Assessment of water quality in Ganga river ghats of Varanasi district, Uttar Pradesh

Abstract

Water is the most vital biosphere component since it sustains all life and circulates and cycles nutrients. Water is also necessary for power generation, navigation, agriculture irrigation, sewage disposal, etc. The increasing demand for water as a result of rising population and industrialization has severely compromised water quality. Water quality assessment is most important process for evaluating the chemical characteristics of water bodies. To assess whether the water is suitable for a variety of uses after locating any pollutants, contaminants, or other potentially hazardous compounds that may be present in the water. A systematic study was conducted to assess the water quality in the Ganga river in the Ghats of Varanasi district of Uttar Pradesh, India, from January to March 2021. The assessment involves collecting water samples from different Ghats namely BabuaPandey ghat (G_1), Digpatia ghat (G_2), Chausatti ghat (G_3), Ranamahal ghat (G_4) and Darbhanga ghat (G_5) along the river. The analytical data from various physicochemical parameters indicates that the pH values were found to be near neutral, EC did not differ significantly, Ca+Mg varied from 22.80 to 28.40 meq/L, Cl^- was found to be 2.40 to 3.20 mg/L, Na^+ varied from 1.0 to 1.10mg/L, K^+ and SO_4^2 was a similar trend, TSS was varied from 400 to 1200 mg/L, DO varied from 5.80 to 7.30 mg/L, COD varied from 16.0 to 22.40 mg/L, NO_3¯N varied from 25.27 to 29.60 mg/L, Bvaried from 4.90 to 5.80 mg/L, SAR is 0.27 to 0.33 mg/L, It is concluded that some of the parameters were almost constant for all the five Ghats samples, like Na^+ and K^+ content; while other parameters varied significantly. Out of thirteen parameters, only three NO_3-N, B, and Cl^- showed an increasing trend.

Keywords: Ganga river, Water quality, Water resources, physico-chemical properties, Varanasi

Introduction

Water is a transparent, tasteless, odorless, and nearly colorless chemical substance that is essential for the survival of life. The rivers have been a crucial source of freshwater for human settlements for thousands of years. They provide water for drinking, agriculture, and industry, among other uses (Verma *et al.* 2022). In India, the Ganga river is the largest and fourth largest in the world. Its catchment area is a huge 861,404 square kilometer area that includes parts of

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various Indian states. It flows for a total length of 2,525 kilometers (1669 miles) before emptying into the Bay of Bengal. The Ganga river basin is one of the most densely populated river basins in the world, with millions of people living in the surrounding areas and relying on the river for their daily needs, including irrigation, transportation, and drinking water (Haritash et al. 2016). Water is also an essential resource for various human activities such as power generation, navigation, and waste disposal. However, the increasing demand for water due to population growth and industrial expansion has put a lot of pressure on freshwater resources (Yadav, 2018). In the Ganga river, the majority of surface discharge sources pollute soil and water bodies across a wide area (Pandey *et al.* 2009 and Saxena and Singh, 2020). Since it travels through densely populated regions, the Ganga river collects vast quantities of human pollutants, which pose substantial health concerns to individuals as well as environmental dangers to the ecosystem's sustainability (Abed and Jazie 2014). To address these challenges, the Indian government has launched several initiatives and programs aimed at cleaning and restoring the Ganga river, which aims to improve water quality and restore ecological health across the entire river basin. An exact and balanced appraisal of water quality is needed for deciding the degree of helpfulness of water bodies for different employments. Many researchers have assessed the water quality in the Ganga river, Abed and Jazie (2014) assessed the physics-chemical properties of water and found that some water samples in the Varanasi district of Uttar Pradesh had pH, hardness, and total dissolved solids (TDS) levels that exceeded the limits set by the world health organization (WHO). Haritash *et al.* (2016) assessed the water quality and suitability of Ganga river in Rishikesh, Uttrakhand, and found that the quality of irrigation water ranged from good to excellent at almost all places except for percent sodium. Kumari *et al.* (2018) analyzed the water quality in the Ganga river at different Ghats of the Patna district of Bihar, it was found the Kali ghat was maximum dissolved oxygen, electrical conductivity biological oxygen demand and chemical oxygen demand indicating higher pollution. Another experiment was carried out to evaluate the physicochemical properties of water in the Ganga river in the Ghazipurdistrict of Uttar Pradesh (Yadav and Srivastav, 2011). The current study is conducted to assess the water quality in the Ganga river of Varanasi city. Varanasi, also known as Banaras or Kashi, is one of the oldest continuously inhabited cities in the world and is regarded as a spiritual and cultural center of India.

Material and Methods

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Site Description:

Varanasi city is situated (Latitude 25°15´N to 25°22'N and Longitude 82°57'E to 83°1´E) in the middle Ganga valley of North India, in the Eastern part of the state of Uttar Pradesh, from Jan to March 2021, it did, along the left crescent-shaped bank of the Ganga River. Varanasi city is located in the northern part of India in the state of Uttar Pradesh. The city is situated on the banks of the holy river Ganges and is bounded by Jaunpur and Ghazipur to the north, Mughal Sarai to the southeast, Bihar state to the east, Bhadohi to the west, and Mirzapur to the south. Varanasi has a humid subtropical climate with hot summers, cool winters, and monsoon rains. The city experiences a less dry climate compared to other parts of Uttar Pradesh. The summer months of May and June are the hottest, with temperatures often exceeding 40 degrees Celsius. The monsoon season in Varanasi typically starts in the third week of June and continues till October. The city receives an annual rainfall of about 1050 to 1200 mm, which is crucial for the agricultural economy of the region. Winter in Varanasi starts in mid-October and lasts till February, with December and January being the coldest months. The average temperature during winter is around 10 degrees Celsius. The fertile land in and around Varanasi is a result of the low-level floods in the Ganges, which continually replenish the soil with nutrients. The agricultural economy of the region depends on this fertile land, which supports a variety of crops like rice, wheat, sugarcane, and vegetables

Sample collection and analysis:

Water samples were randomly collected over the 60 m stretch and 1 m depth of 5 selected Ghats*viz.***,** G_1-Babua Pandey ghat**,** G_2-Digpatiya ghat**,** G_3**-**Chausatti ghat**,** G_4**-**Ranamahal ghat and G_5**-**Darbhanga ghat**,** and the analysis of various chemical properties are shown in Table No 1.

Table 1: Methods used for the analysis of various chemical parameters of Ganga river water of Varanasi city from Jan to March 2021

Parameters	Methods	Indian Standards (BIS) (IS 10500: 1991)
pH	Electrometric method	7.0-8.5
EC	Direct determination	5-50 (dS/m)
Ca& Mg	Complexometric titration	75 (mg/L) & 30(mg/L)
Cl^-	Argentometric method	200-500 (mg/L)

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Na^+	Flame photometric method	20 (mg/L)
K^+	Flame photometric method	8-100 (mg/L)
SO_4^-	Turbidity method	200-500 (mg/L)
TS	Gravimetric method	500-1500 (mg/L)
DO	Winkler method	6 (mg/L)
COD	Winkler method	10 (mg/L)
NO_3-N	Brucine method	10-45 (mg/L)
B	Calorimetric curcumin Method	0.5 (mg/L)
SAR	Richards method	<6 (meq L^{-1})

Results and Discussion

Physico–chemical properties

pH: pH was determined by using a pH meter. which is determined by the concentration of hydrogen ions (H^+) in the solution. The pH values of water were found to be near neutral. The variation was non-significant. In the observed samples we found that sodium content is positively correlated with the observed values of boron (0.20) content and COD (0.90) while it is perfectly correlated with SAR (0.90) value and negatively correlated with potassium (-0.60) and nitrate content (-0.10) (Table 3). These pH values were in the range compared to BIS standards recommended. Indian standards (BIS) (IS 10500:1991) recommendation for pH range from 7.0 to 8.5 in table 2. The pH of water can be influenced by many factors, the role of carbonic acid and the interaction between carbonate and bicarbonate ions are important factors that can affect the pH of water (Mathivanan, 2005). The discharge of sewage into a river can cause a decrease in the pH value of the water at and around the point of discharge(Agrawal *et al.*2009).

Electrical conductivity: The data on electrical conductivity can be used to assess whether water and wastewater are suitable for on-land disposal. Depending on the properties of the soil and the climate, irrigation water up to 2.0 dS/m has been observed to be appropriate for irrigation. EC did not differ significantly among the sites. The minimum mean value of EC is 0.47 dS/m and the maximum value of EC is 0.49 dS/m was recorded at Darbhanga ghat and Chausatti ghat are presented in table 2. The increase in EC values of water suggests the presence of a nearby source of dissolved ions in the vicinity. A greater concentration of dissolved solids signifies a higher concentration of salt ions in water (Bhatt *et al.*1999). The disintegration and mineralization of organic material result in elevated amounts of conductivity and cations (Abida and Harikrishna, 2008). All downstream sites show a large rise in EC, a trend confirmed by observations reported by Srivastava and Sinha, 1996. In the observed samples we found that sodium content is positively correlated with the observed values of boron (0.20) content and

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COD (0.90) while it is perfectly correlated with SAR (1.00) value and negatively correlated with potassium (-0.60) and nitrate content (-0.10) (Table 3).

Calcium+Magnesium: The total concentration of calcium and magnesium cations in a given water sample is referred to as the hardness of the water. In most cases, natural water contains the highest concentrations of calcium. The existence of calcium exists in water is due to deposits of limestone, gypsum, and other minerals (Tripathi *et al.* 1991). Calcium is one of the principal cations involved in water hardness. For the determination of total Ca+Mg content (meq/L), the Ethylene diamine tetra acetic acid (EDTA) method was used. The EDTA method which is based on the reaction of Ca and Mg salts with EDTA or its disodium salt applies to all types of water except wastewater. This method depends on how well EDTA or its disodium salt can combine with calcium and magnesium ions to form stable complexes. The maximum Ca+Mg content was at Digpatia ghat (28.40 meq/L) while it was found to be minimum on Darbhanga ghat (22.80 meq/L) in presented table 2. In the observed samples we found that sodium content is positively correlated with the observed values of boron (0.20) content and COD (0.90) while it is perfectly correlated with SAR (1.00) value and negatively correlated with potassium (-0.60) and nitrate content (-0.10) (Table 3).

Table 2: Physico-chemical parameter levels at different Ghats of the Ganga river at Varanasi city

Parameters	Locations of different Ghats				
	G_1	**G_2**	**G_3**	**G_4**	**G_5**
pH	7.30	7.10	7.40	7.30	7.20
EC (dS/m)	0.48	0.49	0.49	0.48	0.47
Ca+Mg (mg/L)	25.8	27.0	28.4	23.0	22.8
Cl^- (mg/L)	2.40	2.80	2.80	2.80	3.20
Na^+ (mg/L)	1.10	1.10	1.00	1.10	1.10
K^+ (mg/L)	19.0	23.0	35.0	36.0	21.0
SO_4^- (mg/L))	19.0	23.0	35.0	36.0	21.0
TSS (mg/L)	1200	800	400	800	800
DO (mg/L)	6.20	5.80	6.90	7.30	7.00
COD (meq/L)	19.20	22.4	16.0	20.8	22.4
NO_3-N (mg/L)	25.27	26.4	28.2	29.6	29.6
B (mg/L)	4.90	5.00	5.10	5.30	5.80
SAR (mg/L)	0.31	0.30	0.27	0.32	0.33

Where,Babuapandey ghat (G_1), Digpatia ghat (G_2), Chausatti ghat (G_3), Ranamahal ghat (G_4) and Darbhanga ghat (G_5)

Table 3: Correlation between different Physico–chemical parameter levels at different ghats of the Ganga river in Varanasi city

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Parameters	pH	EC (dS/m)	Ca+Mg (mg/L)	Cl (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	TSS (mg/L)	DO (mg/L)	COD (meq/L)	NO_3-N (mg/L)	B (mg/L)	SAR (mg/L)
pH	**1.0**	0.1	0.2	-0.3	-0.7	0.6	0.6	-0.3	0.6	-0.9	0.2	-0.2	-0.5
EC (dS/cm)	0.1	**1.0**	0.9	-0.4	-0.5	0.4	0.4	-0.4	-0.5	-0.5	-0.4	-0.8	-0.9
Ca+Mg (mg/L)	0.2	0.9	**1.0**	-0.4	-0.7	0.1	0.1	-0.4	-0.5	-0.6	-0.6	-0.7	-0.9
Cl (mg/L)	-0.3	-0.4	-0.4	**1.0**	0.0	0.1	0.1	-0.5	0.5	0.4	0.8	0.9	0.3
Na (mg/L)	-0.7	-0.5	-0.7	0.0	**1.0**	-0.6	-0.6	0.8	-0.2	0.9	-0.1	0.2	0.9
K (mg/L)	0.6	0.4	0.1	0.1	-0.6	**1.0**	1.0	-0.7	0.6	-0.5	0.5	0.0	-0.4
SO_4 (mg/L))	0.6	0.4	0.1	0.1	-0.6	1.0	**1.0**	-0.7	0.6	-0.5	0.5	0.0	-0.4
TSS (mg/L)	-0.3	-0.4	-0.4	-0.5	0.8	-0.7	-0.7	**1.0**	-0.4	0.4	-0.5	-0.2	0.6
DO (mg/L)	0.6	-0.5	-0.5	0.5	-0.2	0.6	0.6	-0.4	**1.0**	-0.2	0.9	0.6	0.2
COD (meq/L)	-0.9	-0.5	-0.6	0.4	0.9	-0.5	-0.5	0.4	-0.2	**1.0**	0.1	0.4	0.8
NO_3-N (mg/L)	0.2	-0.4	-0.6	0.8	-0.1	0.5	0.5	-0.5	0.9	0.1	**1.0**	0.8	0.3
B (mg/L)	-0.2	-0.8	-0.7	0.9	0.2	0.0	0.0	-0.2	0.6	0.4	0.8	**1.0**	0.6
SAR (mg/L)	-0.5	-0.9	-0.9	0.3	0.9	-0.4	-0.4	0.6	0.2	0.8	0.3	0.6	**1.0**

Chloride: The chloride (Cl^-) value of the Ganga river of BabuaPandey ghat was found to be 2.4 mg/L which is the minimum value amongst the five Ghats. The maximum values are 3.2 mg/Lof Darbhanga ghat and in between the three ghats have a constant value of 2.8 mg/L. These values are much less than the prescribed range of Indian Standards (BIS) of 200-500 mg/L. The Cl^- analysis was done by silver nitrate titration method. An increase in Cl^- content can be due to the decomposition of organic matter. High concentrations of chloride may also be due to mineral deposits, industrial waste, and domestic waste (Praveen *et al.* 2013). In the observed samples we found that Na^+ content is positively correlated with the observed values of B (0.20) content and COD (0.90) while it is perfectly correlated with SAR (1.00) value and negatively correlated with K^+ (-0.60) and NO_3-N content (-0.10) (Table 3).

Sodium: The sodium (Na^+) content of Ganga river water of all five ghats was almost the same; having a value of 1.1 mg/Lexcept for Chausatti ghat which has a value of 1.0 mg/L. In the observed samples we found that Na^+ content is positively correlated with the observed values of B (0.20) content and COD (0.90) while it is perfectly correlated with SAR (1.00) value and negatively correlated with K^+ (-0.60) and nitrate content (-0.10) (Table 3). These Na^+ values have lower concentrations as compared to BIS standards recommended. (Zafer, 1966, Nayal*et al.* 2008). The Na^+ content of a sample is determined using flame photometry. It is useful for determining the quantitativeand qualitative properties of several cations, particularly metals that are easily excited to higher energy levels at low flame temperatures (Na, Ca, K, Ba, Rb, Cs, and Cu).

Potassium: The potassium (K^+) value of the Ganga river water of all five ghats is variable. The maximum K^+ content is found at Ranamahal ghat (36 mg/L) and the minimum at

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BabuaPandey (19 mg/L). In the observed samples we found that Na^+ content is positively correlated with the observed values of B (0.20) content and COD (0.90) while it is perfectly correlated and SAR (1.00) values and negatively correlated with K^+ (-0.60) and NO_3-Ncontent (-0.10) (Table 3) similar result reported by Singh, 2010. Flame photometry is used for determining potassium because potassium lies in group 1A of the periodic table.

Sulphate: The concentration of sulphate (SO_4^-) in water samples was evaluated using the gravimetric method. This gave SO_4^- content maximum at Ranamahal ghat *i.e.* 36 mg/L and minimum at Babua Pandey ghat *i.e.* 19 mg/L. Indian Standards (BIS) (IS 10500:1991) for SO_4^- content is 200-500 mg/L. Thus the concentration of SO_4^- content at these ghats is lower than the BIS Standards recommended (Agrawal *et al.* 1976). The content of SO_4^- is highest at Ranamahal Ghat and its trend goes on increase, *i.e.* BabuaPandey ghat (19 mg/L) has minimum SO_4^- content whereas it higher on next ghat *i.e.* Digpatia (23 mg/L) then again more at Chausatti (35 mg/L) then highest at Ranamahalghat (36 mg/L), after that it decreases at next ghat i.e. Darbhanga ghat (21 mg/L). So there is an increase in SO_4^- content and at last, a decrease is observed. In the observed samples we found that Na^+ content is positively correlated with the observed values of B (0.20) content and COD (0.90) while it is perfectly correlated with SAR (1.00) values and negatively correlated with K^+ (-0.60) and NO_3-N content (-0.10) (Table 3).

Total solids: Total solid (TS) in the water sample was determined by gravimetric method. TS contents in the Gangariverare estimated at maximum at BabuaPandey ghat (1200 mg/L) and minimum at Chausatti ghat *i.e.* 400 mg/L. Indian Standards (BIS) (IS 10500:1991) for total solid in the water sample is 500-1500 (mg/L). Thus it is observed that the TScontent fell in the range in the collected samples. The TS content at the Babua Pandeyghat is found to be maximum *i.e.* (1200 mg/L) whereas, on the next ghat, its value is lower than the previous *i.e.* at Digpatiya ghat (800 mg/L), lowest at Chausatti ghat (400 mg/L) then on next two ghats its value found to be constant *i.e.* at Ranamahal ghat (800 mg/L) and Darbhanga ghat (800 mgL^{-1}). In the observed samples we found that Na^+ content is positively correlated with the observed values of B (0.20) content and COD (0.90) while it is perfectly correlated with K^+(1.00) and SAR (1.00) value and negatively correlated with K^+ (-0.60) and NO_3-N content (-0.10) (Table 3).

Dissolved oxygen: Winkler method is followed to determine the DO content. The concentration of DO has been found maximum at Ranamahal ghat (7.3 mg/L) and minimum at Digpatiya ghat (5.8 mg/L). The content of DO at Ranamahal ghat is higher than the permissible limit as in Indian Standards (BIS) (IS 10500:1991) for DO is 6 mg/L. So it is unfit for use

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whereas water at Digpattiya ghat has DO content within permissible limits (Rai *et al*, 2008 and Singh and Chaudhary, 2013). The estimated content of DO content in Ganga water was found to be highest at Ranamahal ghat (7.3 mg/L) and there is no trend for its content in water rather it varies randomly. Its value is lowest at Digpatiya ghat (5.8 mg/L), others; Babua Pandey ghat has (6.2 mg/L), Chausatti ghat (6.9 mg/L) and last ghat *i.e.* Darbhanga ghat have to DO content 7.0 mg/L. In the observed samples we found that Na^+ content is positively correlated with the observed values of B (0.20) content and COD (0.90) while it is perfectly correlated with SAR (1.00) value and negatively correlated with K^+ (-0.60) and NO_3-N content (-0.10) in table 3.

Chemical oxygen demand: When boiled with a mixture of potassium dichromate and sulfuric acid, the majority of the organic matter is destroyed, yielding carbon dioxide and water. In a sulphuric acid medium, a sample is refluxed with a specified amount of potassium dichromate, and the excess dichromate is titrated against ferrous ammonium sulphate. The oxygen needed to oxidise the oxidizable organic matter is directly proportional to the amount of dichromate consumed. reported by Arya and Gupta *(*2013). Results are expressed as mg/L of O_2. As per BIS, the permissible limit of COD in water suitable for drinking purposes is 10 mg/L. The COD of Ganga river water is maximum at Darbhanga ghat (22.40mg/L) and minimum at Babuapandey ghat (16.0 mg/L). COD of water samples collected from different ghats are having higher COD than the permissible limit (Pandey *et al.* 2014). In the observed samples we found that Na^+ content is positively correlated with the observed values of B (0.20) content, and COD (0.90) while it is perfectly correlated with SAR (1.00) value and negatively correlated with K^+ (-0.60) and NO_3-N content (-0.10) in table 3.

Nitrate: There are three recommended techniques for measuring NO_3-N in waters and wastewaters; a) Cadmium reduction method, b) Chromotropic acid method and c) Devarda'salloy reduction method**.** The cadmium reduction method is appropriate for NO_3-N concentrations less than 0.1 mg/L. The chromotropic acid method can be used for concentrations ranging from 0.1 to 5.0 mg/L, and Devarda's alloy reduction method can be used for concentrations greater than 2 mg/L or total nitrogen. The chromotropic acid method will be used as the referee method[i]. It has been stated by BIS that a concentration of 10-45 mg/L of NO_3 is permissible in groundwater. For irrigation, a lower NO_3^- concentration than the BIS norm is advised[ii]. The nitrate concentration of Ganga river water is maximum at Darbhanga ghat (29.67mg/L) and minimum at BabuaPandey ghat (25.27mg/L). Water samples taken from the many ghats along the Ganga have been analysed, and it was observed that Darbhanga ghat had a

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higher pollution index as compared to other ghats. In the observed samples we found that Na^+ content is positively correlated with the observed values of B (0.77) content, Ca+Mg (0.69) and COD (0.53) while it is perfectly correlated with K^+ (1.00) and SAR (1.00) values and negatively correlated with Cl^- (-0.55) and NO_3-N content (-0.41) (Table 3).

Boron: Boron (B) in the samples was estimated by Calorimetric curcumin method. As per IS 10500: 1991 the permissible limit for B in the drinking water is 1.0 ppm. The water sample collected from different ghats is having B concentration of more than 5 mg/L which is more than the standard prescribed by BIS. Hence, it's safe to say that this water isn't fit for human consumption. As borate compounds are a component of domestic working agents, wastewater discharges can dramatically increase the borate concentration of surface water. Boron occurs naturally in groundwater mostly as a result of seepage from borates and borosilicate-containing rocks and soils. In the observed samples we found that Na^+ content is positively correlated with the observed values of B (0.77) content, Ca+Mg (0.69) and COD (0.53) while it is perfectly correlated with K^+ (1.00) and SAR (1.00) values and negatively correlated with chloride (-0.55) and nitrate content (-0.41) (Table 3).

Sodium absorption ratio: As represented in table 2, the Sodium Absorption Ratio (SAR) value of the Ganga river is maximum at Shiwala ghat was 0.98 and minimum at Kedar ghat and VijaynaCa+Mg and COD content. In the observed samples we found that sodium content is positively correlated with the observed values of boron (0.77) content, Ca+Mg (0.69) and COD (0.53) while it is perfectly correlated with potassium (1.00) and SAR (1.00) values and negatively correlated with chloride (-0.55) and nitrate content (-0.41) (Table 3). The concentrations of these total dissolved solids are lower than those suggested by BIS standards.

Conclusion

Increasing quantities of various pollutants are polluting the water on a daily basis. Despite being a sacred river, the River Ganga is getting contaminated during this historic pilgrimage, probably as a result of growing anthropogenic influence. There are a number of factors contributing to the declining status of river water quality. The results of the experiments allowed us to draw the conclusion that the pollution levels in Shiwala ghat were higher than those in the other Ghats/Ganges. This might be attributable to the higher concentrations of pH, EC, total solid, dissolved oxygen, sodium, and potassium. With the early implementation of thorough environmental monitoring to assure compliance with environmental regulations, Ganga's water quality may be enhanced to some degree. The current infrastructure is insufficient

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to reduce pollution. The strategies for reviving the Ganga river's water quality may include both defensive and proactive approaches. The defensive approach calls for immediate improvements to the sewage network, increased sewage treatment capacity, and prevention of pollution load from tributaries.

References

Abed, S. A., &Jazie, A. A. (2014). Assessment of some physico-chemical properties for water in Ganga River at Varanasi, India. *Al-Qadisiya Journal for Engineering Sciences*, *7*(2), 148-64.

Abida, B. and Harikrishna. Study on the quality of water in some streams of cauvery river. *E-Journal of Chemistry*, 2008; **5**(2): 377-384.

Agrawal, D. K., Gaur S. D., Tiwari I. C., NarayAnswami, N. and Marwah, S. M. Physiochemical characteristic of ganga water at Varanasi. *Indian of environmental health*, 1976; **18**: 201-206.

Agrawal, N., Joshi, D.M. and Kumar, A. Studies on physico-chemical parameter to assess the water quality of river ganga for drinking purpose in Haridwar District. *Rasayan Journal of Chemistry*, 2009; **2**(1):195-203.

Anand V. Singh & Jitendra Pandey (2014) Heavy metals in the midstream of the Ganges River: spatio-temporal trends in a seasonally dry tropical region (India), Water International, 39:4, 504-516

APHA. Standard Methods for the examination of water and waste water, *American Public Health Association Washington*, 1998.

Arya, S. and Gupta, R. Water quality evaluation of ganga river from up to downstream area at Kanpur City. *Journal of Chemistry and Chemical Sciences*, 2013; **3** (2): 54-63.

Bhatt, L. R., Lacoul, P., Lekhak, H. D. and Jha, P.K. Physicochemical characteristics and phytoplankton of Taudha Lake Kathmandu. *Pollution Research*, 1999; **18**(14): 353-358.

Haritash, A.K., Gaur, S. & Garg, S. Assessment of water quality and suitability analysis of River Ganga in Rishikesh, India. *Appl Water Sci* **6**, 383–392 (2016).

Kiran, Nimisha. (2018) Contribution of Statistical Analysis Methods to Assessment of the Physicochemical Quality of the Ganga River, *Journal of Advances and Scholarly Researches in Allied Education*, 15(4): 508-511.

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Kumari Kriti, Nayak Nivedita, Kumari Pallavi, A.C. Stuti M. Sister (2018) Water quality analysis of river ganges at different ghats at Patna Bihar, Journal of Younf Scientist, 8: 13-19.

Mathivanan, V. Pollution studies on river cauvery in Mettur, Tamil Nadu, India. *Journal of Experimental Zoology India*. 2005; **8**(2):321-328.

Null SE, Mouzon NR, Elmore LR. Dissolved oxygen, stream temperature, and fish habitat response to environmental water purchases. *J. Env. Manag.* 2017;197:559–570.

Pandey, R., Raghuvanshi, D. and Shukla D. N. Assessment of physico-chemical parameter of river ganga at Allahabad With Respect to WQI. *International Journal of Industrial Research science Engineering Technology*, 2014, **3**(9):16339-16349.

Praveen, A., Kumar R., Pratima and Kumar R. Physico-chemical properties of the river ganga at Kanpur. *International Journal of computational Engineering Research.* 2013; **3**(4):134-137.

Rai, A.K., Paul B., Mudra L. and Kishore N. Studies of selected water quality parameters of river ganges at Patna, Bihar. *Journal of Advanced Lab Research Biology*, 201; **2**(4): 162-168.

Saxena, S., & Singh, P. K. (2020). Assessment of health of river Ganga at Varanasi, India.Nature Environment and Pollution Technology, 19(3): 935-948.

Sebastiá-Frasquet MT, Aguilar-Maldonado JA, Santamaría-Del-Ángel E, Estornell J. Sentinel 2 analysis of turbidity patterns in a coastal lagoon. *Remote Sens.* 2019;11(24):2926

Sharma B, Kumar M, Denis DM, Singh SK. Appraisal of river water quality using open-access earth observation data set: A study of river Ganga at Allahabad (India) *Sustain. Water Res. Manag.* 2019;5(2):755–765

Singh, L. and Choudhary, S. K. Physico-chemical characteristics of river water of ganga in middileganga Plains. *International Journal of Industrial Research science Engineering Technology*, 2013; **2**(9):4349-4357.

Singh, N. Physico-Chemical properties of polluted water of river ganga at Varanasi. *International Journal of Energy and Environment*, 2010; **1** (5):823-832.

Sinha, A.K., Singh V. P. and Srivastava, K. Physico–chemical studies on river ganga and its tributaries in Uttar Pradesh the present status. *Pollution and Biomonitoring of Indian Rivers (ed.) Dr. R.K. Trivedi.(Ed.), ABD publishers, Jaipur.* 2000:1-29.

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Srivastava, R. K. and Sinha, A. K. Water quality of the river Ganges at Phaphamau (Allahabad). *Effect of mass bathing during Mahakumb, Environmental Toxicology*, 1996; **11** (1): 212-226.

Tripathi. B.D., Sikander, M., Shukla, Suresh, C. Physico chemical characterization of city sewage discharge into river Ganga at Varanasi, India. *Environment International*, 1991; **17** (5): 469-478.

Verma M, Loganathan VA, Bhatt VK (2022) Development of entropy and deviation-based water quality index: case of River Ganga, India. Ecol Indic 143:109319.

Yadav, R.C., and V.C. Srivastava. "Physico-chemical properties of the water of River Ganga at Ghazipur." *Indian Journal of Scientific Research*, Dec. 2011, pp. 41

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