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Analysis of Physiochemical Parameters to Evaluate the Water Quality of the Tista-Brahmaputra River, Rangpur Division, Bangladesh

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Abstract: *The present research work shows role of the anthropogenic activities on the hydrochemistry of the riverwater of the Tista river in its lower where it flows through plain land and finally fall into the Brahmaputra river in Rangpur division, Bnagladesh. Field works were performed in in the month of July, 2014. Sampling were done in four points along a longtudinal section of the Tista river and Brahmaputra river (near the mouth of the Tista river). Major ion compositions (cations* Ca^{+2}, Mg^{+2}, Na^{+}, K^{+} *and anions* HCO_3^{1-}, Cl^{1-} *and* SO_4^{2-}*) were used to study the hydrochemical characteristics of water in order to evaluate the water quality of the Tista River. The pH value of the river water decreases in the downstream direction where the inflow water from the irrigation areas influence and again the pH increases in the riverwater of the Brahmaputra river. The average TDS value of the study area is 99.6 mg/l, while the highest value is recorded in Kaunia upazila, Rangpur. Major ions distribution along the Tista River showed by Piper diagram. The water type changed from* $Mg\text{-}Na\text{-}HCO_3$ *at first station (Nilphamari), into Mg-Na-Cl to the next station (Gangachara, Rangpur), afterwards that change into Na-Mg-Cl (Kaunia, Rangpur) and finally it transformed into* $Na\text{-}Mg\text{-}Ca\text{-}HCO_3$ *(Chilmari, Kurigram). The average concentration values of the trace metals of the Tista and Brahmaputra river water commonly follow decreasing order as Fe>Mn>As. The concentration of zinc is below the detection limit. All of the water samples contain arsenic below the WHO prescribed limit of 10 µg/L. The change of hydrochemical facies of the Tista River water is related to the dewatering (removal of water for irrigation purposes) of the river, the formations through which the river passes and anthropogenic activities. This also suggests that chemical weathering of rocks and groundwater discharge influence the hydrochemistry of the Tista river.*
Keywords: *Chemical weathering, Hydrochemistry, As, Riverwater and Water quality.*

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I. Introduction

The Tista River, draining through the northern part of Bangladesh. The Tista River is a tributary of the Brahmaputra river. It provides water for 10 million peoples of Rangpur division. The water of this river is an alternative source of water for their irrigation, domestic and industrial purposes. The Tista is a fast flowing river. The Tista river provided huge amount of different kind of fishes. At present time the damming of the river and construction of reservoirs for irrigation purpose in the upstream direction reduced the water flow in the Tista river basin especially during the dry season (Wiejaczka et al., 2018).. It disturbed the aquatic ecosystem of the area. The amount of fish supply has reduced in

Figure 1: Map of the Study area

remarkable quantities. It might have adverse impact on the environment of this region. Simultaneous, the dewatering of the Tista river lead to develop new sand bars (chars) in the basin, where people grow different types of crops. Physicochemical characters of water are one of the principal factors affecting the proper functioning of the river ecosystem (Allan and Castillo, 2007). The mineralogical study of the sediments of the investigated area shows the dominance of the quartz, feldspar, illite, chlorite and kaonilite (Saha et al., 2018). The chemical composition of surface water is resulted from different sources of solutes, including gasses and aerosols from the atmosphere, weathering and erosion of rocks/soil, ion exchange, and anthropogenic effects resulting from human activities (Hem, 1985: Gao et al., 2013). The population density of the downstream direction of the Tista river basin is higher than the upper part of the Sikkim Himalaya and the anthropogenic impacts on the environment (tea, rice, maize and tobacco cultivation) is more prominent in the southern margin, i.e., in the downstream direction (Prokop and Ploskonka, 2014).

Safe and clean water is a fundamental right of human beings. Water quality monitoring and control is a top-priority agenda of the present day world. Contaminants in the water can affect water quality and consequently the human health (Rahamanian et al., 2015). The inorganic chemical components constitute a greater portion of TDS (total dissolved solids) of the both surface water and groundwater. A few studies have assessed on heavy metals in the coal mine area of Rangpur division of Bangladesh. Howlader et al., (2014) conducted a study to assess the water quality of Barapukuria coal mine industrial area, Dinajpur, Bangladesh. Afroza et al., (2009) dealt a study with the hydrochemistry of groundwater of the Lower Tista Floodplain, Bangladesh. Unfortunately, there are very few information about the status of the water quality of river water of the Tista-Brahmaputra river system,. The present research work was carried out to decipher the water quality of the river water that covers both major ions and trace element compositions of the Tista-Brahmaputra river system, Rangpur division, Bangladesh. Arsenic poisoning or arsenicosis is condition caused by the ingestion, absorption or inhalation of dangerous levels of arsenic. Arsenic is a natural semi-metallic element that found all over the world in groundwater (Reza et al., 2010). In some areas of the world, natural levels of arsenic in the water are extremely high concentrations, which is injurious for health and hard to detect, arsenic typically has no flavor or order.

II. Methodology

The river water samples were collected from the Tista and the Brahmaputra rivers in order to study physico-chemical characters of the study area. The p^H, electrical conductance (EC) and temperature of the river water were measured and recorded in situ. The pH meter was standardized by double distilled water and buffer solution. Then 50 ml of river water was taken in a clean 100 ml plastic beaker and immersed the pH meter and waited for five minutes. Then the pH reading was taken from the pH meter and recorded. Sampling was carried out using pre-cleaned polythene bottles. Collected samples were preserved at 4°C and taken into the laboratory for chemical analyses. Ca, Mg, Cu, Fe Mn and As were determined by Atomic Absorption Spectrometer, model Shimadzu AA 7000. Chloride (Cl^-) was determined by standard $AgNO_3$ titration method. Bicarbonate (HCO_3^{-1}) were determined with titration with HCl. SO_4 was determined by UV-visible spectrophotometer, model Shimadzu UV-1800.

III. Results and Discussion

Physical Parameters

pH

The pH value of the water samples vary from 7.7 to 8.5. The average value of pH of the riverwater is 8.15 and the standard deviation is 0.33. The permissible pH value of water for irrigation is 6.5-8.5 (Ayers and Westcot, 1985), drinking purposes is 6.5-8.5 (ADB, 1994) and domestic purposes is 6.5-8.5 (De, 2005). The higher pH values are represent the higher concentrations of chloride and bicarbonate in the riverwater. It is also indicative of the alkaline nature of the Tista river water.

TABLE 1: Physico-chemical parameters of the river water, Tista-Brahmaputra river.

Location		Dimla	Gangachara	Kaunia	Chilmari	Average	STDEV
Temperature	˚C	30	26	29	28	28.25	1.70
pH		8.2	8.2	7.7	8.5	8.15	0.33
EC	µS/Cm	124	137	207	125	148.25	39.60
TDS	mg/L	83	92.3	139.1	84	99.6	26.66
Na	mg/L	11.5	23	69	23	31.625	25.49
K	mg/L	2.34	2.34	2.34	1.95	2.242	0.19
Ca	mg/L	4	4	4	8	5	2
Mg	mg/L	21.87	14.58	7.29	4.86	12.15	7.68
Cl	ppm	6.9	27.6	31.1	20.7	21.575	10.69
SO_4	ppm	2.9	2.52	4.08	4.02	3.38	0.79
HCO_3	ppm	33.5	18.3	21.3	57.9	32.75	18.00
As	µg/L	-	1.7665	1.1548	1.2527	1.3913	0.3285
Mn	ppm	-	0.1136	0.0407	0	0.0514	0.0575
Fe	ppm	-	5.7362	0.193	0.1173	2.0155	3.22

Temperature

The temperature of water samples range from 26ºC to 30ºC. The permissible temperature limit of water is 30.5ºC (DoE, 2001). The fluctuation of river water temperature is usually dependent on the season, geographic location, sampling time and temperature of the effluents that enter into the river (Ahipathy and Puttaiah, 2006). In case of the Tista river the temperature river water is controlled by the melting of ice as it is a glacier fed river (Wiejaczka et al., 2018).

Electrical conductivity (EC)

The magnitude of electrical conductivity (EC) of four sampling stations ranged from 124 µS/cm to 207 µS/cm. The average EC value is 148.25 µS/cm and the standard deviation is 39.60 µS/cm. The values of EC of all the samples are lower than the standard of 700 µS/cm (EQS 1997). The value of EC depends on the concentration and degree of dissociation of the ions a well as the temperature of water samples (Uddin et al., 2014). The soluble ions in the river water derived mainly from the dissolution of rock materials.

Total dissolved solids (TDS)

The total dissolved solids (TDS) is the sum of all dissolved components (both inorganic and organic) in water. The TDS of river waters of the investigated area varies from 83 mg/l to 139.1 mg/l. The mean value of TDS of the study area is 99.6 mg/l and the standard deviation value is 26.66 mg/l. The TDS values of all the river water samples are below the maximum permissible limit of 1000mg/l. From this observation we can conclude that the Tista river water is acceptable for drinking purposes.

Hydrochemistry of River Water

Sodium (Na^+): The concentration of sodium varies from 11.5 mg/l to 69 mg/l. The average value of sodium is 31.625 mg/l and the standard deviation of 25.50 mg/l. Sodium in the river water mainly derived from the dissolution of halite and silicate minerals like plagioclase feldspar, feldspathoid, mica and clay minerals (Khan et al., 2014). The agricultural by products and industrial effluents might be the other sources of sodium content of the groundwater (Hem, 1989).

Potassium (K^+): The mean value of potassium is 2.24 mg/l and the standard deviation of 0.195 mg/l. The concentration of potassium varies from 1.95 mg/l to 2.34 mg/l. Potassium in Tista river waters comes predominantly from weathering of silicate minerals both in metamorphic and sedimentary rocks (Wiejaczka et al., 2018). The chemical weathering of sylvite and silicates especially clay minerals are the principal source of potassium in the water samples of the investigated area. Potassium can be added to river water through breakdown of potash fertilizer and animal or waste products.

Calcium (Ca^{2+}): The maximum concentration of calcium (Ca^{2+}) is 8.00 mg/l, minimum calcium content is 4.00mg/l and the median value for concentration of calcium is 4.00 mg/l. The basic sources of calcium are carbonate rocks, i.e., limestones and dolomites, which are dissolved by acidic rain water. The chemical breakdown of calcic-plagioclase feldspars and pyroxenes may be responsible for calcium in the groundwater (Ganyaglo et al., 2010). Calcium can also originate as lime in agricultural fertilizers.

Magnesium (Mg^{2+}): Magnesium in river water derived from the decomposition of dolomite, ferromagnesian minerals like olivine, pyroxene, amphiboles, and dark coloured micas. In the metamorphic rocks, magnesium occurs in the structure of chlorite, montmorrilonite and serpentine (Nag, 2009). The maximum amount of magnesium is found in the river water of Dimla, Niphamari, 21.87 mg/l and the minimum concentration is reported in the river water of Chilmari, Kurigram whose value is 4.86 mg/l. The median value of magnesium is 10.935 mg/l.

Bicarbonate (HCO_3^-): The concentrations of bicarbonate in the river water samples range from 18.3 ppm to 57.9 ppm. The average bicarbonate content of water samples of the study area is 32.75 ppm with standard deviation value of 18.00 ppm. On the basis of average concentration of anions bicarbonate ion appeared as the highest anion in the river water samples of the study area. The possible source of bicarbonate is the dissolution of carbonate rocks, such as limestone and dolomite (Khashogji and El Maghraby, 2013).

Chloride (Cl^-): The mean concentration of chloride in the river water of present study is 21.57 ppm. The chloride contents of river water of the Tista and Brahmaputra range from 6.90 ppm to 31.1 ppm. Positive correlation of chloride with sodium and potassium indicates that the principal source of chloride is from dissolution of halite and sylvite.

Sulphate (SO_4^{2-}): The oxidation of mercasite and pyrite can contribute sulphate to the natural water (Matthess, 1982; Rahman et al., 2013). The sulphate (SO_4^{2-}) of the river water samples of the study area ranged from 2.52 ppm to 4.08ppm. The average value of sulphate (SO_4^{2-}) content of the groundwater of the study area is 3.38 ppm. The chemical weathering of anhydrite may release sulphate ions to the river waters. The low concentrations of sulphate suggest that bacterial sulphate reduction has occurred (Kirk et al., 2004) and less industrial pollution in the investigated area.

The average concentrations of major cations generally follow decreasing order as $Na^{+}>Mg^{2+}>Ca^{2+}>K^{+}$. Sodium and magnesium account for 85.80% of the total cations on an average. Calcium and potassium are less predominant cations and together comprise only 14.19% of the total cations.

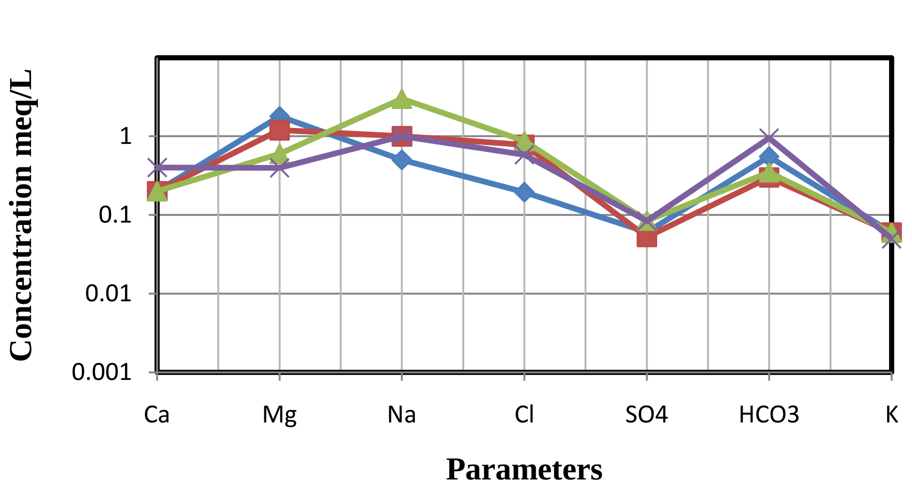
The study of cations change in the longitudinal section of the Tista River revealed that the dewatering of the Tista River for irrigation purposes at Tista barrage might have influenced the cation concentrations of the river water to the increase of sodium and calcium and the concentrations of magnesium and potassium have slightly decreased.

The concentration of sodium cation is lowest in the water sample of the Tista river in the upstream direction where it entered in Bangladesh and showing the increasing trend after the Tista Barrage where the river is flowing to the lower level. The higher concentration of sodium might be resulted from the reduced discharge of river water, agricultural effluents, erosion of agricultural soils and/or dissolution of halite or silicate minerals (Wiejaczka et al., 2018).

Hydrogeochemical Facies

The Schoeller diagram deciphers major ion analyses in meq/L to demonstrate different hydrochemical water types on the same diagram. This type of graphical representation has the advantage that unlike trilinear diagrams, actual sample concentrations is displayed and compared (Talabi et al., 2015). In this study, the Schoeller diagram reveals the dominance of Mg and Na cations as well as Cl^{-1} and HCO_3^{-1} anions in the river water samples of the study area (Fig. 2).

Figure 2: Schoeller plot (1977) for water parameters of the Tista river water, Rainy season



The Piper diagram (Piper, 1944) can be used to explain the chemical composition of the water samples from the Tista and Brahmaputra rivers (Figure 2).

The diagram shows that Mg^{2+} and Na^{+} are dominant cation facies whereas the bicarbonate and chloride are the dominant anion facies. This suggests that chemical weathering of rocks and groundwater discharge influence the hydrochemistry of the Tista river (Wiejaczka et al., 2018). The rate of chemical weathering is related to the particle size of the sediments (Israeli and Emmanuel, 2018) and the sediments of the study area reveals that the grain size decreases to the downstream direction (Saha et al., 2017).

Water facies	No of Samples
Mg-Na-HCO_3	1
Mg-Na-Cl	1
Na-Mg-Cl	1
Na-Mg-Ca-HCO_3-Cl	1

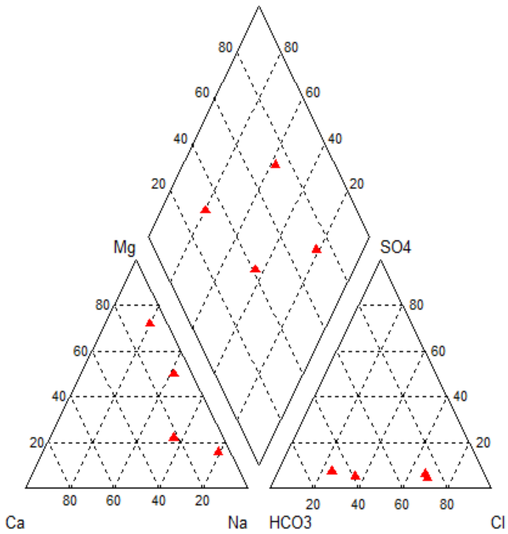


Figure 3: The Piper plot of the Tista riverwater

Evaluation of river water for irrigation purposes

Irrigation water criteria depend on the chemical composition, the nature of the plants to be irrigated, soil type, climate amount and method of irrigation and drainage pattern (Uddin et al., 2014). The suitability of water for irrigation is determined by the amount and

Table **4: Showing the values of irrigation parameters of river water of the study area.**

Location	TH	RSC	PI	SAR	SSP
	mg/L	meq/L	%		%
Dimla	99.63	-1.44	49.77	0.50	21.93
Gangachara	69.75	-1.10	64.61	1.20	43.17
Kaunia	39.88	-0.45	94.55	4.75	79.32
Chilmari	39.92	0.15	109.75	1.58	56.80
Average	62.30	-0.71	79.67	2.01	50.31
Median	54.84	-0.77	79.58	1.39	49.99
STDEV	28.59	0.71	27.37	1.88	24.08
	Soft-75% Moderately soft-25%	Safe-100%	Suitable-100%		

Total Hardness (TH): The Total Hardness (TH) is an important parameter of water for the utility of water in various purposes, for example domestic, industrial or agricultural purposes. The Total Hardness of water results from the excess concentration of Ca, Mg and Fe salts in water. The average value of Total Hardness is 62.30 mg/L. The Total Hardness value of the water samples of the investigated area range from 40-100 mg/L which is less than the permissible limit of WHO.

Residual Sodium Carbonate (RSC): The concentration of bicarbonate and carbonate controls the suitability of water for irrigation (Reddy 2013). One of the empirical approaches was based on the assumption that calcium and magnesium carbonate precipitation, considering this hypothesis Eaton, 1950 proposed by the concept of residual sodium carbonate (RSC) for the measurement of high carbonate waters. Residual sodium carbonate (RSC) determines the hazardous effects of carbonate and bicarbonate on the quality of water for agricultural purpose.

The average value of residual sodium carbonate is -0.71 meq/L. According to US Salinity Laboratory, 1954 the magnitude of all the water samples were less than 1.25 meq/L, which is an indicative of safe water quality for irrigation.

Permeability Index (PI): The permeability of soil is influenced by the continuous use of irrigation water. The amounts of sodium, calcium, magnesium and bicarbonate ions the soil is increased by the utility of irrigation water (Chandu et al., 1995). The permeability index (PI) is a measure the suitability of water for irrigation purpose. The permeability index (PI) is categorized as class I (>75%), class II (25-75%) and class III (<25%). The waters under class I and class II are designated as good for irrigation that have PI 25% and above, while class III waters have PI values less than 25% and unsuitable for irrigation (Doneen 1964; WHO 1989). The permeability index of all the river water of the investigated area is 50% and above, whereas they fall in class I and class II, which are suitable for irrigation purposes.

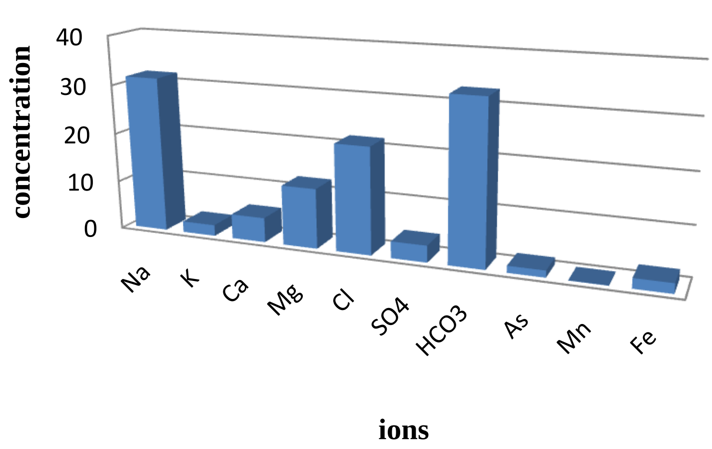
Sodium Adsorption Ratio (SAR): The U.S. Salinity Laboratory showed the sodium adsorption ratio (SAR) reasonably estimates the degree to which irrigation water tends to enter into cation-exchange reaction in soil. High magnitudes of SAR imply a hazard of sodium replacing absorbed calcium and magnesium, and leads to a condition that ultimately damage the soil structure (Khan and Abbasi 2013). The mean value of SAR is 2.02 which denote that the studied water samples are excellent in quality for irrigation.

Soluble Sodium Percent (SSP): The soluble sodium percent is a measure of the tendency for a water to enter into cation—exchange reactions (Khan and Abbassi 2013). It is the percent of total cations made up by Na ions. The divalent cations normally occupy the exchangeable positions on clay minerals, the extensive displacement of calcium and magnesium ions by Na ions unless the SSP is considerably higher than 50% of the total concentration of the solutes is large (Hem 1989). Soluble Sodium Percent (SSP) is an important factor for the classification of irrigation water. A certain ratio of air water in the pore spaces of the soil is essential for the proper nutrition and growth of the plants. The water containing sodium reacts with the soil, accumulates in the void spaces the soil and reduces the permeability of the soil. The sodium concentration is expressed terms of soluble sodium percent. The maximum permissible limit of SSP is 60% for irrigation water. 75% of the studied river water samples have the SSP value less than 60%.

Trace metal composition of the river water

The average concentration values of the trace metals of the Tista and Brahmaputra river water commonly follow decreasing order as Fe>Mn>As. The zinc content of the river water samples were carried out and it was found that the concentration of zinc of all the water samples was zero. Trace metal composition of the river water samples were performed. All of the water samples contain arsenic below the WHO prescribed limit of 10 µg/L (WHO 1996). The river water samples contain arsenic in the range of 1.1548-1.7665µg/L, with the mean value of 1.3913µg/L. The arsenic concentration of water is low in the study area, but regular monitoring of the trace element especially arsenic is required to ensure the quality of the water. The concentrations of trace metals in water are not constant. The concentration of arsenic may increase over time if there is a source of natural or industrial pollution close to the water (personal communication Osama Rahil, 25 January 2019). The minimum concentration of manganese is zero, the maximum is 0.1136 ppm while the mean value of Mn is 0.0514 ppm. The maximum allowable limit of manganese for potable water is 0.10 ppm (WHO 2011) and one water sample exceeds the maximum allowable limit of manganese. Manganese is an essential element for many living organisms, including humans (WHO 2011). The manganese in river water may derive from the dissolution of Mn-bearing rocks or human generated sources (Water Research Australia 2013). The iron content of the river water sample varies from 0.1173-5.7362 ppm. The average concentration of Fe is 2.0155 ppm. Iron is an essential element in human nutrition (Kumar and Puri 2012). The current aquatic life standard is less than 1.0 mg/L based on toxic effects (Kumar and Puri 2012). The trace metal concentrations in the water system resulting from the oxidation process of sulfide minerals which may be concern to human health and the environment (Bhuiyan et al., 2010: Islam et al., 2017).

Figure 4: Tha average concentration of metal ions and anions of river water of the study area (units are given in Table 1).



IV. Conclusion

The pH value of the river water samples vary from 7.7 to 8.5, which indicates that the water of the Tista river is alkaline in nature. The temperature of water samples range from 26ºC to 30ºC. The permissible temperature limit of water is 30.5ºC (DoE, 2001). The TDS of river waters of the investigated area varies from 83 mg/l to 139.1 mg/l, and it indicates that the TDS value of the studied river water is acceptable for drinking purposes. The Piper diagram shows that Mg^{2+} and Na^{+} are dominant cation facies whereas the bicarbonate and chloride are the dominant anion facies. The calculated total hardness value of the water samples of the investigated area range from 40-100 mg/L which is less than the permissible limit of WHO and can be used for drinking and irrigation purposes. The RSC, SAR, PI and SSP concentrations reflect that almost all the river water samples are excellent to good for irrigation purposes. The trace metals especially the arsenic concentrations of all of the river water samples are below the permissible limit of WHO. Further research works can be carried out in order to show seasonal variations of the water quality or microbial content of water.

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