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Water Chemistry of Kolong River, Assam, India and Management Strategies

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Abstract: ***Kolong river which is located in Nagaon district of Assam, India is among the 275 most polluted rivers in India, according to a report of the Central Pollution Control Board, Government of India. The rise in pollution with respect to rivers over the last few decades due to their incredible importance in several human uses as well as a medium for provision of ecosystem services all over the world. The present investigation was carried out for a period of four seasons, namely, Pre-monsoon, Monsoon, Retreating Monsoon and Winter for the year 2017. Samples of water from two sites of the River Kolong, namely, Site I (Jakhalabandha) and Site II (Nagaon Town), were collected and analysed. The physico-chemical parameters such as water temperature, pH, Conductivity, Alkalinity, Transparency, Hardness, Chloride, Magnesium, Phosphate, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) were evaluated. Observations imply that the water quality in Site II was poor and unfit for drinking, compared to Site I. The present study also includes a discussion on the economic implications of Kolong's water quality and the strategies for its management. The study finally emphasizes that state intervention and people's participation is essential for maintaining and preserving the ecological health of the Kolong river in its pristine state.***

Keywords: ***Kolong river, Physico-chemical parameters, Water chemistry, Water economics.***

I. INTRODUCTION

One of the greatest problems faced by developing nations today pertain to the inefficient management of natural river systems with regard to anthropogenic interventions. Hazardous disposal of such wastes has created even more challenges in the context of preserving the environment. Water bodies are the most affected with freshwater systems suffering the most. It should be noted that wastes entering water bodies occur both in solid and liquid forms. The pollution of water has increased due to human population, industrialization, the use of fertilizers in agriculture and man-made activity. The resultant effects of this on human health and nature are usually boundless in magnitude. These include endangering of aquatic resources and other commercially important marine flora and fauna. Outbreaks of water-borne diseases like cholera, gastro-enteritis, etc, are possible health effects of polluted water [1,2].

The water discharged as agricultural run-off and industrial sewage contains a gamut of different nutrients, solids and pathogenic microorganisms. As such, parameters such as temperature, nutrients, hardness, alkalinity, dissolved oxygen, etc. are some of the important factors that determines the growth of living organisms in the water body. Hence, water quality assessment involves the analysis of physico-chemical, biological and microbiological parameters that reflect the biotic and abiotic status of the ecosystem.

A significant consequence of deterioration of water quality is related to increasing household as well as state expenditures. Pollution has a tendency of touching all aspects of life and as such, assessing the economics of water quality in case of freshwater resources is key to environmental law-making approaches. Extensive discussion and research prove critical in this context, so as to preserve not only the ecological health of a river, but also paving a way for economic efficiency in the management of water quality and treatment costs.

The present paper envisages to assess the water chemistry of Kolong river which is among the 275 most polluted river stretches in India as per a study by the Central Pollution Control Board (CPCB). The introductory section is followed by a discussion on the materials and method employed, followed by enumeration of the assessment results augmented with a general discussion on the economics of water quality.

II. METHODOLOGY

The Kolong river, located at 26^0 21′6″ N and 92^0 40′52″ E, is a tributary of the Brahmaputra river. The river is approximately 250 km in length, and flows through the districts of Nagaon, Morigaon and Kamrup.

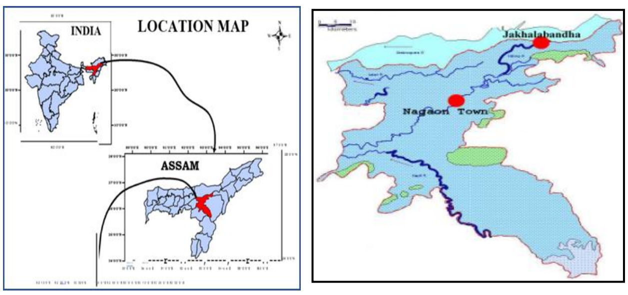

Fig. 1: Location Map of River Kolong in Nagaon, Assam, India and the sampled sites.

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The investigation in our present study will enable us to assess the status of pollution of the Kolong river. Notably, a number of works have been done in India and also in the state of Assam on different riverine systems on varied aspects of eco-biology, pollution etc. As regards the hydrobiological conditions are concerned, works have been done by [3,4,5,6,7]. Despite the large number of works, the present area of study has been neglected so far.

The present study has been confined to the surrounding areas of Site I (Jakhalabandha) and Site II (Nagaon town). The coordinates for Site I are 92° 59'' East and 26° 35'' North and the coordinates for Site II are 92° 40'' East and 26° 21'' North. These have been selected due to their proximity to residential areas where there is frequent washing of clothes along with discharge of wastes throughout the year.

Based on the distribution of rainfall, the year has been climatologically classified into four seasons, namely, Pre-monsoon (March, April and May), Monsoon (June, July, August and September), Retreating Monsoon (October and November) and Winter (December, January and February) [8]. Data has been collected for each station for the four seasons, for the year 2017. Means and standard deviations were also computed. The samples collected from the sampling sites were mixed thoroughly and were stored in ice boxes to retard biochemical activities. The samples were analyzed as per standard methods mentioned in [9]. The standard reagents used for analysis were prepared using double distilled water. Thirteen physico-chemical parameters, namely Water Temperature (WT), pH, Transparency (Trans.), Total Alkalinity (TA), Hardness (TH), Conductivity (Cond.), Chloride (Cl), Magnesium (Mg), Phosphate (PO_4), Sulphate (SO_4), Dissolved Oxygen (DO) Biochemical Oxygen Demand (BOD) and (COD) were monitored.

As regards the economics of water quality, the methodology of this study warrants a discussion on the background of why gauging the economic implications of water quality is essential and how such implications can be dealt with effectively. The idea of examining water quality and its associated economics pertains to the concept of economic efficiency. To assess this several methods have been developed over the years. The most common technique involves computation of water treatment costs that arises as an outcome of the deterioration of water quality and associating them with the concept of economic efficiency. It is knowns that as the quality of a natural system worsens, more expenditure has to be incurred so as to preserve it. Same is the case with water. Rivers are traditionally exposed to a large number of contaminating effluents from agricultural discharges, industrial run-offs and several other activities. Although industrial points of pollution can be controlled, it is hard to identify agricultural sources and hence, preventing run-off from them is near impossible. It is imperative to note here that economic efficiency can be optimized if and when its contamination is abetted through fiscal or monetary policies, restrictions are placed, bribes given or mutual settlement among parties occurs. Moreover, optimizing pollution outcomes prior to state or community interventions would require substantial research and development which undoubtedly necessitates good amount of public expenditure. Besides that, treatment plants and municipality water management infrastructure are essential for maintaining and alleviating deterioration of water quality levels. The methodology for discussing the economics of the water quality of Kolong river pertains to citing implications based on theoretical basis and delving upon possible interventions based on the assessment of its physico-chemical parameters.

III. RESULTS

The physico-chemical parameters of Kolong's water quality has been displayed in table (1). This is followed by a discussion on the estimates of the given parameters with regard to the two sample sites.

IV. DISCUSSION

A. Physico-chemical parameters

An important factor in biological and chemical system of natural water is pH which helps in assessing the toxicity of water systems. In this present investigation, moderate variations were observed in both the selected sites. Variation has been observed more in pre-monsoon than the post-monsoon season in both the sites. pH values are observed to be higher in summer than other seasons.

The temperature of water enjoys a central role in an organism's metabolic activities. This underlines its importance in water chemistry. Changing climatic conditions determine the variation in water temperature. The mean temperature ranged from 19.75^0C to 29.03^0C in Site I whereas it ranged from 18.85^0C to 28.90^0C in Site II, for all four seasons.

The mean for water transparency ranged from 37.175 to 66.175 mg/l in Site I and 39.43 to 46.1 mg/l in Site II, for all the seasons.

As regards the alkalinity, the mean varied from 70.73 to 86.85 mg/l in site I and 72.35 to 109.33 in Site II, for all the chosen seasons. Maximum value was recorded in monsoon season compared to the other seasons.

Hardness defines the total polyvalent cat ions present in the water, the most divalent cat ions are calcium and magnesium. The hardness of water in Site I was observed with a mean of 126.20 mg/l (Pre-monsoon period) and 88.20 mg/l (Retreating monsoon period). At site II, the mean of hardness was 121.93 mg/l (pre-monsoon period) and 86.95 mg/l (retreating monsoon period). The hardness of water is not a pollution parameter but indicates water quality.

Conductivity is a measurement of the ability of an aqueous solution to carry an electrical current and depends on the concentration of ions and load of nutrients. In case of Ganga river, lowest and highest values of conductivity varied between 0.096 to 0.516 µmhos/cm in a stretch from Rishikesh to Kanpur [10]. Low conductivity due to absence of pollution in a canal of Krishna river near delta region was observed by [11]. [12] observed high level of

Table-1: Mean value and Standard Deviation of Physico-Chemical parameters in Station I (2017)

Water Parameters	Pre-Monsoon		Monsoon		Retreating Monsoon		Winter	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Water Temperature (^oC)	27.78	±1.81	29.03	±1.21	23.93	±1.32	19.75	±1.19
pH	7.13	±0.25	7.05	±0.31	7.38	±0.31	7.90	±0.37
Transparency (cm)	50.55	±4.29	37.175	±4.77	66.175	±6.25	61.5	±3.44
Total Alkalinity (mg/l)	70.73	±8.00	86.85	±8.41	73.35	±4.85	77.20	±6.91
Total Hardness (mg/l)	126.20	±8.63	75.33	±7.78	88.20	±8.33	99.48	±8.40
Conductivity (µmhos/cm)	168.5	±10.15	199.75	±13.62	149.5	±14.20	120.25	±13.65
Chloride (mg/l)	56.05	±7.49	45.63	±5.67	36.80	±7.95	33.10	±4.80
Magnesium (mg/l)	43.55	±6.17	51.38	±6.51	36.00	±6.52	29.55	±6.33
Phosphate (mg/l)	0.95	±0.34	1.53	±0.69	1.45	±0.55	0.80	±0.39
Sulphate (mg/l)	7.18	±1.24	10.20	±1.98	7.03	±1.41	4.55	±1.56
Dissolved Oxygen (mg/l)	5.95	±0.87	6.55	±0.68	6.08	±0.76	5.45	±0.62
B.O.D (mg/l)	4.03	±0.72	3.45	±0.58	4.43	±0.69	5.10	±0.85
C.O.D. (mg/l)	11.45	±1.69	13.53	±2.00	13.88	±3.07	16.73	±2.79

Table-2: Mean value and Standard Deviation of Physico-Chemical parameters in Station II (2017)

Water Parameters	Pre-Monsoon		Monsoon		Retreating Monsoon		Winter	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Water Temperature (^oC)	25.15	±1.48	28.90	±1.28	21.05	±1.65	18.85	±1.24
pH	6.88	±0.36	6.83	±0.39	7.03	±0.30	6.98	±0.26
Transparency (cm)	46.1	±6.48	39.43	±6.12	55.7	±5.34	52.1	±6.49
Total Alkalinity (mg/l)	74.83	±9.88	72.35	±7.94	89.68	±8.79	109.33	±11.14
Total Hardness (mg/l)	121.93	±12.12	85.98	±9.32	86.95	±8.38	119.05	±11.54
Conductivity (µmhos/cm)	118.5	±12.82	139.75	±17.15	109.00	±11.92	101	±13.49
Chloride (mg/l)	78.60	±11.08	71.25	±11.37	63.75	±8.44	49.88	±11.55
Magnesium (mg/l)	38.63	±4.90	44.93	±6.00	30.08	±5.38	30.63	±3.66
Phosphate (mg/l)	1.25	±0.60	2.23	±0.44	2.00	±0.50	1.23	±0.33
Sulphate (mg/l)	7.90	±1.50	10.28	±1.52	7.00	±1.04	5.80	±1.12
Dissolved Oxygen (mg/l)	5.55	±0.66	6.28	±0.75	5.50	±0.75	5.33	±0.74
B.O.D (mg/l)	5.08	±0.68	4.98	±0.38	5.08	±0.28	5.95	±0.85
C.O.D. (mg/l)	11.80	±2.31	14.63	±1.71	16.05	±2.67	19.40	±1.53

conductivity at highly disturbed points of river by human activities through infrastructure works in the Northern Salado River of Argentina. In the present study, this parameter had means ranging from 120.25 to 199.75 µmhos/cm in Site I, and 101 to 139.75 µmhos/cm in Site II. Magnesium concentration existed with a mean of 29.55 in winter season to 51.38 in monsoon season for Site I while for site II, the values were 30.08 to 44.93 respectively. The mean of phosphate concentration was highest in monsoon in both the sites while lowest during winter. In case of sulphate concentration, highest mean was observed during monsoon in both the sites and the lowest values were recorded during winter.

Chloride is present in all types of water. Chloride concentration shows the presence of pollution due to sewage. Higher amount of chloride reacts with sodium making the water salty and also increases TDS values of water. In natural waters, its concentration remains usually low. In the present study the mean for chloride content ranged from 33.10 to 56.05 mg/l in Site I and 49.88 to 78.60 mg/l in site II, for all the seasons. Chloride content may be amplified as a result of the release of domestic sewage or effluents.

This may result in a moderate increase in levels of chlorides corroborating the study of [13].

One of the most important parameters in water quality assessment is dissolved oxygen. Water quality of Bagjola canal was observed by [14] wherein it was noticed that dissolved oxygen ranged from below detectable limit to 1.75 mg/l which showed hypoxic condition of the canal. [15] observed DO values of 6–7 mg/l at the Kistobazar nala, Purulia which are relatively low but not lethal for the biotic communities. Mean value of dissolved oxygen ranging from 1.8 mg/l to 5.9 mg/l of river Ganga at Varansi [16]. The highest DO was found at minimum pouring of discharge of sewage effluent from town and lower values obtained where the higher sewage discharge and human activity were taking place. At Suvaw Nala (Balrampur) dissolved oxygen ranged from 2.02 mg/l to 7.8 mg/l, the lowest value was found mainly because of the industrial organic effluents as well as sewage load [17]. [18] reported 6% fall in dissolved oxygen due to mass bathing on Ram Navami festive day in river Ganga at Har Ki Pauri, Haridwar. In the present study, the mean for DO ranged from 5.95 (Pre monsoon) to 5.45 (winter). The values in pre monsoon may be due to decrease solubility of oxygen in summer months.

BOD determination is considered the best available single test for assessing organic pollution. [19] observed BOD of water samples value that were indication for entry of organic waste in the river Ganga at Varansi and showed that high values are indication of organic pollution. [20] recorded high value of biochemical oxygen demand in Purna River and concluded that the river is highly polluted due to organic enrichment. [21] observed the creek water of Thane district (Maharashtra) showed high values of BOD and stated that the origin of these pollutants is mainly from the entry of effluents from surrounding industries. [22] noticed BOD exceeded the permissible limit during the mass bathing in river Ganga at Haridwar. Due to heavy reflux of sewage in TD-7 drainage canal the BOD values were observed 97-305 mg/l at Turkey [23]. [24] observed low level of BOD indicating less pollution status of river Cauvery. The value of BOD in the present study was higher on site II as compared to Site I. The higher values were recorded due to organic waste discharge from various sources.

COD, defined as the amount of oxygen required for a sample to oxidize at its organic and inorganic matter, enables us to find the pollution strength of industrial waste and sewage. [25] have observed COD value ranged from 74 to 154 mg/l at Tapti river in Khandesh region. [26] found evidence of higher COD due to organic matter discharged by fish farms and other sources like sewage. The effect of Ganga Action Plan was studied by [27] and noticed the recovery of river health from organic load by reduction in COD values at Varansi. [28] observed high level of COD in river at various places of Bihar mainly due to raw sewage, municipal waste, industrial effluents and anthropogenic disturbances. In Suvaw nala, higher values of COD during summer are mainly due to increased volume of sewage flow in the river. In the present study of the river Kolong, the mean of COD values for both the sites ranged from 11.45 mg/l to 19.40 mg/l in all the chosen seasons.

B. Economic implications of Kolong's water quality and related interventions:

Given the assessment of physico-chemical parameters in the previous section, it can be observed that alkalinity levels have been observed to be moderate to high in the study area. The reasons for this can be both industrial and agricultural. As regards alkalinity levels, it should be noted that this has direct implication on agricultural productivity and has also been associated with crop loss, time and again. Different crops have different alkalinity tolerance levels and hence, exposure to negative water quality can prove quite detrimental. Moreover, high pH level of water can negatively affect human health while inhibiting growth of some plants. Efforts concerning its treatment can result in high cost both for the state and households.

Besides this, treating chloride by setting up plants can cost thousands of dollars [30, 31]. The cost factor for households might even be larger as it involved exposure to serious diseases. Additionally, a review of research works done in this context points out that greater amount of BOD and COD indicates the necessity of treating water, thereby signaling the need for higher expenditure. It has been observed that approximately USD 1,000,000 is required to set up municipal treatment stations in India, which excludes the cost of research and development as well as other variable costs [32,33].

In order to preserve Kolong's natural water quality and alleviate its status, an array of economic strategies can assist related state and community interventions, some of which have been discussed in the following paragraphs.

The need for a water management firm is felt at the foremost in the context of Kolong basin. These kinds of firms assist in internalizing the consequent externalities [34], done through capacity building, research and development, monitoring and several other activities. Such a firm could also be built on the basis of a private-public-philanthropic partnership. It must be kept in mind that establishing such firms and achieving abatement goals should also focus on not putting an excess burden on stakeholders, but just enough to make them realise the significance of their activities and pay for the damage they have caused.

A very important fiscal policy intervention could implementation of effluent charges on polluting units. This is a popular policy employed worldwide to prevent pollution at high discharge sources. The banks of Kolong have witnessed growth of tanneries and other small-scale industries that have proved to be great contenders of effluent discharge. Since identifying agricultural run-off sources is difficult, effluent charges could be put on industrial units. These, however, have to be levied according to the concentration of pollution in Kolong with respect to different physico-chemical characteristics. Such charges could be monitored by the water management firm and the collected funds as well as penalties could be spent on treatment plants or mitigating the health costs of affected households.

Stream standards could also be effectively applied on the stretches of Kolong that are facing high pollution. This is mostly applicable in case of Nagaon town (Site II). This policy is first initiated in the United States after a legislation was passed to control pollution. It is important to note that stream standards have been recommended by both the state and central government, which have not implemented in a strict manner, as can be witnessed in case of Kolong. Moreover, no uniform authority has been appointed to review the implementation.

Lack of trained personnel and motivation of officials have resulted in lackluster behaviors from the authorities as well as weak implementation of monitoring plans.

The role of municipality in treating Kolong water at their individual stretches is very crucial. Joint municipality treatment plants could be constructed wherein resources of both municipalities could be brought in to achieve a higher goal. This can help lighten the burden on state financial resources.

Like most developed nations, implementation of a fertilizer tax can result in tremendous benefits for the affected population. Such a tax should be deployed in conjunction with the concentration of nutrients in river stretches. For instance, where water is rich in nitrates, a tax on nitrate-rich fertilizer should be deployed. This process however needs rigorous research and appropriate policy action.

V. CONCLUSION

The examination of physico-chemical parameters in this study provides us with the positive evidence of existence of pollution in Kolong river. High contamination of the river water is seen at both the selected sites during the course of study, rendering it inept for consumption, domestic and may be irrigation purposes too. The study of the associated economics of water quality points out to the need for assessing the costs of water treatment and related fiscal burden on the state and population. An efficient water management strategy, thus, is called for. As such, maintaining the ecology of the river needs minimisation of anthropogenic disturbances and restoration of the dynamic nature of the Kolong river system. For restoration of the river water quality, public awareness is essential Therefore, urgent steps must be taken to improve the quality of Kolong river.

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