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Multivariate Statistical Analysis of Water Quality Parameters of Kakund River Basin (Lentic Ecosystem)

Rakhi Chahar[1], Rana Mukherji[2], Sukalyan Chakraborty[3], Ravneet Chug[4], Manishita Das Mukherji[5]*, Manmohan Singh Chauhan[6]*

[1,4,5,6]Amity University Rajasthan, Jaipur, India- 303002

[2]ICFAI Tech, The ICFAI University, Jaipur, India- 302031

[3]Department of Civil and Environmental Engineering, BITS, Mesra, Jharkhand, India- 835215

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KEYWORDS
Water Quality Index, Physio-chemical properties, PCA, Statistical Analysis, Ecosystem

ABSTRACT:
Assessment of physico-chemical parameters of dam (Bandh Baretha) water is carried out to check the water quality. The Bandh Baretha is the main water reservoir which supplies water to the Bharatpur and areas near to Baretha. Total fifteen physico-chemical parameters like dissolved oxygen (DO), temperature, pH, BOD, COD, total hardness, turbidity, conductivity, chloride, phosphates, sulphates, nitrates, alkalinity, acidity, total dissolved solids (TDS) were studied to assess water quality of Bandh Baretha at selected sites located at Bharatpur district, Rajasthan. Water quality index (WQI) used to determine the quality of water and it conclude that water is not suitable for the consumption. By using Principal component analysis (PCA) and Hierarchical cluster analysis (HCA) show the degradation of quality of water. PCA generates 4 PCs which contributes (96%) in influencing the quality of Dam water. Due to anthropogenic activities the quality of water deteriorate gradually which causes eutrophication.

1. INTRODUCTION

Water is required for all living organisms. It is the resource of nature. Increasing anthropogenic activities in and around the water bodies deteriorate the water quality and damage the aquatic ecosystem and are responsible for eutrophication due to change in physico-chemical properties of water (Nama & Dhan, 2018). Water plays a significant role for the environment in different purposes for the organisms, for production of food, human health and improvement of economic. The water quality parameters are very significant for ecosystem. And these parameters are affected by various factors like chemical, physical, and biological pollutants and cause severe health problems (Chouhan & Chhipa1, 2021). Monitoring the many parameters impacting water quality is important in order to determine the most relevant parameter and components that significantly affect water quality (Giri et al., 2019). Anthropogenic and natural activities are responsible for the degradation of water quality within a region (Gyimah et al., 2021). Regular monitoring is required to examine the consistency of the water quality and the temporally fluctuation of a river's water composition. A complicated water quality dataset has been reduced and meaningfully interpreted using multivariate analysis (Bostanmaneshrad et al., 2018; Noori et al., 2012). The interaction of biotic and abiotic factors, such as microbes and climate, determines the quality of water surface. The hydrochemical properties of water are regulated by these abiotic agents as a effect of continuous interactions among the water body and its surroundings (Setia et al., 2021). The assessed concentrations of several parameters showed an alarming state of contamination (Chauhan et al., 2020). Ministry of Environment, Forest and Climate Change, government of India, proposed the National Plan for Conservation of Aquatic Ecosystems (NPCA) guidelines so that assessed parameters values can be compared with prescribed limitis. Various parameters have been described by WHO to determine the quality of water in water bodies. Similar parameters are used in this study to estimate the quality of water of Bandh Baretha.

1. MATERIALS AND METHODS

Study area: This study was conducted on the Baretha Dam (25°1′30″N 74°51′29.99″E) Bharatpur covering the area 36 km^2. It is main source of water for Bharatpur and nearby areas of Baretha. The periods from January to June are pre monsoon season considered to be dry season. Bandh Baretha is located in the Bharatpur District 65 km from Bharatpur. The

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dam construction began in 1866 by Maharaja Jaswant Singh on Kakund River which originates from the hills of Karauli district. After one year the construction work was stopped, the construction work was again started by Maharaja Ram Singh during his ruling period and was completed in 1896-97. About 200 square kms of area surrounding the dam was declared as wildlife sanctuary in 1985. Currently it is under the administration of the Forest Department. Endangered animals like Sambar, Cheetal, Blue Bull and Striped Hyena are found in this wildlife sanctuary. The main importance of the dam area is the surrounding wetland habitats for native and migratory birds. Although the reservoir is one of the main sources of water for Bharatpur, the Kakund watershed's concern is a limited supply of water, overexploitation of ground water and a deteriorating quality of ground water with salinity and nitrate as the major problems. The region's typical annual rainfall is 1050 mm. The hottest month of the year is May, with maximum temperatures sometimes exceeding 48-degree Celsius. The minimum temperature frequently drops below 5-degree Celsius in the winter months of December and January (Singh & Hermans, 2019).

Sampling framework: In six months, samples were taken from three distinct Dam locations (January 2022-June 2022). All sampling sites were located bank of the Dam. Samples of water were collected from the dam at about 0.3–0.5 m under the water surface. After the sample collection chemical measurements done in laboratory. For Dissolved Oxygen (DO), water samples were filled in 300 ml borosil glass bottles and in the field DO fixed in the field by adding 2ml of manganese sulphate and 2ml of alkali iodide azide and determined by using Wrinkler's Method. Additionally, samples for the measurement of other parameters were taken in 2-liter plastic bottles that had been washed with distilled water before to collecting the water sample and treated with 2 ml of 2% nitric acid. Samples were stored in from 0 ℃ to 4 ℃ for subsequent chemical analysis. Coordinated of sampling locations along with landmark are represented in Table 1. The location of Baretha Dam can be seen on map as shown in Fig.1.

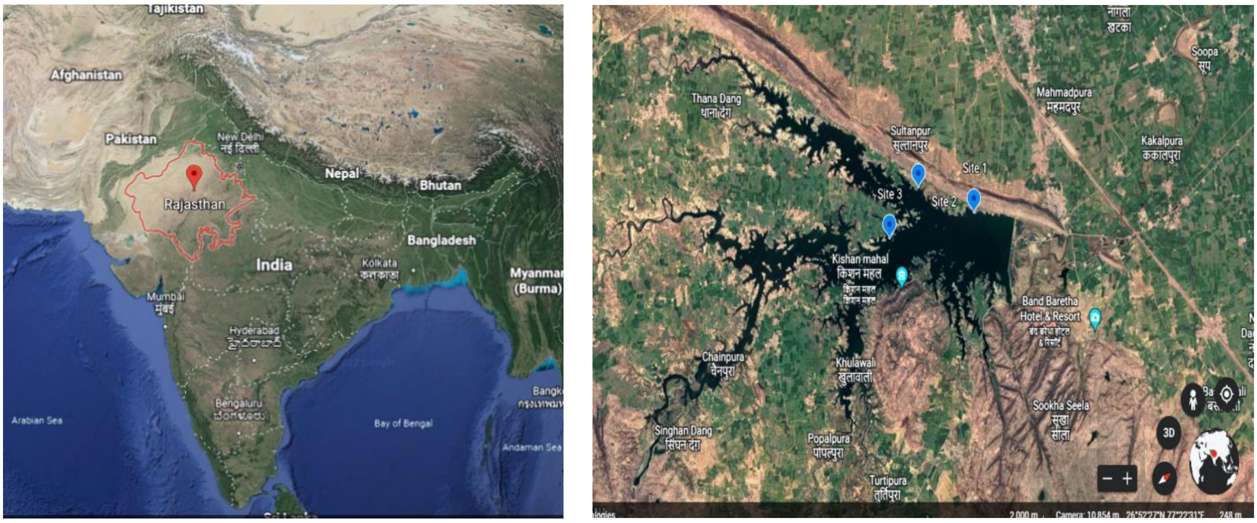
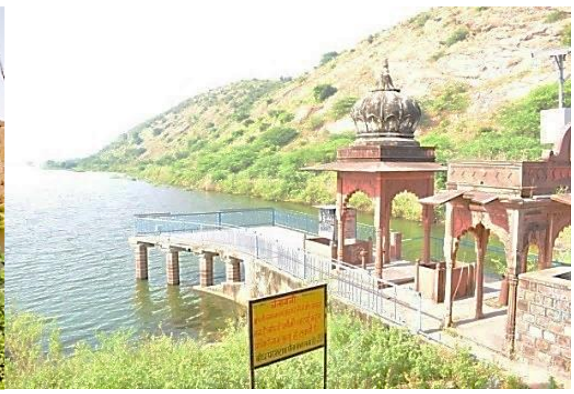


Fig. 1 Location Map of Bandh Baretha Bharatpur on Google Earth Image

Site 1



Site 2

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Site 3

Fig. 2. Locations of sampling areas.

Table 1. Details of Sampling Locations

Location	Coordinates
Sampling Spot 1	26˚53'49" N 77˚22'00" E
Sampling Spot 2	26˚53'28" N 77˚21'44" E
Sampling Spot 3	26˚52'40" N 77˚21'31" E

Analytical procedure: Fifteen parameters according to Indian Standards and American Public Health Association 2000 (APHA 2000) methods. Remove the electrodes from the storage solution and give them a quick washing in distilled water before use.

pH: It was determined by LBMAN LMMP-30. It is calibrated by buffers of pH 7, 9.2, 4 and checked for the negative errors and then electrodes immersed in the sample and take the three readings and calculate the average value.

Temperature, TDS and EC: Such parameters were measured by using LABMAN LMMP-30 by immersing the electrodes in sample.

DO: It was measured by Wrinkler's method; samples were collected in DO bottles without bubbling so that no air space remains. And add 2 ml of $MnSO_4$ followed by 2ml of alkali iodide azide reagent and then add 2 ml concentrated Sulphuric acid and titrate with 0.025 N sodium thio-sulphate using starch indicator.

Total Hardness: It determined by titration method by using the buffer solution of pH 10 and indicator EBT (Erichrome Black-T) and EDTA.

Turbidity: It was measured by water analyser-371. Prepared a calibration curves in the range of 0-400 unit carrying out appropriate dilution of solution stock turbidity suspension & standard turbidity Suspension & taking reading with turbidity meter. And take the reading at ambient temperature.

Alkalinity: It was measured by titration with 0.02 N H_2SO_4 using phenolphthalein indicator. *Acidity*: It was determined by titration with 0.05 M NaOH by using methyl orange indicator. Chlorides: It was measured by using indicator K_2CrO_4 and titrate with standard $AgNO_3$.

Nitrates, Phosphates and sulphates: These are determined by UV-VIS spectrometer (ThermoFischer) at the wavelength of 410 nm, 690 nm and 420 nm respectively.

BOD: It was measured by putting the sample in incubator for 3 days at 27℃ and after three days in samples titrates with thio-sulphate by using starch indicator.

COD: It was determined by reflux apparatus; add Hg_2SO_4, Ag_2SO_4, H_2SO_4 in a reflux flask with sample and reflux for 2.5 hours at 80℃, cool and diluted for minimum of 150 ml. cool and titrated, excess with 0.1N $[Fe(NH_4)_2(SO_4)_2]$ using ferroin indicator.

Duration of Study: The samples were collected from the Dam during January 2022 to June 2022. A comprehensive investigation of physico-chemical parameters was planned and performed on the basis of monthly sampling and testing.

Protocols Followed: For the sampling and testing of Dam water samples the protocols followed are according to Indian Standards and American Public Health Association 2000 (APHA 2000) methods, as shown in Table 2.

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JCHR (2023) 13(6), 2274-2290 | ISSN:2251-6727

Table 2. Protocols / test methods followed for different parameters.

S. No.	Test Parameter	Test Methods / Instruments	Unit
1	pH	pH meter	-
2	Temperature	LABMAN LMMP-30	℃
3	TDS (Total Dissolved Solids)	LABMAN LMMP-30	Mg/L
4	EC (Electrical Conductivity)	LABMAN LMMP-30	µS/cm
5	DO (Dissolved Oxygen)	Wrinkler's Method	Mg/L
6	Total Hardness	EDTA Titrimetric method	Mg/L
7	Turbidity	Water analyser	NTU
8	Alkalinity	Titrimetric method	Mg/L
9	Acidity	Titrimetric method	Mg/L
10	Chlorides	Titrimetric method	Mg/L
11	Nitrates	UV Spectrophotometric method	Mg/L
12	BOD (3 Days at 27℃)	Wrinkler's Method	Mg/L
13	COD	Reflux reaction	Mg/L
14	Phosphates	UV Spectrophotometric method	Mg/L
15	Sulphates	UV Spectrophotometric method	Mg/L

Data Treatment and statistical analysis: All the mathematical and statistical calculations are done by using Microsoft Office Excel 2010, and Statistical Package for Social Sciences (SPSS) version 26. The standardization of data is done by statistical procedures. The data are given to PCA to reduce the dimensionality of the data by explaining the correlations between a large number of variables in terms of a smaller number of underlying factors (principal components, or PCs), and then after running the FA that simplifies the analysis of the data, using R&Q mode varimax rotation to discover more precisely defined factors called varifactors, or VFs (Giri et al., 2019). Finally, Q-mode HCA was used to determine how similar each sample was to the others (Reghunath et al., 2002).

Statistical procedure: In Principal component analysis, scree plot and eigenvalue are the two criteria were used to eigenanalysis of the data is made to elucidate the principal components. For Hierarchical Cluster Analysis (HCA), the Euclidean distance between normalized data was used to evaluate the similarities between the sites. Standardization of data was done by ward's method and in vertical dendrogram output results were represented. All mathematical calculations were made using Microsoft Office Excel 2007, and statistical computations were made using Statistical Package for Social Sciences (SPSS) version 26.

Data standardization: For the data suitability to perform the PCA, Kaiser-Meyer-Olkin (KMO) and Bartlett's test are used. KMO used to determine the adequacy of sample water. The PCA can be used in that case when only KMO value will be greater than 0.5, shown in table 3. Bartlett's test assess the relationship between the variables at a significance level. In this study, the KMO value from January 2022 to June 2022 was 0.786.

Table 3: KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.786
Bartlett's Test of Sphericity	Approx. Chi-Square	654.956
	df	3
	Sig.	.000

Journal of Chemical Health Risks

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JCHR (2023) 13(6), 2274-2290 | ISSN:2251-6727

2. RESULT AND DISCUSSION

Water quality parameters: The parameters of water quality include a wide range of chemical, physical and biological properties. According to the different water quality standards proposed by WHO, CPCB, are listed in table 4.

Table 4: Water quality standards proposed by WHO (World Health Organisation), CPCB (Central Pollution Control Board).

Characteristics	WHO (World Health Organisation)
pH (pH units)	6.5-8.5
TDS (mg L^{-1})	500-2000
Temperature (°C)	-
Turbidity (NTU)	2.5
DO (mg L^{-1})	6.5-8
Hardness (mg/L)	<75 (Soft water) 76 to 150 mg/L (moderately hard) 151 to 300 mg/L (hard) >300 mg/L (very hard)
Alkalinity (mg/L)	200-600
Sulphates (mg/L)	200-400
Nitrates (mg/L)	45
Chloride (mg/L)	250-1000
BOD (mg/L)	30*
COD (mg/L)	250*
Conductivity μS/cm	400 μS/cm
Phosphates (mg/L)	0.1

*According to standards of CPCB (Central Pollution Control Board).

Table 5. Table presents the findings from the descriptive study of the water quality that illustrates how the pre-monsoon water quality parameters vary.

MONTHS / PARAMETERS	JANUARY			FEBRUARY			MARCH			APRIL			MAY			JUNE		
	S-1	**S-2**	**S-3**	**S-1**	**S-2**	**S-3**	**S-1**	**S-2**	**S-3**	**S-1**	**S-2**	**S-3**	**S-1**	**S-2**	**S-3**	**S-1**	**S-2**	**S-3**
DO (mg/L)	14.5*	12*	13*	10.6*	11.2*	10.8*	10*	11.2*	11*	10*	12*	10*	9*	8.5*	7*	6*	5.86*	7.12*
Temperature(°C)	18	19	17	19	20	20	24	22	23	27	26	28	30	29	30	30	30	29
pH	6.7	6.6	6.7	6.7	6.5	6.0	6.8	6.7	6.8	6.9	6.6	6.8	6.9	6.9	6.7	6.9	6.9	6.8
Acidity (mg/L)	80	70	50	60	70	90	20	30	40	10	30	40	30	20	40	50	40	50
Alkalinity (mg/L)	1040*	1290*	1180*	1200*	1280*	1310*	1040*	1180*	1110*	1160*	1180*	1170*	600*	1120*	1160*	1360*	1280*	1320*

TDS	400	410	500	1000	720	890	300	330	400	480	500	430	490	500	900	850	750	800
Turbidity (NTU)	0.42	0.43	0.52	1.63	1.01	1.11	0.31	0.35	0.41	0.49	0.51	0.48	0.55	0.57	0.99	1.12	1.03	1.11
Conductivity (μs)	1232*	1246*	1366*	1297*	1356*	1306*	1297*	1323*	1357*	1415*	1435*	1397*	1294*	1237*	1314*	1269*	1306*	1296*
Hardness (mg/L)	220*	160*	108*	330*	275*	350*	390*	510*	473*	460*	415*	340*	410*	350*	500*	410*	420*	418*
Chlorides (mg/L)	5.9	4.6	2.8	8.9	7.8	9.4	10.2	13.7	12.6	12.2	11.2	9.4	10.9	9.5	13.5	10.2	10.5	10.5
BOD (mg/L)	50*	60*	50*	50*	60*	80*	80*	68*	90*	60*	70*	50*	70*	60*	80*	96*	150*	88*
COD (mg/L)	170	100	78	110	92	130	160	178	160	122	180	80	150	88	106	232	310*	176
Sulphates (mg/L)	1.1	1.7	1.1	0.0013	0.0015	0.0014	0.05	0.042	0.053	0.039	0.036	0.039	0.048	0.026	0.024	0.22	0.12	0.34
Nitrates (mg/L)	385*	386*	387*	342*	339*	343*	270*	263*	264*	238*	240*	241*	327*	325*	255*	229*	225*	196*
Phosphates (mg/L)	0.67*	0.62*	0.62*	0.47*	0.48*	0.5*	0.23*	0.23*	0.23*	0.01*	0.01*	0.01*	0.18*	0.15*	0.18*	0.08*	0..09*	0.13*

*Above the standard limit

Physico-chemical characteristics of the Bandh Baretha

DO (Dissolved Oxygen): The most important factor in determining water quality is DO. A healthy body of water must have DO between 4-6 mg/L of the standard limit, with 14.6 mg/L being the ideal value, in order to maintain adequate water quality for aquatic life (Gupta et al., 2017). The variations of the concentration of dissolved oxygen (DO) observe vary in all 3 different sites and found from 5.8 mg/L to 14.5 mg/L. The DO maximum was observed in month of January for **site 1**, 14.5 mg/L which is indicating that the respiratory rate of organisms decreases due to low temperature of water bodies, while the DO minimum value is observed in month of June at **sites 1** and **2** which is 6 and 5.8 mg/L respectively and their low value due to an increase in temperature also causes aquatic species' metabolic and respiratory rates to increase, which raises the amount of oxygen that the water is consuming. WHO provides the guidelines with permissible value for DO of Designated Healthy water which should be **above 6.5-8 mg/L.** During January to June, it is observed that all the water samples of different sites of Dam have DO value in range of permissible limit except in June at **site 1 and 2** due to the presence of bio-degradable material in water bodies.

Journal of Chemical Health Risks
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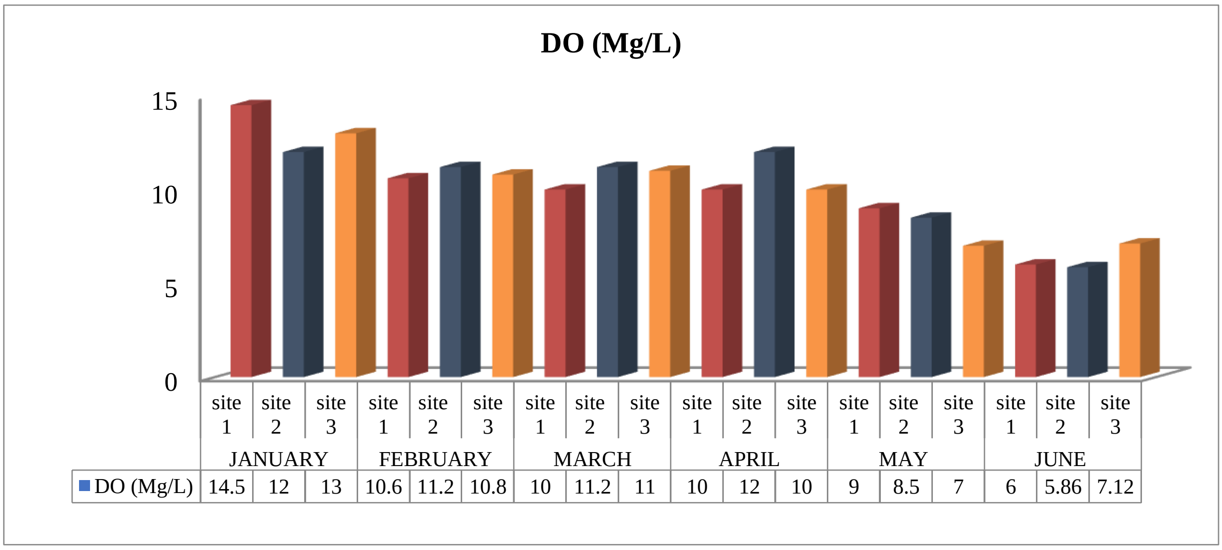

Fig 3: Variations of DO from January to June of site 1,2 and 3.

BOD: BOD (3) is the primary criteria used for assessment and control of water pollution. BOD (3) provides information about physiologically oxydisable organic matter and has several uses in environmental applications. As shown in table 5 we observed that BOD (3) has positive correlation with COD, alkalinity, turbidity, TDS and negative correlation DO, nitrates, phosphates and sulphates. It means that the BOD (3) is affected by the concentration of DO, nitrates, phosphates and sulphates. The value of BOD (3) increases with increase of the value of COD There is an alarming point to note that during the whole study period, According to the CPCB standards for variable usage, the BOD (3) of dam water was determined to be higher than the permitted level of 30 mg/L. The exponential increase of BOD (3) at site 2 in the month of June which indicates that dam water is polluted with the organic matter and it may be due to human activities. Hence, it should be first treated for any kind of further usage as well as it creates unhygienic conditions and dangerous for aquatic life as the organic matter will absorb the DO available in water to get itself oxidized.

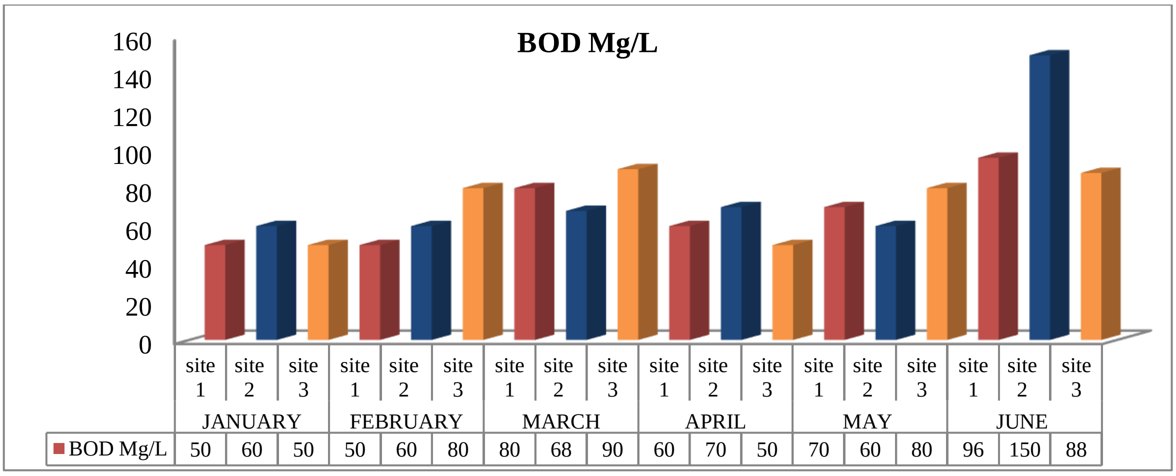

Fig 4. Variations of BOD from January to June of site 1,2 and 3.

COD: The presence of organic materials and inorganic compounds in water is indicated by high COD values. According to standards of CPCB (Central Pollution Control Board) the permissible limits for the COD is 250 mg/L. During the study at Baretha Dam, COD of water ranges from 78 mg/L to 310 mg/L. During January maximum COD level recorded at **site 1** as 170mg/L whereas minimum COD level recorded at **site**

Journal of Chemical Health Risks

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JCHR (2023) 13(6), 2274-2290 | ISSN:2251-6727

3 as 78mg/L. In February maximum COD recorded at **site 3** as 130 mg/L and minimum at **site 2** as 92 mg/L. In the month of March COD levels slightly changes maximum at **site 2** as 178 mg/L and minimum at **site 1** and **2** as 160 mg/L. in April maximum COD recorded at **site 2** as 180 mg/L and minimum at **site 3** as 80 mg/L. During May COD maximum valued at **site 1** as 150 mg/L and minimum at **site 2** as 88 mg/L. and during June maximum valued at **site 2** as 310 mg/L and minimum at **site 3** as 176 mg/L. Highest COD during the study at site 2 of January indicated that inorganic and organic materials that could be chemically oxidised were contaminating the water.

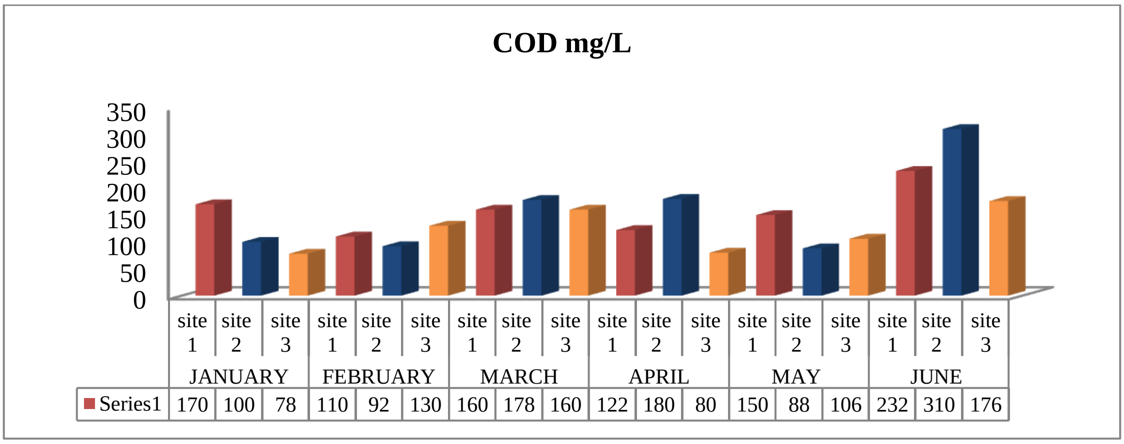

Fig. 5: Variations of COD from January to June of site 1,2 and 3.

pH, Alkalinity and Acidity: The hydroxide (OH^-) and hydrogen ion (H^+) concentrations are balanced out by the pH scale. It is regarded as a crucial factor in determining quality of the water. pH of dam water varied from 6.5 to 6.9. The chemical components of sediments have an impact on the pH level in the water bodies. The pH values indicated that the pH observations were acceptable (pH 6.5 to 8.5) reported by WHO and water specified as in class A. And Water can be used for drinking after disinfection but before traditional treatment.

According to the World health organization (WHO) desired and acceptable levels of alkalinity in water are 200 mg/L and 600 mg/L respectively. During the study alkalinity were recorded 600 mg/L to 1360 mg/L which were more than the permissible limits. The highest values of alkalinity recorded in month June which were due to human activities or anthropogenic activities such as use of pesticides, fertilizers, disposal of waste, brackish water intrusion, which starts the weathering process of the subsurface geology. Alkalinity is negatively correlates to the acidity. The concentration of acidity increases with decrease of concentration of alkalinity. High alkalinity water unsuitable for drinking as well as plant irrigation.

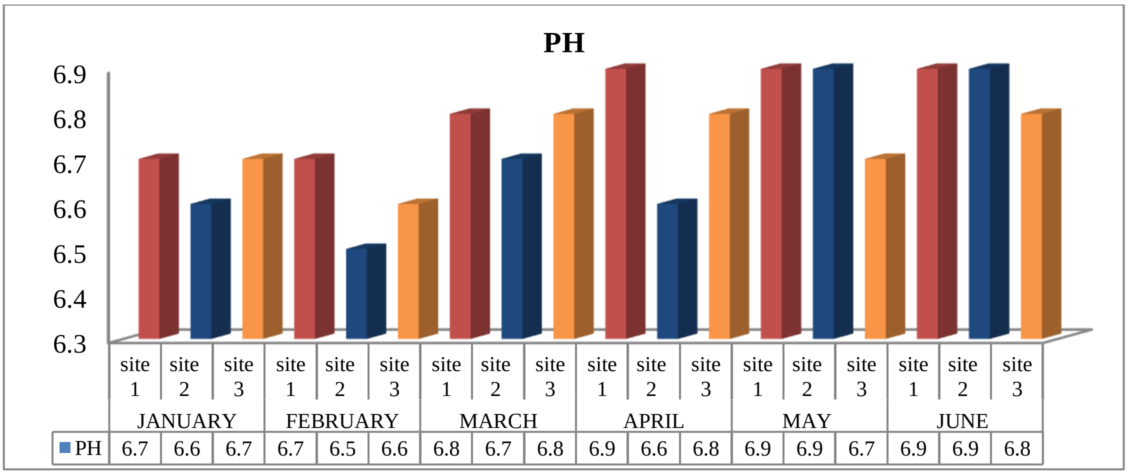

Fig. 6: Variations of pH from January to June of site 1,2 and 3.

Journal of Chemical Health Risks
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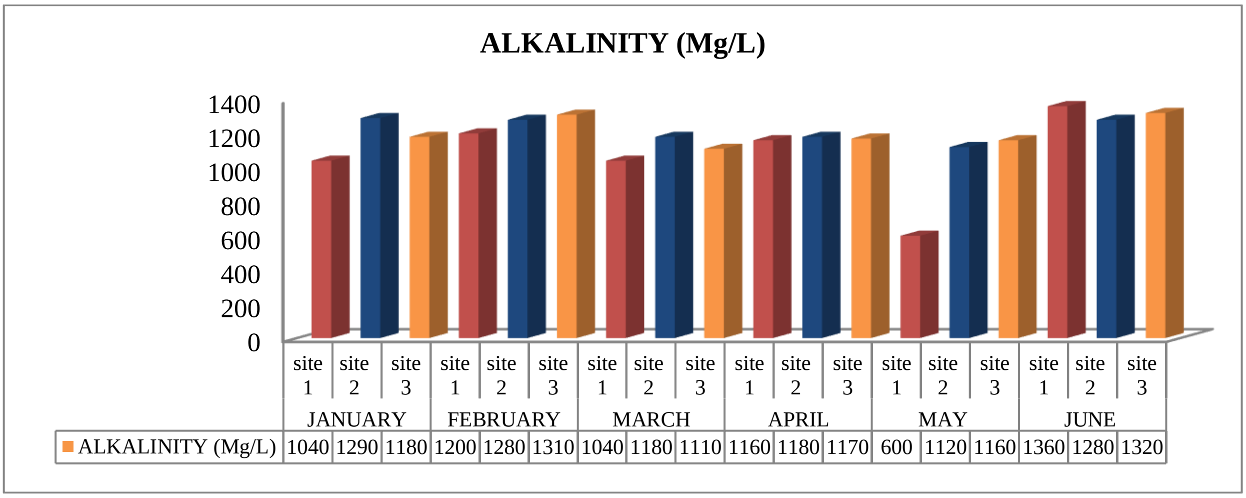

Fig. 7: Variations of alkalinity from January to June of site 1,2 and 3.

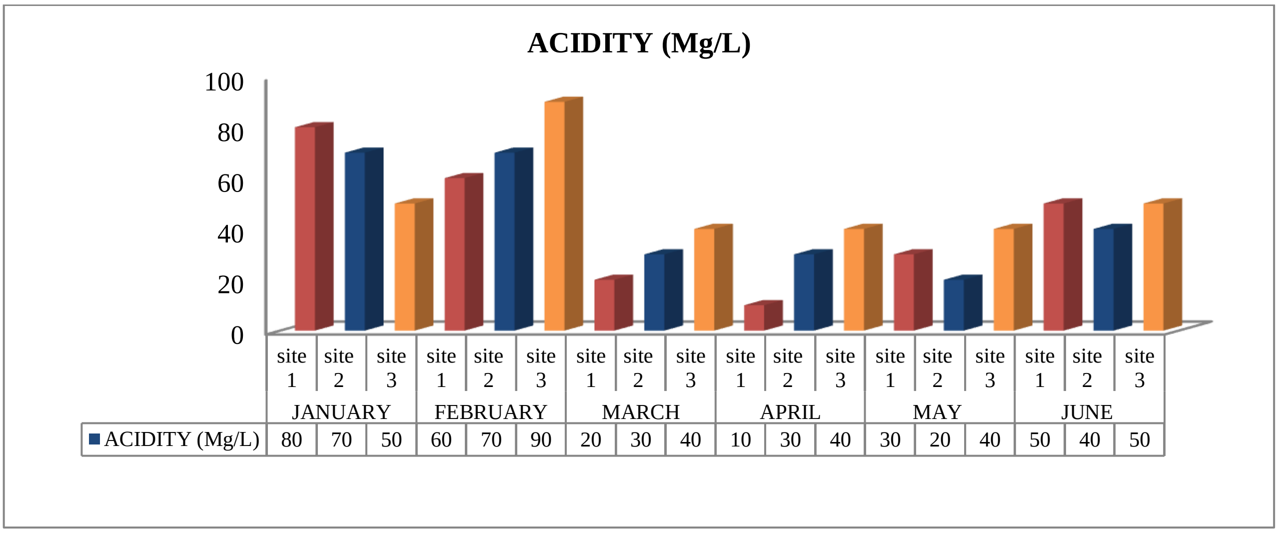

Fig. 8: Variations of acidity from January to June of site 1,2 and 3.

Total Hardness and Chlorides: The amount of calcium and magnesium ions present, measured in milligrams per litre (mg/L), is referred to as the calcium and magnesium hardness. Calcium carbonate concentrations are used to determine the hardness of water. Below 75 mg/L is commonly regarded as soft, 76 mg/L to 150 mg/L is moderately hard, 151 mg/L to 300 mg/L is hard, and more than 300 mg/L is extremely hard (very hard) https://www.healthvermont.gov/environment/drinking-water/hardness-drinking-water. Water becomes permanently hard due to the presence of soluble calcium and magnesium compounds like sulphates and chlorides. During January to June the variations in the concentration of total hardness were 108 mg/L to 510 mg/L. During January maximum level of hardness measured at **site 1** as 220 mg/L whereas minimum at **site 3** as 108 mg/L. This indicate that at site 1 and 2 hard water is present which is unsuitable for drinking whereas at site 3 moderately hard water present. In the month of February

maximum hardness seen at **site 3** as 350 mg/L and minimum at **site 2** as 275 mg/L. In February dam water is very hard and unsuitable for drinking purpose. In March the maximum amount of hardness measured at **site 2** as 510 mg/L and minimum at **site 1** as 390 mg/L. During April Maximum value measured at **site 1** as 410 mg/L and minimum at **site 3** as 340 mg/L. In the month of May maximum hardness value measured at **site 3** 500 mg/L whereas minimum valued at **site 2** 350 mg/L. And in June maximum valued at **site 2** 420 mg/L and minimum at **site 1** 410 mg/L. According to the above

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JCHR (2023) 13(6), 2274-2290 | ISSN:2251-6727

categorization, except in January at site 3, all sampling sites have hard water from January to June. According the above data we can say that hardness of water increases with increase of temperature.

Chloride has a salty taste and can often have negative health effects at larger concentrations. The chloride concentration was ranged from 2.8 mg/L to 13.7 mg/L. The values recorded are within the permissible limit of 250 mg/L to 1000 mg/L as per the standards of WHO.

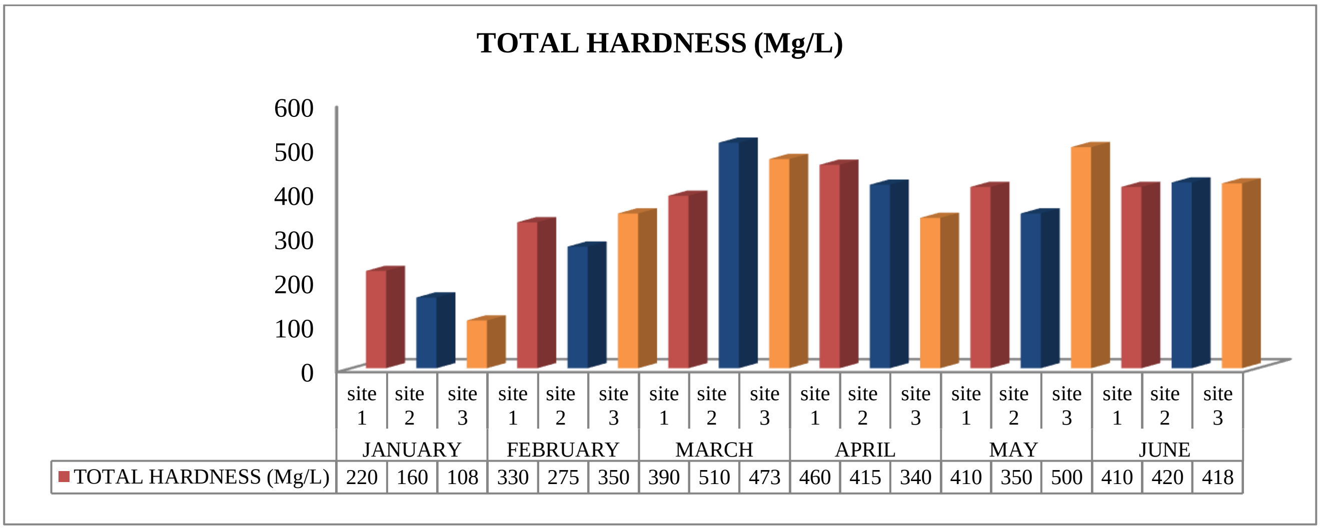

Fig. 9: Variations of total hardness from January to June of site 1,2 and 3.

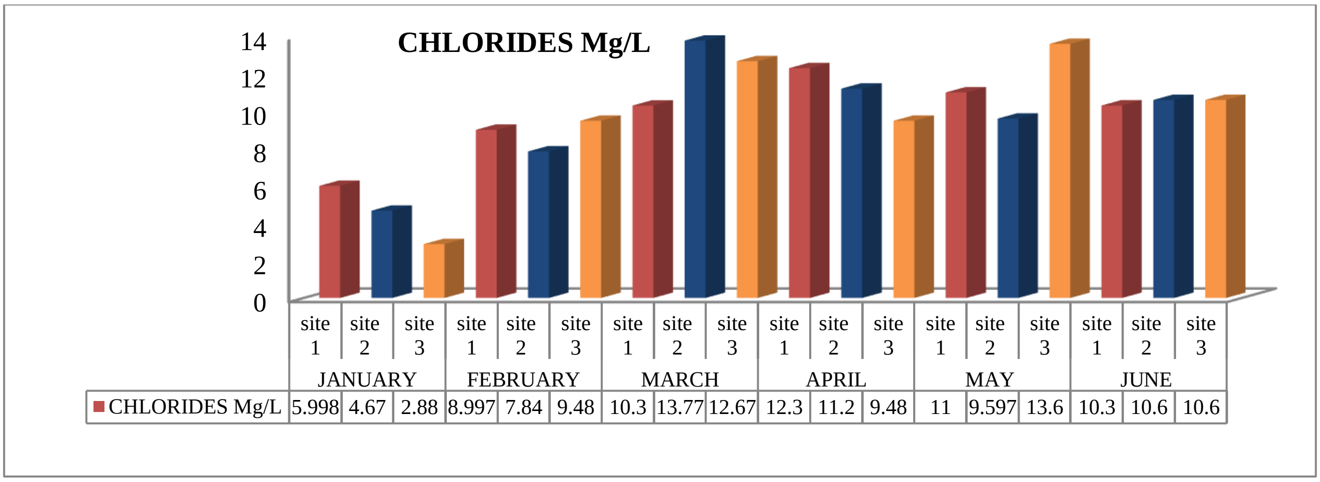

Fig. 10: Variations of chlorides from January to June of site 1,2 and 3.

Conductivity: Conductivity of water is the ability to conduct electric current. Conductivity generally expressed as µS/cm. Conductivity water sample of Baretha Dam vary from 1232 µS/cm to 1435 µS/cm. From table 5 we can predict that from January to June conductivity is very high from the permissible limit given by WHO (400 µS/cm). This indicates that ions concentration in water increases due to increase of chloride ions. The concentration of electrolytes rises when water temperature rises because warmer weather speeds up the evaporation of lake water, which raises the concentration of electrolytes. The variations in the rate of organic matter decomposition may possibly be the cause of the fluctuations in EC values seen during the current investigation. While continual evaporation causes an increase in electrolytes, the decomposition of organic matter results in the release of dissolved chemicals and nutrients. These two elements can raise the EC of water (Parray et al., 2010).

Journal of Chemical Health Risks
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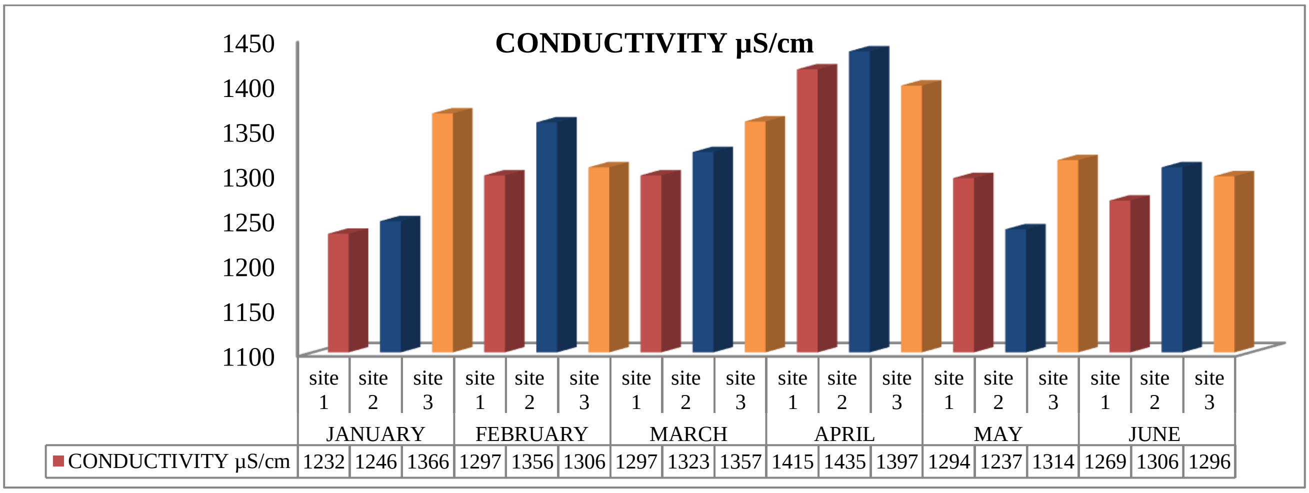

Fig. 11: Variations of conductivity from January to June of site 1,2 and 3.

Turbidity and Total dissolved solids: The amount of total solids in water has a direct impact on turbidity, which is the opacity of the water. The breakdown of organic matter in water-suspended clay-like material causes turbidity. Higher the value of total solids, because of lower the transparency level of that water which lowers the turbidity level. The graph showed the large regional fluctuation of TDS, EC, and TH. According to WHO, TDS acceptable limit and permissible limit in the absence of alternate source is 500 mg/L and 2000 mg/L respectively. The ranges of turbidity from 0.31 NTU to 1.36 NTU and total solids from 300 mg/L to 1000 mg/L. In January maximum turbidity and total solids recorded at **site 3** as 0.52 NTU and 500 mg/L respectively and minimum at **site 1** as 0.42 NTU and 400 mg/L. In the month of February the maximum valued were at **site 1** as 1.36 NTU and 1000 mg/L and minimum at **site 2** as 1.01 NTU and 720 mg/L respectively. In March the maximum ranges of turbidity and total solids were at **site 3** as 0.41 NTU and 400 mg/L while minimum at **site 1** as 0.31 NTU and 300 mg/L respectively. During the month of April the amount of turbidity and total solids maximum valued at **site 2** as 0.51 NTU and 500 mg/L whereas minimum values were at **site 3** as 0.48 NTU and 430 mg/L respectively. In May the maximum range recorded at **site 3** turbidity as 0.99 NTU and total solid as 900 mg/L and minimum valued at **site 1** turbidity as 0.55 whereas total solids were 490 mg/L. And in the month of June maximum turbidity and total solids recorded at **site 1** as 1.12 NTU and 850 mg/L and minimum at **site 2** as 1.03 NTU and 750 mg/L respectively. The TDS value for the past six months in the study area ranges from a minimum of 300 mg/L to a maximum of 1000 mg/L, revealing that the TDS does not rise above the allowable limits during the months of January to June.

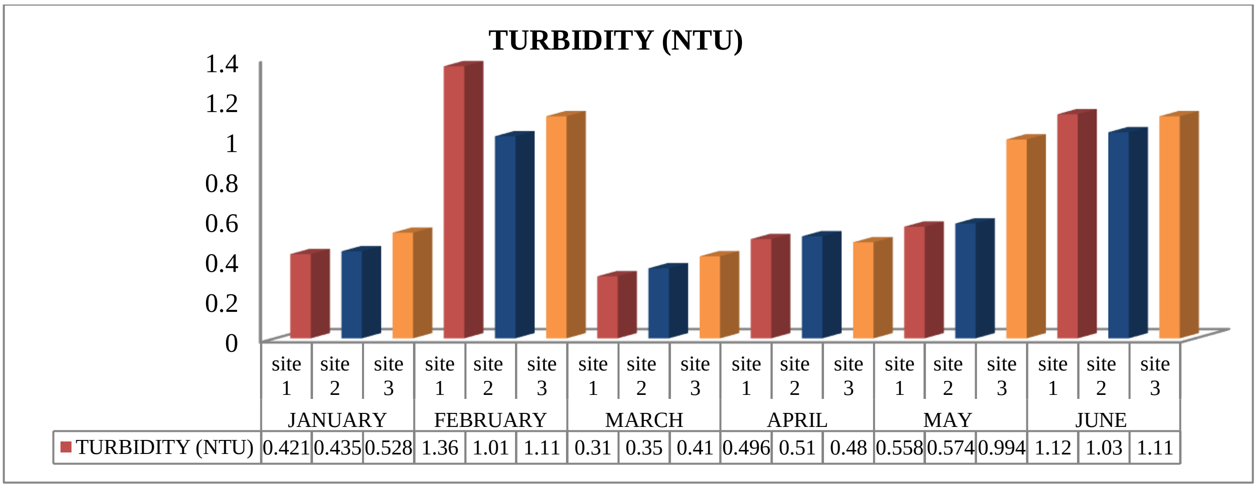

Fig. 12: Variations of turbidity from January to June of site 1,2, and 3.

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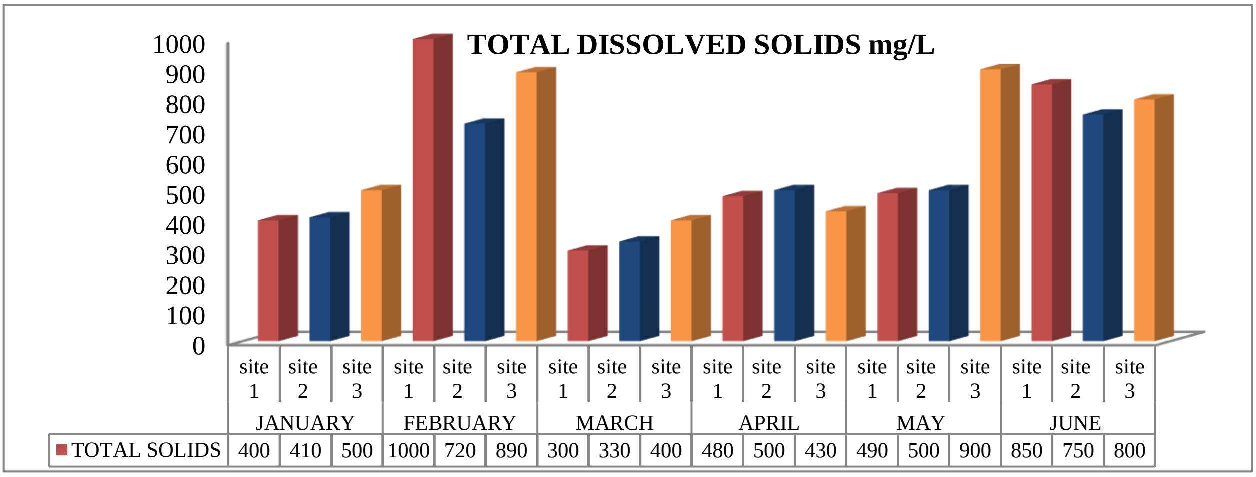

Fig. 13: Variations of total solids from January to June of site 1,2 and 3.

Sulphates: One of the main anions in water, sulphate, has a major impact on human population when it is present at higher concentrations. Surface runoff from farms and sewage discharge both cause increase of sulphates to enter aquatic bodies. Higher level of sulphates indicated that man-made, natural, and mixed source pollution. According to WHO the Acceptable Limit and Permissible limit in the absence of alternate source are 200 mg/L and 400 mg/L. In Baretha Dam amount of sulphates varied from 0.0013 mg/L to 1.1 mg/L. During the month of January maximum amount of sulphates recorded at **site 2** as 1.7 mg/L and minimum at **site 2** and **3** as 1.1 mg/L. In February maximum sulphates at **site 1** as 0.0015 mg/L and minimum at **site 1** as 0.0013 mg/L. In the month of March maximum sulphates recorded at **site 3** as 0.053 mg/L and minimum at **site 2** as 0.042 mg/L. In April highest concentration seen at **site 1 and 3** as 0.039 mg/L whereas minimum at **site** 2 as 0.036 mg/L. During the month of May maximum sulphates recorded at **site 1** as 0.048 mg/L and minimum at **site 3** as 0.024 mg/L. And in June maximum valued at **site 3** as 0.34 mg/L whereas the minimum valued at **site 2** as 0.12mg/L. During the January increased amount of sulphates indicated that released agricultural runoff and high human activities.

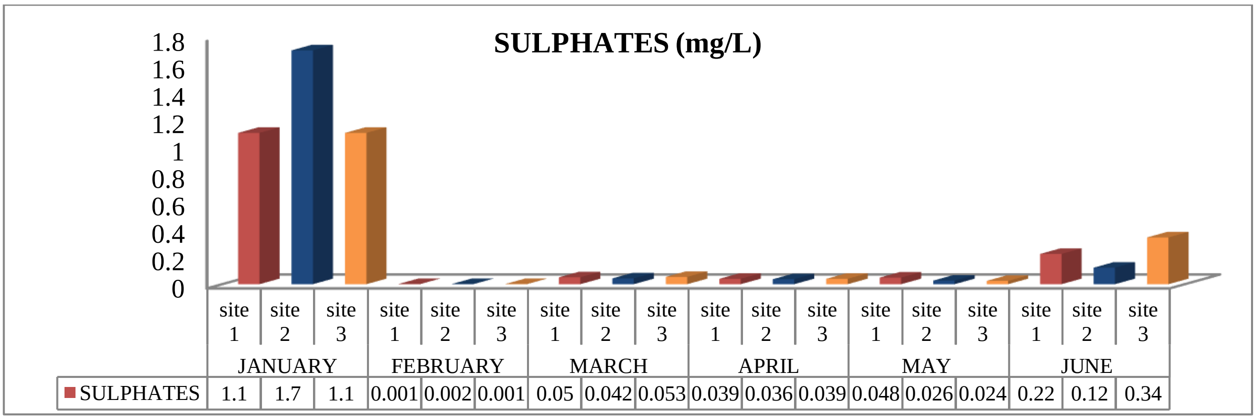

Fig. 14: Variations of sulphates from January to June of site 1,2 and 3.

Nitrates and Phosphates: Nitrate levels in water bodies increased due to an increase in the concentration of organic matter in the water. Nitrate ion concentration is a crucial indicator of drinking water quality because if it is measured more than 45 mg/L, it can result in blue newborns (methemoglobinemia) in children (Ward et al., 2018). Excess amount of nitrates and phosphates in water causes eutrophication (Suteja & Purwiyanto, 2018). According to WHO acceptable limit of nitrates is 45 mg/L. The concentration of nitrates varied from 196 mg/L to 387 mg/L. and phosphates ranges from 0.014 mg/L to 0.67 mg/L. Maximum amount of phosphates measured at **site 1** during the month of January as 0.67 mg/L and nitrates recorded at **site 3** as 387 mg/L whereas minimum concentration of phosphates recorded at **site 2** and **3** as 0.62 mg/L and nitrates at **site**

Journal of Chemical Health Risks
www.jchr.org
JCHR (2023) 13(6), 2274-2290 | ISSN:2251-6727

1 as 385 mg/L. This due to increased agricultural runoff. In February maximum amount of phosphates at **site 3** as 0.5 mg/L and nitrates at **site 3** as 343.5 mg/L and minimum amount of phosphates recorded at **site 1** as 0.47 mg/L and nitrates at **site** 2 339.5 mg/L. In march at all sites amount of phosphates same whereas maximum amount of nitrates recorded at **site 1** as 270 mg/L and minimum amount of nitrates at **site 2** as 263.8 mg/L. In April the maximum amount of phosphates valued at **site 1** as 0.017 mg/L and nitrates at **site 2** as 240.6 mg/L whereas minimum amount of phosphates at **site 3** as 0.014 mg/L and nitrates at **site 1** as 238.1 mg/L. During May the maximum amount of phosphates recorded at **site 1** and **3** as 0.18 mg/L and nitrates at **site 1** as 327.3 mg/L and minimum amount of phosphates at **site 2** as 0.15 and minimum amount of nitrates at **site 3** as 255.6 mg/L. And in June maximum amount of phosphates recorded at **site 3** as 0.13 mg/L and nitrates at **site 1** as 229.6 mg/L whereas minimum amount of phosphates valued at **site 1** as 0.085 mg/L and nitrates at **site 3** as 196.8 mg/L. In June month concentration of nitrates and phosphates or low as compared to other months because during this month there were no use of chemical fertilizers. At the study area all the sites from January to June have increased level of nitrate concentration beyond the permissible limits which indicate the use of pesticides in the fields near the dam area which leaked from fertilized soil.

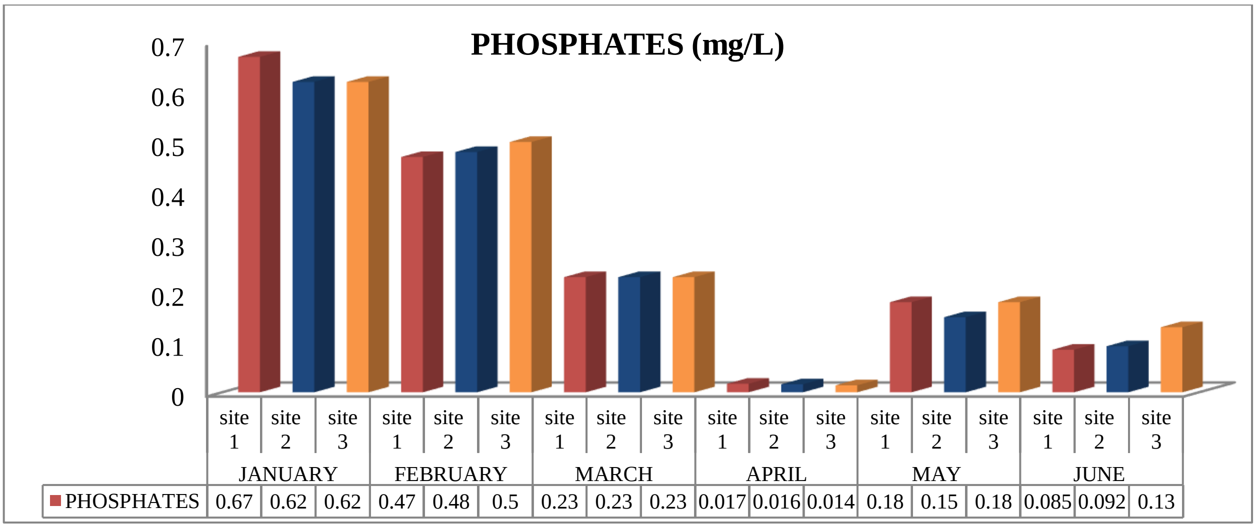

Fig. 15: Variations of phosphates from January to June of site 1,2 and 3.

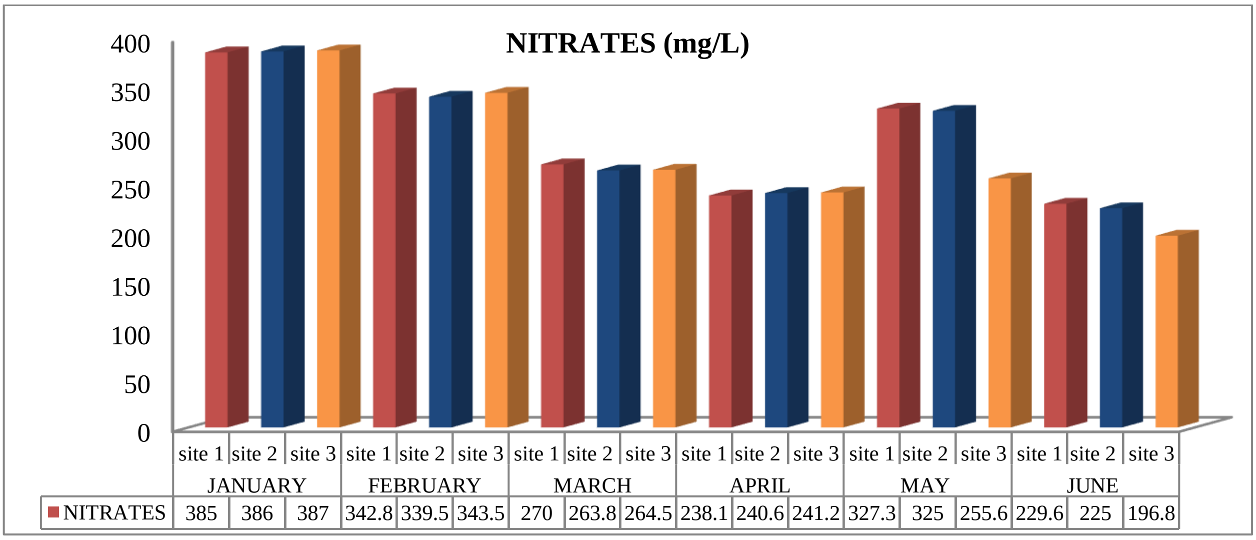

Fig. 16: Variations of nitrates from January to June of site 1,2 and 3.

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JCHR (2023) 13(6), 2274-2290 | ISSN:2251-6727

Water Quality Index (WQI): The quality of the water at the various Bandh Baretha sites is checked using a water quality index. This water quality index uses 13 physico-chemical parameters pH, Total solids, EC (Electrical conductivity), DO (Dissolved Oxygen), Total Hardness, Turbidity, Alkalinity, Chlorides, BOD (3 days), COD, Phosphates, Nitrates, Sulphates. Surface water and groundwater have different water quality indexes. Weighted Arithmetic Water Quality Index is one of the indices developed by various international organizations, Weighted Arithmetic Water Quality Index (WAWQI). By applying the formula it is concluded that water is not suitable for consumption. Because the all sites have water WQI above the 100. And water is categorizes in class E.

The WAWQI is calculated as follows:

$$WQI = \frac{\sum_i^n WiQi}{\sum Wi} \quad \ldots\ldots\ldots\ldots\ldots \text{(i)}$$

Where, Wi = weight of every parameter used in quality of water assessment, and is calculated as follows:

$$Wi = \frac{K}{Sstd} \quad \ldots\ldots\ldots\ldots\ldots \text{(ii)}$$

and,

$$K = \frac{1}{\sum \frac{1}{Sstd}} \quad \ldots\ldots\ldots\ldots\ldots \text{(iii)}$$

K = proportionality constant

S_{std} = standard value used for different parameters.

Qi = quality rating scale of the i^{th} parameter, for all the n parameters of water quallity. It is calculated as follows:

$$Qi = \left(\frac{Q - Qi}{Sstd - Qi}\right) \quad \ldots\ldots\ldots\ldots\ldots \text{(iv)}$$

Where,

Qa = actual measured value of the parameter, and

Qi = ideal value of the parameter in pure water.

Qi = 0 for all parameters, except for DO and pH. (Qi for DO = 14.6 mg/L, and pH = 7.0), Rating scale for WAWQI is as given in table 6.

Table 6: Rating scale for WAWQI (Weighted Arithmetic Water Quality Index).

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

Table 7: Site- wise comparison of water quality of Bandh Baretha

SITE	Index values	Condition
SITE 1	352.8415606	Water is unfit for consumption
SITE 2	350.0831987	
SITE 3	374.4169818	

PCA: The current study also evaluate the quality of different water quality parameters and shown the monthly variation. Common descriptive statistics of all the parameters from January 2022 to June 2022 shown in table.

Component Matrix[a]

Table 8: Extraction Method: Principal Component Analysis.

	1	2	3	4
DO	**-.825**	-.460	-.143	.271
Temp	**.907**	.013	.108	-.230

Journal of Chemical Health Risks
www.jchr.org
JCHR (2023) 13(6), 2274-2290 | ISSN:2251-6727

pH	.696	-.309	**.620**	-.050
Acid	**-.779**	.624	-.041	.043
Alk	-.080	**.730**	-.024	**.678**
TDS	.093	**.890**	-.309	-.252
Turb	.059	**.922**	-.331	-.166
Cond	.252	-.422	-.583	**.601**
Hard	**.930**	-.108	-.230	-.073
Chloride	**.893**	-.176	-.307	-.103
BOD	**.706**	.552	.382	.085
COD	.621	.466	.492	.348
Sulp	**-.721**	-.058	**.649**	.139
Nitr	**-.942**	-.042	.000	-.331
Phosp	**-.948**	.176	.112	-.113
Eigenvalues	7.53	3.65	1.93	1.33
% of Variance	50.18	24.33	12.88	8.86
Cumulative %	50.18	74.51	87.39	96.25

In table 8, PC1 (First principal component)t exhibited a strong loading on the parameters like dissolved oxygen (DO) (-0.825), temperature (0.907), acidity (-0.779), total hardness (0.930), chloride (0.893), BOD (0.706), sulphates (-0.721), nitrates (-0.942), phosphorus (-0.948) accounting for 50% of the total variance in the set of data. The strong loading of ions in PC1 indicate that anthropogenic activities and agricultural runoff. And COD and BOD are affected by the domestic and agricultural organic waste. Total hardness is due to the high calcium and magnesium concentration (Bharti, 2017)

PC2 exhibited a strong positive loading on ionic parameters like alkalinity (0.730), TDS (0.890), turbidity (0.922) and accounting 24% of total variance. Strong loading of ions of PC2 indicate that the pollution which comes from agricultural runoff, transport of sediments into the dam, and domestic discharge.

PC3 have moderately loading on the parameters such as pH (0.620), sulphates (0.649), and accounting for the variance level of 13%. Because of this, the phosphate loading is probably of the moderate variety. Agricultural runoff or weathering processes increase the oxidation-reduction and ion exchange conditions. These together increase the solubility of nutrients (Böhlke et al., 2007).

PC4 showed moderately loading of alkalinity (0.678) and conductivity (0.601) explaining the total variance of 9%. Moderately loading of alkalinity showed that the poor sanitation system of the water (Charan et al., 2013).

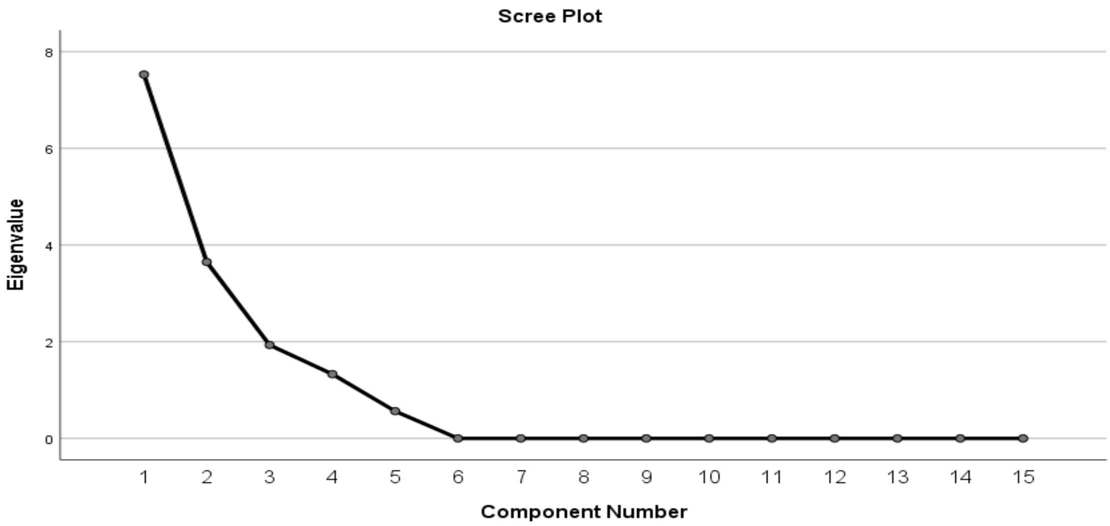

Fig. 17: Scree plot of eigenvalues of physico-chemical variables of water of Bandh Baretha.

Journal of Chemical Health Risks

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JCHR (2023) 13(6), 2274-2290 | ISSN:2251-6727

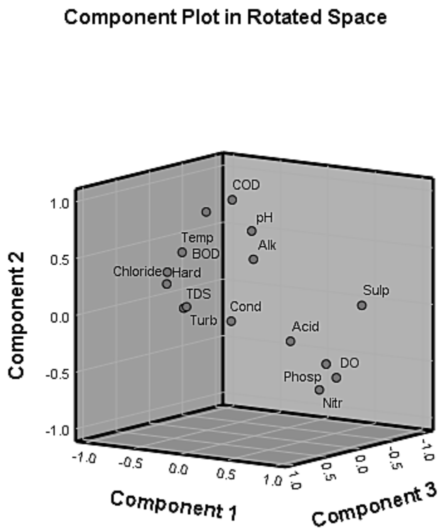

Fig. 18: Loading plot of principal component analysis of Bandh Baretha.

Hierarchical Cluster Analysis: Objects or records that are "similar" to one another are grouped together in hierarchical cluster analysis (also known as hierarchical clustering), a general method to cluster analysis.

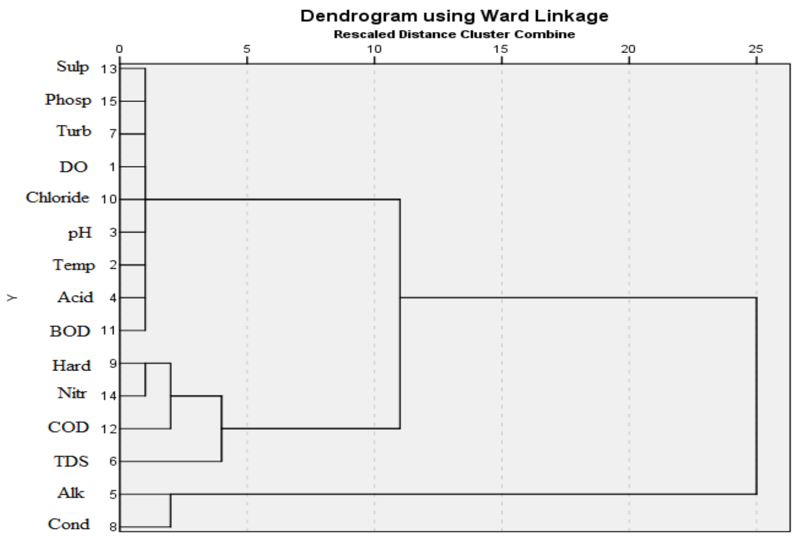

Fig. 19: Dendrogram of sampling sites of Bandh Baretha using Ward Method. Where, Sulp = Sulphates, Phosp = Phosphates, Turb = Turbidity, DO= Dissolved Oxygen, Temp = Tempreature, Acid= Acidity, BOD= Biological Oxygen Demand, Hard= Total Hardness, Nitr = Nitrates, COD = Chemical Oxygen Demand, TDS = Total dissolved Solids, Alk = Alkalinity, Cond = Conductivity.

3. CONCLUSION

The physico-chemical stud is very useful to get perfect idea for the quality of water by determining some parameters experimentally. By comparing the assessed parameters of the dam water with standards prescribed by WHO, we can interpret that the water of Baretha Dam is eutrophic due to the increased concentration of nutrients such as nitrates and phosphates. Unchecked use of fertilisers accelerates this process. This might be caused on by human activity close to the dam area and agricultural runoff or fertiliser leaks from the fields. It disturbs both the biological balance and the quality of the water. By principal component analysis, four PCs are selected that indicated that the anthropogenic activities and nutrient released through agricultural runoff are the main factors that affect the quality of water.

Journal of Chemical Health Risks

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JCHR (2023) 13(6), 2274-2290 | ISSN:2251-6727

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