Lemna* sp.

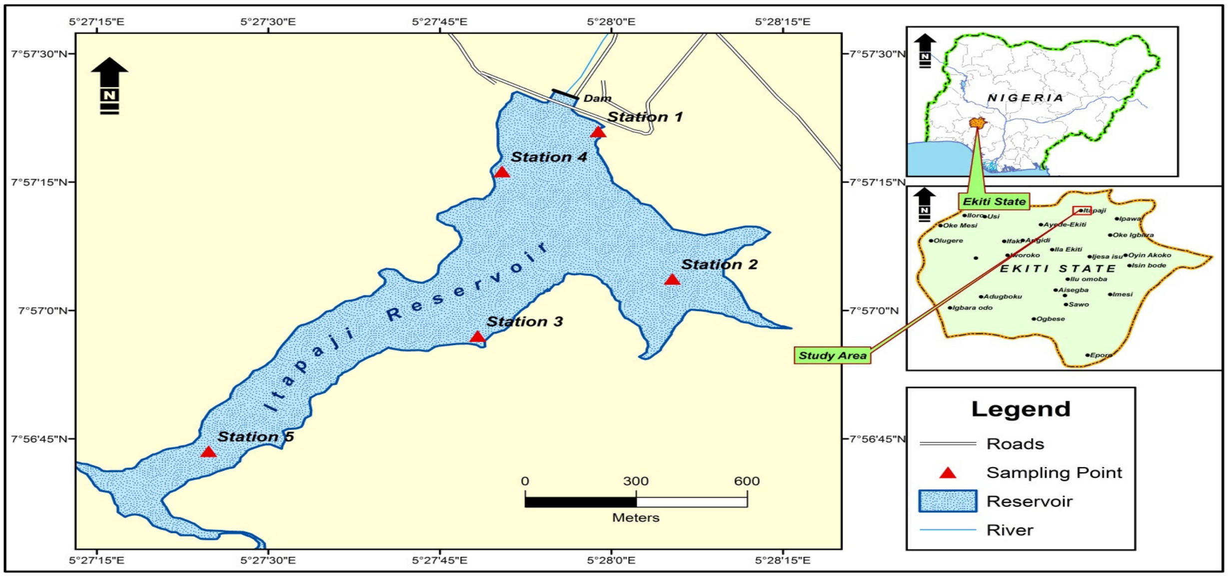

Figure 1: The Map of Study Area
(Source: Cartographic unit, Department of Geography, University of Ibadan, Nigeria)

Experimental/ Sampling Design and Analysis

Five sampling stations were selected on the reservoir based on the proximity to different anthropogenic activities around the reservoir. Sampling for physico-chemical parameters was done once monthly for 24 months (April 2013 to March 2015) between 08:00-11:00 hours on each sampling days across the five sampling stations. Field measurements of temperature and transparency were determined using mercury- in-glass thermometer and Secchi-disc (Ruttner, 1963, and Wetzel and Likens, 2000), respectively. Surface water samples for chemical parameters were collected in 2L plastic bottles and kept in a refrigerator prior its analysis, while water samples for heavy metals were collected in 1L bottles and preserved with 1ml of concentrated nitric acid. Water sample for dissolved oxygen was collected in 250ml glass sampling bottles and fix immediately with 2ml each of Winkler's solutions A & B accordingly, as described by Mackereth (1963). Likewise, water sample for Biochemical Oxygen Demand (BOD) was collected in 250ml amber sampling bottle, incubated in the dark cupboard in the laboratory at 20°C for 120hrs (5 days) and fix thereafter with 2ml each of Winkler's solutions A & B in the laboratory.

Laboratory Analysis

All the parameters were analysed in Central Laboratory, Federal University of Technology Akure, Ondo State, Nigeria using standard method (APHA, 1998).

Statistical Analysis of Data

Bivariate and multivariate statistics as provided by the SPSS Version 22.0 and

MS Excel 2010 software were used in the analysis of the data. The determination of spatial variance equality (homogeneity) in the means of the physico-chemical parameters was made with one-way analysis of variance (ANOVA),further mean separation was made with the Duncan Multiple Range Test (DMRT), while seasonal comparison of these variables was made with the student's t-test of significance.

The factor analysis procedure, using principal components analysis (PCA) extracted method for data reduction was used to removed redundant (highly correlated) variables from the data file and replacing the entire file with a smaller number uncorrelated variables (factor), and to further examine the underlying relationships between the variables. Factor rotation for the transformation of extracted factors to a new position for interpretation was achieved with the Varimax method. The magnitudes of the eigenvalues and 75% (0.75) rule for variance contribution were used for factor selection (Manly, 1986).

Results and Discussion

The descriptive results of the physico-chemical parameters of the Itapaji Reservoir in Ikole LGA of Ekiti State, southwestern Nigeria measured across the sampling locations from April 2013 to March 2015 are shown in Table 1. Of all the parameters measured, total suspended solid, phosphate, zinc, copper, iron, lead, and chromium exceeded the NESREA (2011) recommended limit for aquatic organisms, while copper and iron were observed to exceed the WHO (2008) standard limit for drinking water. High concentration in TSS might be attributed to run-off and erosion of solid waste from the adjourning farm lands. The tendency of this parameter to impair light penetration into the reservoir and subsequent effect on water transparency was established in this study, as period of high TSS coincides with the period of low transparency of the reservoir.High TSS is capable of clogging fish gill which could further result into fish stress, reduced growth, suppressed-immune system leading to increased susceptibility to disease and osmotic dysfunction and death, as earlier suggested by Bilotta and Brazier (2008). This agreed with the previous report on high TSS concentration and its subsequent effects by Ajibade (2004) in Asa Dam (Kwara State), and Osibanjo *et al.* (2011) in Rivers Ona and Alaro in Ibadan. Lower phytoplankton abundance in Itapaji Reservoir during the dry season as earlier observed by Adebayo and Ayoade (in press) might have adduced for less utilization of the phosphate concentration thereby resulted to their higher concentration during the dry season, similar to Beadle (1981) and Kemdirim (1987), and Obunwo *et al.* (2004) findings.

Likewise, the exceeding concentrations of heavy metals in the reservoir could be related to runoff, its use in agriculture and domestic activities. The enrichment of Fe, Zn and Cu concentrations in the reservoir can be associated with several decades of intensive cropping with agrochemicals used to improve production and quality; especially fertilizer inputs, some kinds of pesticides and germicides, as well as run-off from galvanized roofing sheet. While erosion of leaded gasoline spillage from the adjoining roads, exhaust gases of petrol engines, pesticides, fertilizer impurities, and atmospheric fallout from the combustion of fossil fuels are the most likely sources of Pb in the reservoir. Although, trace metals act as micronutrients at low concentrations, but at high level, they become toxic depending on the prevalent chemical form (that is, speciation) of the trace element in water. Also, bioaccumulation and food chain magnification of trace metal may occur.

Seasonal Variation in Physico-chemical Parameters

Seasonal significant difference at $p<0.05$ were recorded in temperature, transparency, total suspended solid, alkalinity, chloride, sodium, zinc, manganese, copper, iron, lead, and chromium (Table 2). This might be due to climatic variation which is characterized by high solar radiation (insolation), little or no run-off, and subsequent reduction in the volume of the reservoir in the dry season. Generally, the higher values recorded for the metals in the dry season except manganese could be due to dilution and water spillage during rainy season (since the reservoir can only outflow during the rainy season due to non- utilization of the water for municipal usage over time). This agreed with Edokpayi *et al*. (2016) who accounted the higher values in dry season to evaporation from water bodies which can lead to an increase in the concentrations of contaminants as the dilution factor is removed.

Table 1: Descriptive statistics of the Physicochemical Parameters of Itapaji Reservoir

Parameter	Minimum	Maximum	Range	Mean ± SE	NESREA (2011)	WHO (2008)
Temperature (°C)	23.00	29.50	6.5	27.5 ± 0.125	a	30-32
Transparency (m)	0.49	2.54	2.05	1.54 ± 0.049	NS	-
pH	6.06	9.20	3.14	7.27 ± 0. 058	6.5-8.5	7.0-8.5
Conductivity (µS/cm)	68.00	970.00	902.00	274.87 ± 20.480	NS	≤1,000
Total dissolved solids (mg/L)	10.54	108.50	97.96	43.52 ± 2.741	NS	≤200.0
Total suspended solids (mg/L)	7.67	34.81	27.14	16.64 ± 0.673	0.25	≤5.0
Total solid (mg/L)	19.54	123.50	103.96	59.68 ± 2.573	NS	-
Alkalinity (mg/L)	20.60	240.00	219.40	72.01 ± 4.647	NS	-
Chloride (mg/L)	18.40	168.63	150.23	57.03 ± 4.236	300	-
Total Hardness (mg/L)	16.00	63.00	47.00	38.57 ± 1.018	NS	-
Nitrate (mg/L)	2.20	10.20	8.00	5.45 ± 0.182	9.1	≥10.0
Sulphate (mg/L)	3.50	24.10	20.60	10.28 ± 0.619	100	≤200.0
Phosphate (mg/L)	2.50	18.60	16.10	7.23 ± 0.483	3.5	≤75.0
Dissolved Oxygen (mg/L)	0.50	8.50	8.00	4.88 ± 0.194	Not <6.	≥5.0
BOD (mg/L)	0.40	5.00	4.60	2.42 ± 0.106	3.0	≤5.0
COD (mg/L)	1.02	6.40	5.38	2.83 ± 0.115	30.0	-
Sodium (mg/L)	5.60	16.50	10.90	11.70 ± 0.204	120.0	-
Potassium (mg/L)	3.40	19.80	16.40	12.36 ± 0.338	50.0	-
Calcium (mg/L)	8.46	24.00	15.54	15.47 ± 0.339	180.0	-
Magnesium (mg/L)	8.00	24.30	16.30	14.99 ± 0.370	40.0	≤30.0
Zinc (mg/L)	0.00	3.60	3.60	1.25 ± 0.069	0.01	≤5.0
Manganese (mg/L)	0.00	0.20	0.20	0.01 ± 0.003	NS	0.1-0.5
Copper (mg/L)	0.00	2.40	2.40	0.92 ± 0.819	0.001	≤0.50
Iron (mg/L)	0.01	25.60	25.59	10.96 ± 0.642	0.05	0.30
Lead (mg/L)	0.00	0.21	0.21	0.07 ± 0.007	0.01	-
Chromium (mg/L)	0.00	1.30	1.30	0.22 ± 0.024	0.001	-

SE = standard error of mean, BOD = Biochemical Oxygen Demand, COD = Chemical Oxygen Demand, NS = Not Specified, and a = [a]except in mixing zones, temperature increase by a 7-Day Average of the Daily Maximum temperatures (7-DADMax) shall not be more than 0.3 ºC above natural background conditions

Table 2: Seasonal variations in the physicochemical parameters of Itapaji Reservoir (P<0.05)

Parameters	Season	Mean ± SE	t	p-value
Temperature (°C)	Rainy	27.03 ± 0.21	5.852	0.000*
	Dry	28.30 ± 0.77		
Transparency (m)	Rainy	1.39 ± 0.08	4.571	0.000*
	Dry	1.83 ± 0.05		
pH	Rainy	7.38 ± 0.09	1.943	0.058
	Dry	7.12 ± 0.09		
Conductivity (µS/cm)	Rainy	311.38 ± 37.37	1.617	0.112
	Dry	243.98 ± 22.07		
TDS (mg/L)	Rainy	45.75 ± 3.34	0.990	0.327
	Dry	39.68 ±4.78		
TSS (mg/L)	Rainy	19.23 ± 1.15	5.343	0.000*
	Dry	12.42 ± 0.30		
TS (mg/L)	Rainy	58.45 ± 4.37	0.145	0.886
	Dry	57.59 ± 3.47		
Alkalinity (mg/L)	Rainy	91.95 ± 8.10	6.183	0.000*
	Dry	41.32 ± 1.93		
Chloride (mg/L)	Rainy	72.79 ± 6.99	5.370	0.000*
	Dry	31.90 ± 2.32		
Total Hardness (mg/L)	Rainy	37.95 ± 1.43	0.268	0.790
	Dry	38.58 ± 1.76		
Nitrate (mg/L)	Rainy	5.23 ± 0.27	0.473	0.638
	Dry	5.42 ± 0.28		
Sulphate (mg/L)	Rainy	10.47 ± 0.89	0.524	0.603
	Dry	9.73 ± 1.03		
Phosphate (mg/L)	Rainy	6.68 ± 0.69	0.784	0.437
	Dry	7.55 ± 0.80		
Dissolved Oxygen (mg/L)	Rainy	4.92 ± 0.28	0.938	0.353
	Dry	4.43 ± 0.35		
BOD (mg/L)	Rainy	2.64 ± 0.15	1.813	0.076
	Dry	2.25 ± 0.15		
COD (mg/L)	Rainy	2.65 ± 0.20	1.933	0.059
	Dry	3.13 ± 0.15		
Na (mg/L)	Rainy	11.19 ± 0.32	2.357	0.022*
	Dry	12.23 ± 0.29		
K (mg/L)	Rainy	12.11 ± 0.56	1.088	0.282
	Dry	12.83 ± 0.42		
Ca (mg/L)	Rainy	15.16 ± 0.60	0.975	0.334
	Dry	15.93 ± 0.50		
Mg (mg/L)	Rainy	14.84 ± 0.58	0.000	1.000
	Dry	14.84 ± 0.54		
Zn (mg/L)	Rainy	0.94 ± 0.11	5.055	0.000*
	Dry	1.64 ± 0.73		
Mn (mg/L)	Rainy	0.02 ± 0.01	2.800	0.007*
	Dry	0.00 ± 0.00		
Cu (mg/L)	Rainy	0.76 ± 0.13	2.461	0.017*
	Dry	1.18 ± 0.12		

Fe (mg/L)	Rainy	8.64 ± 1.03	4.461	0.000*
	Dry	14.36 ± 0.73		
Pb (mg/L)	Rainy	0.05 ± 0.01	2.209	0.032*
	Dry	0.08 ± 0.01		
Cr (mg/L)	Rainy	0.16 ± 0.03	2.618	0.012*
	Dry	0.31 ± 0.04		

N.B: Values with superscript * differed significantly, SE = standard error of mean, TDS= Total Dissolved Solid, TSS= Total Suspended Solid, TS= Total Solid, BOD= Biochemical Oxygen Demand and COD= Chemical Oxygen Demand

Spatial Variation in Physico-chemical Parameters

The physico-chemical parameters of Itapaji Reservoir in Ekiti State, like any other aquatic ecosystem, is prone to ecological imbalances resulting from both natural and anthropogenic impacts arising from man's quest for the exploitation of natural resources for sustainability and livelihood. The marked spatial variation and significant differences in some physico-chemical parameters of the water (Table 3) indicate different environmental conditions. These variations may be related to patterns of water use, and run-off that brought in different allochthonous materials during rainfall. Similar observation has been reported by Ayoade *et al*. (2006); Atobatele and Ugwumba (2008); Mustapha (2009), and Edward and Ugwumba (2010).

Principal Component Analysis (PCA)

The PC test shows that the physicochemical variables were successfully sorted into distinct categories that exhibited similar trends and created surrogate trend line representing all of the other parameters. According to Simmons *et al.* (2004), though PCA is useful for detecting possible groupings of related variables in a large multivariate data set, it is important to note that the derived PCs are strictly hypothetical and that a PC that is significantly correlated with another may or may not represent an actual causal factor.

The PCA identified four (4) factors responsible for the observed variation in the data (Table 4 and Figure 2 respectively). Phosphate, transparency, total solid and potassium extracted by PCA could be regarded as nutrient, physical and trace metal factors. This extraction clearly reveals three major groups of variables which are key drivers in ecosystems productivity. These four factors accounted for 77.655% of the total variation, with PC1 (Phosphate) alone contributing as high variability as 38.855 % in the reservoir. The levels of phosphate are higher than recommended limits; there is need for urgent action to prevent further increase. This is because phosphate has been considered to be the most significant among the nutrients responsible for eutrophication in aquatic ecosystems, as it is the primary initiating factor (Adeyemo *et al.,* 2008). High levels of both phosphate and nitrate can lead to eutrophication, which increases algae growth and ultimately reduces dissolved oxygen levels in the water. Among the other parameters with high loadings for factor 2 (that accounted for 16.229%), Transparency was prominent. Transparency is often affected by dissolved and suspension of eroded materials in water body, as well as inhabited phytoplankton that impair the transmission of light rays into water body. Also mixing of the water body as a result of turbulence does contribute to low transparency of the water body. The third component was highly correlated with total solid which could originate from accumulation of the eroded particles from the adjourning rivers and surrounded land.

The fourth component was most correlated with potassium which could be regarded as trace metal factors and could originate from dissolution of the plant materials that was brought into the reservoir.

Although, trace metals act as micronutrients at low concentrations, but at high level, they become toxic depending on the prevalent chemical form (that is, speciation) of the trace element in water. Also, bioaccumulation and food chain magnification of trace metal may occur.

The rotated component matrix revealed that the first principal component (PC 1) was most highly correlated with phosphate (0.904); PC 2 with transparency (0.886); PC 3 with total solid (0.882) and PC 4 with potassium (-0.730). Total suspended solid singly might have act as a vector of nutrients, most especially phosphorus, from the land surface to the water body, and thus accounted for the recorded high phosphate concentration in the reservoir. Similar high TSS concentration and its subsequent effects have been previously reported by Ajibade (2004) in Asa Dam (Kwara State), and Osibanjo *et al.* (2011) in Rivers Ona and Alaro in Ibadan.

More also, high TSS has tendency of reducing the light penetration into the reservoir as observed in this study, which may further lead to a reduced photosynthesis with consequent effects on both phytoplankton and zooplankton populations of the aquatic environment. It's equally capable of clogging fish gills which could result into stress, reduced growth, suppressed-immune system leading to increased susceptibility to disease and osmotic dysfunction and death.

Table 3: Spatial variation in Physico-chemical parameters of Itapaji Reservoir using Duncan Multiple Range Test (DMRT) (P< 0.05)

PARAMETERS	STATIONS				
	1	2	3	4	5
Temperature (°C)	27.50 [a]	27.57 [a]	27.32 [a]	27.72 [a]	27.38 [a]
Transparency (m)	1.54 [a]	1.64 [a]	1.78 [a]	1.39 [a]	1.34 [a]
Ph	7.24 [a]	7.45 [a]	7.22 [a]	7.26 [a]	7.26 [a]
Conductivity	287.50 [a]	302.13 [a]	274.63 [a]	257.71 [a]	232.75 [a]
Total Dissolve Solid (mg/L)	46.46 [a]	41.31 [a]	43.23 [a]	42.61 [a]	43.63 [a]
Total Suspended solid (mg/L)	16.57 [a]	16.74 [a]	15.18 [a]	17.71 [a]	18.37 [a]
Total Solid (mg/L)	64.65 [a]	57.86 [a]	55.88 [a]	60.46 [a]	59.54 [a]
Alkalinity (mg/L)	70.21 [a]	88.35 [a]	82.59 [a]	68.07 [a]	63.90 [a]
Chloride (mg/L)	56.07 [a]	51.26 [a]	61.12 [a]	57.33 [a]	58..26 [a]
Total Hardness (mg/L)	41.07 [a]	37.89 [a]	38.24 [a]	37.39 [a]	38.13 [a]
Nitrate (mg/L)	4.99 [a]	5.85 [a]	5.41 [a]	5.49 [a]	5.53 [a]
Sulphate (mg/L)	9.83 [a]	11.51 [a]	13.08 [a]	10.12 [a]	9.81 [a]
Phosphate (mg/L)	6.70 [a]	7.27 [a]	7.44 [a]	6.87 [a]	7.37 [a]
Dissolved Oxygen (mg/L)	4.73 [a]	4.28 [a]	4.34 [a]	5.69 [a]	4.99 [a]
Biochemical Oxygen Demand (mg/L)	2.31 [a]	2.54 [a]	2.31 [a]	2.78 [a]	2.64 [a]
Chemical Oxygen Demand (mg/L)	2.86 [a]	2.83 [a]	3.07 [a]	2.82 [a]	2.56 [a]
Sodium (mg/L)	10.73 [b]	11.66 [ab]	12.35 [a]	11.44 [ab]	12.37 [a]
Potassium (mg/L)	12.46 [a]	13.96 [a]	11.89 [a]	12.28 [a]	12.85 [a]
Calcium (mg/L)	17.07 [a]	15.27 [a]	15.65 [a]	14.61 [a]	15.38 [a]
Magnesium (mg/L)	14.70 [b]	13.80 [b]	16.92 [a]	13.93 [b]	15.75 [ab]
Zinc (mg/L)	0.90 [a]	1.21 [a]	1.40 [a]	1.37 [a]	1.44 [a]
Manganese (mg/L)	0.03 [a]	0.00 [a]	0.01 [a]	0.00 [a]	0.00 [a]
Copper (mg/L)	0.90 [a]	0.85 [a]	0.92 [a]	0.74 [a]	1.19 [a]
Iron (mg/L)	9.25 [a]	10.37 [a]	11.90 [a]	11.68 [a]	11.63 [a]
Lead (mg/L)	0.19 [a]	0.07 [a]	0.07 [a]	0.07 [a]	0.06 [a]
Chromium (mg/L)	0.21 [ab]	0.11 [b]	0.36 [a]	0.23 [ab]	0.21 [ab]

N.B: Values with the same superscript along same row are not significantly different at P<0.05

Table 4: Loadings of 26 experimental variables on principal components for Itapaji Reservoir

	Components			
Parameters	**1**	**2**	**3**	**4**
Temperature (ºC)	0.075	0.880	0.165	0.132
Transparency (m)	0.009	**0.886**	0.048	0.119
pH	0.885	-0.253	0.036	0.077
Conductivity (µS/cm)	-0.274	-0.228	-0.581	-0.474
Total Dissolved Solid (mg/L)	0.059	0.257	0.879	0.024
Total Suspended Solid (mg/L)	-0.048	-0.789	-0.177	0.331
Total Solid (mg/L)	0.042	0.064	**0.882**	0.115
Alkalinity (mg/L)	-0.143	-0.875	-0.080	0.355
Chloride (mg/L)	-0.104	-0.772	-0.438	0.215
Total Hardness (mg/L)	-0.140	0.091	0.740	-0.421
Nitrate (mg/L)	0.478	0.058	0.706	0.333
Sulphate (mg/L)	0.897	-0.080	0.153	0.356
Phosphate (mg/L)	**0.904**	0.111	0.310	0.146
Dissolved Oxygen (mg/L)	-0.709	-0.223	-0.175	0.076
BOD (mg/L)	-0.581	-0.361	-0.412	0.021
COD (mg/L)	0.787	0.415	0.205	-0.034
Sodium (mg/L)	0.605	0.337	-0.214	-0.289
Potassium (mg/L)	0.314	0.185	-0.266	**-0.730**
Calcium (mg/L)	0.168	-0.038	-0.078	0.557
Magnesium (mg/L)	0.736	-0.108	0.058	-0.492
Zinc (mg/L)	0.386	0.802	0.002	-0.072
Manganese (mg/L)	0.013	-0.574	-0.183	-0.380
Copper (mg/L)	0.738	0.518	-0.316	-0.017
Iron (mg/L)	0.601	0.753	0.079	0.052
Lead (mg/L)	0.745	0.454	-0.294	0.083
Chromium (mg/L)	0.600	0.554	-0.344	0.059

BOD = Biochemical Oxygen Demand and COD = Chemical Oxygen Demand

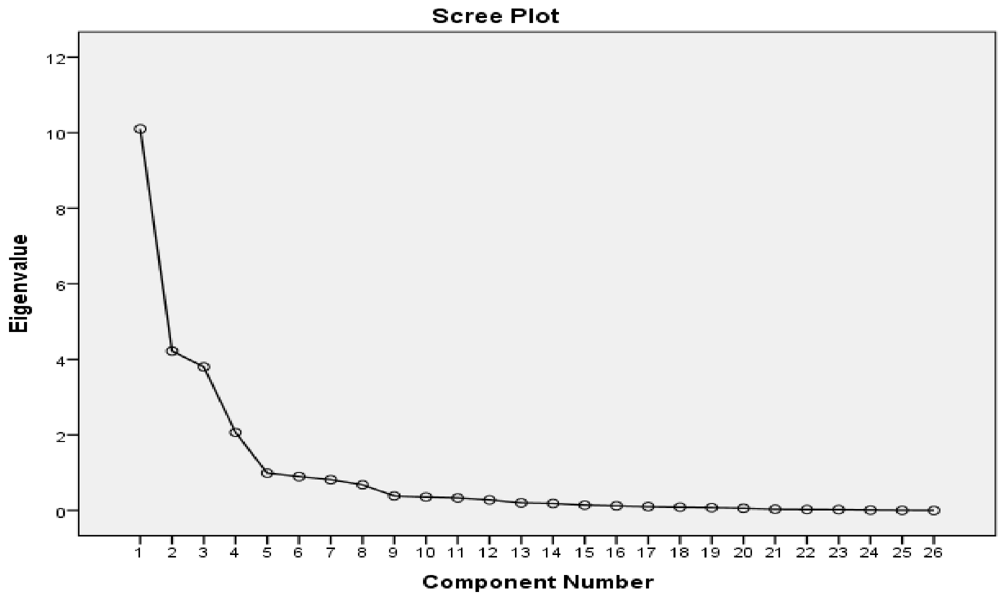

Figure 2: Score plot of eigen values versus components along with % variance components in Itapaji Reservoir.

Conclusion

Based on the results of physico-chemical parameters of the present study, Itapaji Reservoir is under pollution stress. This situation may aggravate the risk to environment in general and specifically to human health in particular. It is, therefore, suggested that the application of agro-based chemical fertilizers and pesticides with high heavy metals content should be avoided around the reservoir, and regular discharge of the reservoir should be ensure to avoid accumulations of the pollutants, for sustainable use of Itapaji Reservoir.

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