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RESEARCH ARTICLE

Analyses of water quality using different physico-chemical parameters: A study of Saryu river

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Abstract

Saryu river is considered the holy river in Ayodhya, Uttar Pradesh, India. But, due to human anthropogenic activities, water quality is deteriorating. The present study aimed to analyse physicochemical parameters with seasonal variations, and bacterial population to monitor river water quality using standard methods. Most of the physicochemical parameters (mainly pH, DO, BOD and TDS) were found with in permissible limits recommended by regulatory authorities. Other parametrs like chemical oxygen demand (COD) and total suspended solids (TSS) values were slightly excess of the permissible standards. Microbial analyses were carried out, that showed the presence of bacterial and fungal populations. Bacterial count was higher in rainy season followed by summer and winter seasons. The findings of this study can be useful to monitor the water quality in different seasons, for drinking and irrigation purposes.

Keywords: Seasonal effects, Saryu river, Physicochemical, Microbial population, Ayodhya, Pollution.

Introduction

India is having utmost importance in the world due to their geographical, historical, religious, and sociocultural reasons (Sharma *et al.,* 2020). Several contaminants coming directly or indirectly in the river water are playing a pivotal role in polluting them (Sharma *et al.,* 2020). It is now become prime concerns for the most of the metropolitan cities of the developing nations for cleaning and sanitation of river water in populated areas. It is assessed that approximately 71% of the planet Earth is covered by oceans having 1386 million cubic kilometres volume of water fed area where only about 2% of the earth water supply to human and other activities (Leong *et al.,* 2018). Generally majority of the potable water is obtained from rain-fed rivers (Mamun and Zainudin, 2013). It is reported by earlier researchers that rivers are susceptible freshwater systems that support life as well as channels of vital significance globally (Farah *et al.,* 2002). It provides major water resources to local, industrial, and agricultural purposes along with it also helps to maintain soil fertility, wildlife conservation, and development of forest resources (Suther *et al.,* 2009). The Ayodhya is famous and revered city because it is the birth place of Lord Ram and situated at the bank of holy river Saryu. Saryu/Ghaghra is also known as Karnali. It is a perennial trans-boundary river originating on the Tibetan plateau near lake Manasarovar. It is the largest tributary by volume and second longest tributary by length of the river Ganges after Yamuna. Lower Ghaghra is also called as Saryu river and Ayodhya district is situated on its right bank. The Saryu river forms at the confluence of the Karnali (Ghaghara) and Mahakali (Sharda) in Bahraich district of Uttar Pradesh, India. The flows of the Saryu river initially into south western direction till it reaches Ramnagar, where it takes a turn towards the west and flows towards the towns of Ayodhya (Saryu action plan_2_uppcb.com/ 5 June 2019). It is well known that religious rituals are always organized on the bank of Saryu river round the year. Due to the activities likes bathing, cloth washing, garbage, dead animals and open cremation deteriorates the quality of river. It is well understood that quality of drinking water is a vital factor for the betterment of human health (Francis *et al.,* 2015). Suitable supply of safe drinking water is become most

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challenging tasks in various developing nations of the world (George *et al.,* 2021). It is demonstrated by earlier researcher that healthy aquatic ecosystems are well supported by its physicochemical and biological diversity present in water body (Leong *et al.,* 2018). It is imperative that river water quality needs regular monitoring and assessment in order to prevent any sort of disease outbreak and further deterioration. Microbiological studies reveal the occurrence of contamination by microbial overgrowth that may have been plausible reason for the potential dissemination of animal and plant pathogens in water (Leong *et al.,* 2018).

Water is considered as one of the most significant and necessary resources for all living things in the world. Clean water is a fundamental need for every people inhabit on the planet earth. For essential human requirements including drinking, sanitation, and agriculture, freshwater sources such as lakes, reservoirs, rivers, and aquifers are crucial. According to Khatri and Tyagi (2015), anthropogenic activities frequently deteriorate the quality of water resources by virtue of rapid industrialization and enormous uses of variety of chemicals in agricultural sectors Integrating knowledge from other fields, such as hydrology, microbiology, and ecology, would improve understanding of pollution levels and potential sources of contamination (Pandey *et al.,* 2014). Monitoring of physicochemical and biological properties of water is a crucial step to improve the water quality of any water body (Alley, 2007). Physical parameters include color, odor, temperature, transparency, turbidity, total solid wastes etc. Chemical characteristics involve parameters such as pH, dissolved oxygen (DO), free CO_2, alkalinity, total hardness, presence of ammonia, phosphate, chlorine, calcium, magnesium etc. Likewise, biological indicators of water quality include fishes, macrophytes and phytoplankton. The selection of parameters used to test water is based on the degree to which its quality and purity are required (Patil *et al.,* 2012). It is warranted to elucidate important parameters of water quality assessment in order to estimate the overall potability of water, such parameters are essential to aware the people for its suitability of common public welfare (Shittu *et al.,* 2008). The objective of the present study is to evaluate the bacteriological and physicochemical parameters of the river water sources used by living population for drinking and swimming purposes.

Materials and Methods

Site Selection and Sampling

A total of 1-liter samples were taken from water and sediment of the Saryu river in the Ayodhya district ((27°20'59.99" N 81°22'59.99" E) of Uttar Pradesh, India, area in order to estimate the microbial and physicochemical analyses (Figure 1). In Ayodhya at Laxman Ghat (26°.81/N 82°.20/E and 20 cm depth) on the banks of the Saryu river, water and sediment samples were collected from three different places (bathing, middle, and more elevated from mid) in summer, winter, and rainy seasons. Samples were aseptically collected from each sampling site in sterile glass bottles and transported to laboratory in ice box and analysed within 6 hours of sample collection.

Microbial Analysis

Isolation and Enumeration

One mL of the water samples was transferred into 9 mL sterile saline blank water and after thorough mixing serial dilutions were performed. In 100 µL aliquot of each diluted sample was inoculated onto appropriate pre-sterilized and solidified growth medium on petri plates and incubated at appropriate temperature and time combination for the count of different microbial groups following standard procedure (AOAC, 1990). Accordingly, colony forming unit (CFU) were counted on plate count agar (PCA) medium. Total coliform count was performed on MacConkey agar medium (MAM), while Yeast, mold and algal counts were done on Sabouraud dextrose agar (SDA) and ASN III medium, respectively. After the pour plates had cooled down and the agar had fully hardened, they were flipped over and placed in an incubator set to 37°C for 24 hours. For yeast, mold and algal counts the petri plates incubated at 37°C for a period of 48 hours.

Physiochemical Analysis of Water

For the various tests to analyse the physico-chemical characteristics (likes pH, temperature, BOD, COD, TDS, sodium, potassium, and fluoride ions) of groundwater pollution, standard analysis methods provided by The American Public Health Association (APHA. 1998), Indian Standard Institute (Saxena and Sharma 2017) and the Bureau of Indian Standards (BIS, 2012) were used.

Statistical Analyses

Triplicates of each experiment were carried out. Using the Microsoft Excel programme, the standard deviation was computed, and the findings are shown as mean ± SD values.

Results and Discussion

Microbial Analysis

Physicochemical and microbiological analyses were done for 3 seasons namely, summer, monsoon, and winter. This study demonstrated the presence of several bacterial populations belonging to the members of the family Enterobacteriaceae, identified in the water samples at Laxman Ghat in Saryu river, Ayodhya. It is seen from Table 1 that colony forming units for *Escherichia,* yeast-*m*old, and total microbes for the summer season. In Table 1 colony forming units (CFU/mL) for bacteria, fungi, and algae are demonstrated for the summer, rainy and winter seasons (Table 1). The total plate count was found to be higher in the rainy season (22.3×10^6 CFU/mL) on plate count agar, and it was less

in the winter season. Further, the coliform count was estimated higher in the summer (225×10^5 CFU/mL) than in the other two seasons. Additionally, the fungal count on SDA medium was found to be higher in the summer season (95 × 10^5 CFU/mL) than in the rainy and winter seasons. The algal count was found to be higher in the winter season (74 x 10^4 CFU/mL) than in the summer and rainy seasons as shown in (Table 1). In one of the reported studies, the monsoon season had a higher total coliform count than summer and winter did across the Barak river, Assam, India. Between 13 and 49 (x10^3) mL^{-1}, 11 and 42 (x10^3) mL^{-1}, and 8 and 26 (x10^3) mL^{-1} of total coliform were found during the monsoon, summer, and winter seasons, respectively (Rajkumar & Sharma 2013). Our results agree with higher microbial contamination in the rainy season compared to summer and winter. The presence of high CFU counts in river water may be contamination by anthropogenic activities such as the release of organic pollutants, pharmaceuticals, fecal, or even pathogenic micro-organisms (Leong *et al.,* 2018). The coliform bacteria are gram negative, non-spore forming, aerobic and facultatively anaerobic rod-shaped bacteria that digest lactose with gas and acid formation in 24 to 48 hours at 35°C. *Escherichia coli* and various members of the genera *Enterobacter*, *Klebsiella*, and *Citrobacter* are all considered members of the family Enterobacteriaceae, which also includes other coliform bacteria (Yasin *et al.,* 2015). The water quality of river Saryu at Ayodhya district lies under category- D specified as per IS – 2296-1982, according to Central Pollution Control Board (CPCB) use based classification of surface waters in India (Saryu action plan_2_ uppcb.com/ 5 June 2019). Microbiological assessment of the Saryu river water suggests the vulnerability due to the presence of indicator and enteric bacteria. The overall results showed that the consumption of such contaminated water may be harmful to living populations.

Physicochemical Analysis of Water

Different physicochemical characteristics were examined in the collected water samples. In this study, the samples of water were analyzed for mean temperature measurements. It is found to be ranged between 22.8 to 28.6°C (Table 2). In winter, the minimum mean temperature of 22.8°C was recorded while, in summer season it was found to be a maximum of 28.6°C. It is well-proven that temperature is one of the important physicochemical parameters used to estimate and evaluate potable water quality. It also affects several phenomena such as rate of chemical reactions in the water body, reduction in solubility of gases and amplifications of tastes and colors of water (Olajire and Imeokparia, 2001). The variations in temperature of the water samples may be attributed to sampling locations such as surface water in direct exposure of sunlight, richness in organic matter and microbial activities could be possible reasons for alteration in temperature (Yasin *et al.,* 2015).

The pH level of water plays a key role in regulating the carbonate and bicarbonate levels in water. pH is really a measure of the relative amount of free hydrogen and hydroxyl ions in the water. Since pH can be affected by chemicals in the water, pH is an important indicator of water that is changing chemically. In this study, the water sample was estimated for the mean pH and found to be in the range of 7.3 ± 0.13 to 8.3 ± 0.05 with alkaline nature (Table 2). It is observed from Figure 2 that the mean pH was high in summer as compared to winter and rainy seasons. The mean pH values recorded in all water samples of three different seasons were found within the recommended standards of the European Commission and World Health Organization (WHO) (ranges from 6.5–8.5) for potable waters (WHO, 1996; Yasin *et al.,* 2015). Sharma et al. (2020) reported the mean pH values (ranges 7.6–7.7) for Yamuna river water in three consecutive years (2017, 2018 and 2019). They suggested that mean pH values were moderate and not changes much with time. Earlier studies reported that the pH values of municipal waste water of different major drains opening to Saryu river were found in the 6 to 7.7 pH (Singh *et al.,* 2007). They suggested that the fluctuation in pH in rainy season may be due to the dilution of industrial and sewage effluents.

In this study, the water sample was estimated for mean DO and found to be in the range of 6.17 to 6.93 mg/L (Table 2). It is observed that the DO values of river water were within the permissible limit of WHO standard (>5 mg/L). DO of Yamuna river were studied by earlier researchers and found in the range of 8.7 to 8.9 mg/L (Sharma *et al.,* 2020). Studies published over the previous decade reveal a DO concentration range between 2.07 to 6.6 mg/L in the Saryu River (Singh *et al.,* 2007). Dissolved oxygen is an important water quality parameter and has special significance

Table 1: Colony forming units (CFU/mL) for *Escherichia,* fungi, algae and total microbes in summer, rainy and winter seasons

Sample code	*PCA*		*MAM*		*SDA*		*ASNIII*	
	Count	*CFU/mL*	*Count*	*CFU/mL*	*Count*	*CFU/mL*	*Count*	*CFU/mL*
SwM-01 (Summer season	181	181×10^5	225	225×10^5	95	95×10^5	Nil	Nil
SM-02 Rainy Season)	223	22.3 x 10^6	164	16.4×10^6	53	53x 10^3	27	27 x 10^4
SM-03 (Winter season)	13	13.0 x 10^5	2	2.0×10^5	53	53x 10^3	74	74 x 10^4

PCA: Plate count Agar (total plate count); MAM: MacConkey Agar Media (total coliform count); SDA: Sabouraud dextrose Agar (Yeast and Mold count); ASNIII Media:(total algal count); dilution used: 10^{-3}; Sample amount plated: 100 µL

Table 2: Physiochemical properties obtained for water sample collected in summer, rainy and winter seasons

Seasons	*Parameters*											
	PH	*Temp (°C)*	*BOD (mg/L)*	*COD (mg/L)*	*DO (mg/L)*	*Alkalinity (mg/L)*	*TDS (mg/L)*	*TSS (mg/L)*	*TS (mg/L)*	*Sodium ions (mg/L)*	*Potassium ions (mg/L)*	*Fluoride ions (mg/L)*
R_1	8.3	29	3	120	6.5	22	150	42	192	40	25	1.3
R_2	8.4	28	2.9	110	7.4	30	148	50	198	43	30	1.1
R_3	8.3	29	3.3	125	6.9	25	151	55	206	42	28	1.2
S.D.	8.33 ± 0.04	28.66 ± 0.47	3.067 ± 0.16	118.33 ± 6.23	6.93± 0.37	25.66 ± 3.29	149.67 ± 1.25	49 ± 5.35	198.66 ± 5.73	41.67 ± 1.24	27.66 ± 2.05	1.2 ± 0.08
Rainy												
R_1	7.8	27	3	104	6	25	450	110	560	25	30	0.8
R_2	7.9	28.5	3.9	117	7.2	27	456	114	570	27	33	0.9
R_3	7.6	26.4	3.4	114	5.8	28	465	120	585	29	37	0.7
S.D.	7.7 ± 0.125	27.3 ± 0.89	3.43 ± 0.37	111.67 ± 5.56	6.33± 0.62	26.67 ±1.23	457 ± 6.16	114.67 ± 4.11	571.67 ± 10.27	27 ± 1.63	33.33 ± 2.87	0.8 ± 0.08
Winter												
R_1	7.3	23	3.3	137	6.2	27	177	75	252	38	27	0.7
R_2	7.2	21.9	3.5	156	5.9	29	182	77	259	35	29	0.8
R_3	7.5	23.5	3	152	6.4	31	192	84	276	32	31	0.7
S.D.	7.33 ± 0.125	22.8 ± 0.67	3.27± 0.205	148.33 ± 8.18	6.17 ± .020	29 ± 1.63	183.67 ± 6.24	78.67 ± 3.86	262.33 ± 10.08	35 ± 2.45	29 ± 1.63	0.73 ± 0.05

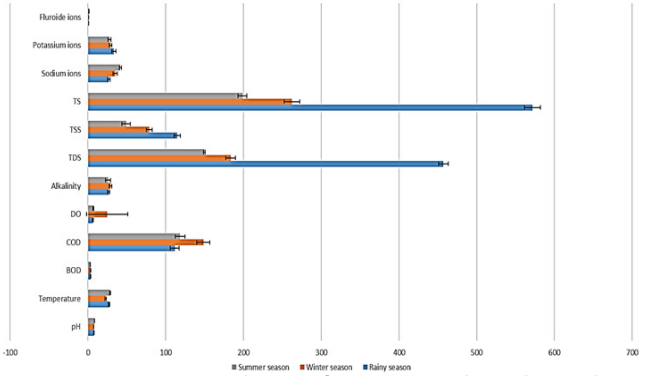

Figure 1: Histogram showing fluctuation in physiochemical properties of water samples in rainy, winter, and summer seasons

for aquatic organisms in natural waters. Lower levels of dissolved oxygen are harmful to higher types of aquatic life. biochemical oxygen demand (BOD) is the measurement of oxygen present in the water that aerobic organisms require for oxidation of the biodegradable substrate. Further, the water sample was estimated for mean BOD values and found to be in the 3.0 to 3.43 mg/L range presented in Table 2. BOD value is under the acceptable limit as per Bureau of Indian Standard (BIS). It is seen from Figure 1 that BOD was maximum in rainy season compared to the summer and winter seasons. Similar trends were reported by elsewhere for the Yamuna river (Sharma *et al.,* 2020). Earlier researchers have estimated the BOD of municipal wastewater from the Saryu river drains, with values ranging between 44.5 to 214.6 mg/L (Singh *et al.,* 2007). This shows that after years' BOD of this river is became low due to changing surrounding and environmental conditions. Low BOD indicates that water is less polluted with low nutrients and more oxygen in the river (Leong *et al.,* 2018; Aniyikaiye ., 2019).

Chemical oxygen demand (COD) is an important parameter for the characterization of water bodies, sewage, industrial wastes, and treatment plant effluents. It is an essential variable of water, indicating the health scenario of freshwater bodies. It is generally used to measure pollution load in natural and waste water bodies. In the present study, the water sample was estimated for mean COD and varied from 111 to 148 mg/L (Table 2). From Figure 1, it is demonstrated that COD was found to be maximum in winter and lowest in rainy seasons. Higher COD in winter may be due to the pollution load caused by mixing sewage water, garbage dumping and industrial effluents without pretreatment (Zeb *et al.,* 2011). Another reason could indicate more oxidizable organic material in the sample, which in turn lowers the quantity of dissolved oxygen (DO). Studies published over the previous decade reveal a COD concentration of 452 mg/L in municipal wastewater coming to the Saryu river through drains (Singh, 2007). This shows that after years' COD of this river is became low due to the changing environmental conditions.

The mean TDS values varied from 149 to 457 mg/L. The lowest TDS was 149 mg/L recorded in summer and the highest value (457 mg/L) was obtained in rainy season, which is below the maximum allowable limit (1000 mg/L) recommended by WHO and 500 mg/L by BIS (WHO. 1996; BIS, 2012). TDS generally measures the nature of water

quality. The TDS includes several cations and anions such as carbonate, bicarbonate, chloride, sulfate, phosphate, calcium, magnesium, sodium, and other ions. It also affects drinking water's taste if present above the recommended level. The TDS values recorded in the present study could be considered tolerable. However, the variability in the recorded TDS data was significantly high as compared to the earlier report (83 to 99 mg/L) made from Yamuna river (Sharma *et al.,* 2020). Total dissolved solids are a measurement of all inorganic and organic materials that are present in a liquid in a suspended, ionized, or molecular form (Balachandar, 2010). On the other hand**s**, the overall mean total soluble substances (TSS) recorded in this study ranged between 78 to 198 mg/L with the lowest measurements being observed in winter (78 mg/L) and highest in rainy season (198 mg/L). The published research shows that the TSS content in the Saryu river varies from 310 to 602 mg/L (Singh *et al.,* 2007). The plausible reason for high TSS concentration in the water samples may be due to poor sanitation practices and the possibility of contamination of the water sources with municipal wastes and plant debris (Yasin *et al.,* 2015). It is also seen from Figure 2 that rainy season has TDS and TSS more than the winter and summer seasons.

This study's estimated mean alkalinity values ranged between 25 to 29 mg/L (Table 1). It is observed that the alkalinity was moderate in all the samples and found to be below the standard limits reported by BIS. The observed alkalinity in this study is comparatively less as reported elsewhere (Bhat and Ramchandra, 2019). They studied the water quality of Hebbal Lake, Bangalore and presented that the alkalinity values ranged between 108 to 250 mg/L, 170 to 450 mg/L and 300 to 460 mg/L, in summer, monsoon and post-monsoon seasons. It is demonstrated that alkalinity in natural waters may be due to the dissolution of CO_2 in water (Patil *et al.,* 2018). The presence of high alkalinity reveals the presence of strongly alkaline industrial wastewater and sewage (Bhat and Ramchandra, 2019). Metal ion concentrations were also estimated in water samples. Sodium, potassium and fluoride ions were found to be in range from 27 to 41 mg/L, 27 to 33 mg/L and 0.7 to 1.2 mg/L, respectively (Table 1).

Conclusions

The microbiological quality of the river water samples analyzed in the current study did not meet the standards set for drinking water. Seasonal variation in various physicochemical parameters of the Saryu river was studied and the water quality index was determined. The water quality index of river Saryu river is put under category- D specified as per IS – 2296 to 1982, according to Central Pollution Control Board (CPCB) use-based classification of surface waters in India. Most of the physicochemical data indicated marginally tolerable quality concerning pH, DO, BOD and TDS but poor quality concerning COD and TSS with values slightly in excess of the permissible standards. Many factors influence fluctuations in river water quality. The present study provides a baseline water quality status of the Saryu rivers in Ayodhya and future water quality assessments.

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