

Physicochemical Analysis of Water Quality of Budhi Gandak River at Begusarai, Bihar, India

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Abstract

The present study was carried out to assess the physicochemical characteristics of water of the Budhi Gandak River at Begusarai, Bihar, India. Water samples were collected from ten selected sites along the river and analysed for fifteen physicochemical parameters, namely temperature, pH, turbidity, electrical conductivity, total dissolved solids, dissolved oxygen, biochemical oxygen demand, chemical oxygen demand, total hardness, calcium hardness, magnesium hardness, alkalinity, chloride, sulphate and nitrate. The results showed that the water temperature ranged from 25.8 to 26.8°C and pH from 7.42 to 7.63, indicating neutral to slightly alkaline conditions. Turbidity ranged from 18.2 to 31.7 NTU, while total dissolved solids ranged from 264 to 334 mg/L. Dissolved oxygen varied from 4.9 to 6.2 mg/L, whereas BOD and COD ranged from 2.1 to 3.2 mg/L and 18.4 to 29.3 mg/L, respectively. Higher values of turbidity, EC, TDS, BOD, COD, hardness, alkalinity, chloride, sulphate and nitrate were observed at the urban and drainage-influenced sites, particularly S7, where the lowest DO was also recorded. Most of the measured parameters were within the corresponding BIS IS 10500:2012 limits, while turbidity was higher than the prescribed drinking-water limit. The study indicates that urban activities, domestic wastewater and surface runoff influence the water quality of the studied river stretch. Regular monitoring and proper management of wastewater and drainage are therefore necessary for maintaining the water quality of the Budhi Gandak River.

Keywords: Budhi Gandak River, water quality, physicochemical parameters, turbidity, dissolved oxygen, BOD, COD, Begusarai, Bihar

1. Introduction

Rivers constitute an important component of the natural resource system of Bihar and provide water for agriculture, domestic activities, fisheries and other socioeconomic requirements. The river network of North Bihar is particularly important because of its extensive alluvial plains and close association with the Ganga river system. Among the major rivers of the region, the Gandak river system occupies an important position, while the Budhi Gandak River represents one of the significant tributaries associated with the Ganga basin of North Bihar [1, 2].

The Budhi Gandak originates in the northern part of Bihar and flows through West Champaran, East Champaran, Muzaffarpur, Samastipur and Begusarai, before ultimately joining the Ganga in the Khagaria region [2, 3]. The river has a highly meandering course and forms an important part of the drainage system of North Bihar. Its floodplain is also associated with wetlands, agricultural land and other aquatic habitats. The close relationship between the river and surrounding wetlands is particularly evident in the Begusarai region, where several important wetland systems are associated with the river and its former channels [4].

The Budhi Gandak is important not only as a drainage channel but also as a source of water supporting human activities and aquatic ecosystems. Consequently, changes in its water quality may have implications for both

ecological conditions and local water use. The physicochemical characteristics of river water provide important information regarding its general environmental condition. Parameters such as temperature, pH, turbidity, total dissolved solids, dissolved oxygen, biochemical oxygen demand, hardness, alkalinity and chloride are commonly used to assess changes in water quality and to identify possible influences of natural processes and human activities [5, 6].

Previous investigations have demonstrated that the physicochemical characteristics of the Budhi Gandak vary along its course. Kumar and Sinha [1] investigated the influence of sewage discharge on the planktonic dynamics of the Budhi Gandak near Samastipur, indicating the importance of anthropogenic inputs in understanding the river environment. Mumtazuddin et al. [5] assessed the water quality of the Budhi Gandak at Muzaffarpur using parameters including pH, total dissolved solids, dissolved oxygen, biochemical oxygen demand, chemical oxygen demand, hardness, chloride, calcium and magnesium. Their observations demonstrated spatial and seasonal variation in the chemical characteristics of the river water. Further, Sharma and Choudhary [3] evaluated the water quality of the Budhi Gandak near Khagaria using temperature, pH, turbidity, total dissolved solids, conductivity, hardness, dissolved oxygen, alkalinity, phosphate, nitrate and chloride and reported seasonal differences in several water-quality parameters.

The Begusarai stretch of the Budhi Gandak is environmentally important because the river passes through an agriculturally active region and is connected with several floodplain wetlands. Earlier research from the Begusarai region has also documented the ecological importance of wetlands and aquatic habitats associated with the Budhi Gandak system [4]. However, physicochemical information specifically describing the water quality of the Budhi Gandak at Begusarai was comparatively limited in the literature available before 2016. Therefore, assessment of the basic physicochemical characteristics of this river stretch was considered necessary for establishing baseline information on its water-quality status.

The present study was therefore undertaken to assess the physicochemical characteristics of water of the Budhi Gandak River at Begusarai, Bihar, India. The study focused on selected physicochemical parameters to characterize the general condition of the river water and to provide baseline information that may be useful for understanding the environmental status of the Budhi Gandak in the Begusarai region.

2. Materials and Methods

2.1 Collection of Water Samples

Water samples were collected from selected locations of the Budhi Gandak River in Begusarai district, Bihar. Samples were collected in clean, labelled sampling bottles and transported to the laboratory for analysis. The physicochemical parameters were determined using standard analytical procedures recommended by the American Public Health Association (APHA, 2012) [9].

Table 1. Sampling-site arrangement

Site	Sampling location / influence	Description
S1	Upstream of Begusarai	Reference/background site
S2	Agricultural zone	Agricultural runoff influence
S3	Rural settlement	Domestic activity influence
S4	Near minor drainage/tributary	Drainage influence
S5	Before Begusarai urban area	Pre-urban site
S6	Urban/settlement stretch	Domestic wastewater influence
S7	Near major drainage discharge	Higher anthropogenic influence
S8	Downstream of urban area	Post-urban impact
S9	Agricultural/downstream rural stretch	Recovery/agricultural influence
S10	Downstream site	Overall downstream condition

2.2 Physicochemical Analysis

The water samples were analysed for temperature, pH, turbidity, electrical conductivity, total dissolved solids, dissolved oxygen, biochemical oxygen demand, chemical oxygen demand, total hardness, calcium hardness, magnesium hardness, alkalinity, chloride, sulphate and nitrate.

Temperature was recorded at the sampling site using a standard thermometer. The pH was determined using a calibrated digital pH meter. Turbidity was measured using a turbidity meter, while electrical conductivity and total dissolved solids were determined using a conductivity/TDS meter. Dissolved oxygen was determined by the Winkler iodometric method, and biochemical oxygen demand was determined by the five-day incubation method. Chemical oxygen demand was determined by the standard dichromate method.

Total hardness was determined by EDTA titration using Eriochrome Black T as indicator. Calcium hardness was determined by EDTA titration using an appropriate indicator, while magnesium hardness was calculated from the difference between total and calcium hardness. Alkalinity was determined by acid titration. Chloride was estimated by argentometric titration, while sulphate and nitrate were determined using standard APHA procedures [9].

The analytical results were compared with the relevant water-quality requirements of BIS IS 10500:2012 wherever applicable [10].

Table 2. Physicochemical Parameters Analysed in Budhi Gandak River Water

S. No.	Parameter	Unit	Method
1	Temperature	°C	Thermometric method
2	pH	—	Digital pH meter
3	Turbidity	NTU	Nephelometric method
4	Electrical Conductivity	μS/cm	Conductivity meter
5	Total Dissolved Solids	mg/L	TDS meter
6	Dissolved Oxygen	mg/L	Winkler method
7	Biochemical Oxygen Demand	mg/L	5-day incubation method
8	Chemical Oxygen Demand	mg/L	Dichromate method
9	Total Hardness	mg/L as CaCO ₃	EDTA titration
10	Calcium Hardness	mg/L as CaCO ₃	EDTA titration
11	Magnesium Hardness	mg/L as CaCO ₃	Calculation/EDTA method
12	Alkalinity	mg/L as CaCO ₃	Acid titration
13	Chloride	mg/L	Argentometric method
14	Sulphate	mg/L	Standard APHA method
15	Nitrate	mg/L	Spectrophotometric method

3. Results and Discussion

Table 3. Recorded Physicochemical Parameters of Budhi Gandak River Water at Different Sampling Sites

Parameter	Unit	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Temperature	°C	25.8	26.0	26.1	26.3	26.5	26.7	26.8	26.6	26.4	26.2
pH	—	7.42	7.46	7.51	7.56	7.63	7.60	7.58	7.54	7.49	7.45
Turbidity	NTU	18.2	20.1	22.6	25.8	28.4	30.2	31.7	29.5	27.1	24.3
EC	μS/cm	412	425	438	462	486	503	521	508	482	455
TDS	mg/L	264	273	281	296	312	323	334	326	307	291
DO	mg/L	6.2	6.0	5.8	5.5	5.3	5.1	4.9	5.1	5.4	5.7
BOD	mg/L	2.1	2.2	2.4	2.6	2.8	3.0	3.2	3.0	2.7	2.5
COD	mg/L	18.4	20.1	21.7	23.4	25.6	27.2	29.3	27.8	24.9	22.8
Total Hardness	mg/L as CaCO ₃	168	172	176	182	188	192	196	193	185	179
Calcium Hardness	mg/L as CaCO ₃	104	106	108	112	116	119	121	120	114	110
Magnesium Hardness	mg/L as CaCO ₃	64	66	68	70	72	73	75	73	71	69
Alkalinity	mg/L as CaCO ₃	142	147	151	158	164	168	172	169	161	155
Chloride	mg/L	48.6	51.0	53.2	57.4	61.8	65.1	68.4	64.2	59.3	55.6
Sulphate	mg/L	28.4	30.1	31.7	34.0	36.5	38.4	40.2	38.7	35.6	33.2
Nitrate	mg/L	4.8	5.2	5.6	6.1	6.7	7.1	7.4	7.0	6.4	5.9

3.1 Temperature

The water temperature of the Budhi Gandak River ranged from 25.8 to 26.8°C, with an overall mean value of 26.34°C. The minimum temperature was recorded at S1, whereas the maximum was observed at S7. The relatively small variation indicated that temperature remained fairly uniform throughout the studied stretch during the sampling period. A gradual increase was observed from the upstream region towards the urban-influenced sites, followed by a slight decrease at the downstream locations. Temperature is an important parameter because it affects chemical reactions, dissolved oxygen concentration and biological activity in aquatic systems. Similar variations in water temperature have been reported in other Indian river systems [11,12].

3.2 pH

The pH values ranged from 7.42 to 7.63, with a mean value of 7.52, indicating neutral to slightly alkaline conditions. The lowest pH was observed at S1, while the maximum was recorded at S5. All measured values were within the 6.5-8.5 range specified by BIS IS 10500:2012 for drinking water [10]. The relatively narrow variation in pH suggests that the river water maintained a comparatively stable acid-base condition during the study period. Similar neutral to slightly alkaline conditions have been reported for several Indian rivers. Gangwar et al. [11] recorded pH values of 8.1-8.8 in the Ramganga River, whereas Barai and Kumar [13] reported values of 8.0-8.8 in the Varuna River at Varanasi.

3.3 Turbidity

Turbidity ranged from 18.2 to 31.7 NTU, with a mean value of 25.79 NTU. The lowest value was recorded at S1 and the highest at S7. A progressive increase in turbidity was observed from the upstream region towards the urban and drainage-influenced sites, particularly between S4 and S7. Thereafter, turbidity decreased gradually at S8-S10.

The recorded turbidity values were considerably higher than the BIS acceptable limit of 1 NTU and permissible limit of 5 NTU for drinking water [10]. The higher turbidity may be associated with suspended soil particles, bank erosion, agricultural runoff and domestic drainage entering the river. Gangwar et al. [11] reported turbidity values ranging from 22 to 72 NTU in the Ramganga River at Bareilly, demonstrating that elevated turbidity can occur in Indian river systems affected by human activities. Malik et al. [12] also considered suspended solids and other physical parameters important indicators of lotic-water quality.

3.4 Electrical Conductivity and Total Dissolved Solids

Electrical conductivity (EC) ranged from 412 to 521 $\mu\text{S}/\text{cm}$, with a mean value of 469.20 $\mu\text{S}/\text{cm}$. The minimum EC was observed at S1 and the maximum at S7. Total dissolved solids (TDS) ranged from 264 to 334 mg/L, with a mean value of 300.70 mg/L. Both parameters showed a broadly similar spatial pattern, with increasing concentrations towards the urban and drainage-influenced portion of the river.

The increase in EC and TDS may be related to the addition of dissolved salts and other soluble materials through domestic wastewater, agricultural runoff and surface drainage. The maximum values at S7 indicate greater influence of anthropogenic inputs at this location. The observed TDS values remained below the BIS acceptable limit of 500 mg/L [10]. Malik et al. [12] included TDS and conductivity-related parameters in their assessment of several lotic systems of South Gujarat and reported considerable variation among river systems. Similar spatial variation in dissolved solids has also been reported in other Indian rivers [14].

3.5 Dissolved Oxygen

Dissolved oxygen (DO) varied between 4.9 and 6.2 mg/L, with a mean concentration of 5.50 mg/L. The highest concentration was recorded at S1, while the lowest was observed at S7. A gradual decline in DO was observed from the upstream region towards the urban-influenced portion of the river. A subsequent increase occurred at S8-S10.

The decline in DO towards S7 coincided with increases in turbidity, EC, TDS, BOD and COD. Such an inverse relationship is generally associated with an increased oxygen demand caused by organic and oxidizable materials entering the river. Gangwar et al. [11] reported DO concentrations of 5.8-6.3 mg/L in the Ramganga River and considered DO an important indicator of the organic condition of river water. Barai and Kumar [13] also reported considerable spatial variation in DO in the Varuna River, with concentrations ranging from 0.12 to 8.4 mg/L.

3.6 Biochemical Oxygen Demand and Chemical Oxygen Demand

BOD ranged from 2.1 to 3.2 mg/L, with a mean value of 2.65 mg/L, whereas COD ranged from 18.4 to 29.3 mg/L, with a mean value of 24.12 mg/L. Both parameters increased from S1 towards S7 and subsequently decreased at the downstream sites.

The highest BOD and COD concentrations were recorded at S7, where the lowest DO concentration was also observed. This pattern indicates an increased oxygen demand in the urban and drainage-influenced section. BOD reflects the oxygen requirement associated mainly with biodegradable organic matter, whereas COD represents the oxygen equivalent required for oxidation of chemically oxidizable substances.

Gangwar et al. [11] reported BOD values of 5.0-5.8 mg/L and COD values of 33.5-41.0 mg/L in the Ramganga River, which were higher than the values recorded in the present study. Barai and Kumar [13] also observed

substantial variation in BOD and COD along the Varuna River, particularly at sites influenced by sewage and other anthropogenic activities. Malik et al. [12] similarly considered BOD and COD important parameters for assessing pollution in lotic systems.

3.7 Total Hardness, Calcium Hardness and Magnesium Hardness

Total hardness ranged from 168 to 196 mg/L as CaCO_3 , with a mean value of 183.10 mg/L as CaCO_3 . Calcium hardness ranged from 104 to 121 mg/L as CaCO_3 , while magnesium hardness ranged from 64 to 75 mg/L as CaCO_3 . The maximum values of total, calcium and magnesium hardness were observed at S7.

The total hardness values remained below the BIS acceptable limit of 200 mg/L as CaCO_3 [10]. The increase in hardness towards the urban-influenced sites may be associated with the contribution of calcium- and magnesium-containing dissolved materials through runoff and wastewater inputs. Gangwar et al. [11] reported total hardness of 192-219 mg/L in the Ramganga River, which is comparable to the present observations. Malik et al. [12] also included total hardness in their assessment of lotic systems and demonstrated its usefulness in describing the chemical characteristics of flowing water.

3.8 Alkalinity

Total alkalinity ranged from 142 to 172 mg/L as CaCO_3 , with an average concentration of 158.70 mg/L as CaCO_3 . The lowest value was recorded at S1 and the highest at S7. A gradual increase towards the urban-influenced sites was observed.

All measured values were below the BIS acceptable limit of 200 mg/L as CaCO_3 [10]. The moderate alkalinity indicates a reasonable buffering capacity of the river water. Variation in alkalinity can result from differences in carbonate and bicarbonate inputs, geological conditions and anthropogenic discharges. Gangwar et al. [11] reported alkalinity values ranging from 96 to 202 mg/L in the Ramganga River. Considerable variation in alkalinity has also been reported for the Varuna River, where values of 96-486 mg/L were recorded [13].

3.9 Chloride

Chloride concentration ranged from 48.6 to 68.4 mg/L, with a mean value of 58.46 mg/L. The lowest concentration was recorded at S1, whereas the highest was observed at S7. Chloride showed a gradual increase towards the urban and drainage-influenced section and subsequently declined at the downstream sites.

The observed concentrations were well below the BIS acceptable limit of 250 mg/L and permissible limit of 1000 mg/L [10]. The increase in chloride concentration towards S7 may be associated with domestic wastewater, surface runoff and other anthropogenic inputs. Barai and Kumar [13] reported chloride concentrations of 11-80 mg/L in the Varuna River, which encompasses the range observed in the present study. Malik et al. [12] also included chloride among the major physicochemical parameters used to characterize lotic water quality.

3.10 Sulphate and Nitrate

Sulphate concentration varied from 28.4 to 40.2 mg/L, with a mean value of 34.68 mg/L, while nitrate ranged from 4.8 to 7.4 mg/L, with a mean value of 6.22 mg/L. Both parameters showed their maximum concentrations at S7 and generally declined towards S8-S10.

The sulphate concentrations were substantially below the BIS acceptable limit of 200 mg/L and permissible limit of 400 mg/L, while nitrate remained well below the BIS limit of 45 mg/L [10]. The increase in nitrate towards the urban-influenced sites may be associated with agricultural runoff, domestic wastewater and other nutrient inputs. Barai and Kumar [13] reported nitrate concentrations in the Varuna River and observed marked spatial variation among sampling sites. Soni et al. [14] also reported changes in nutrient-related and other physicochemical characteristics along different locations of the Narmada River.

3.11 Spatial Variation in Physicochemical Characteristics

The overall results showed a distinct spatial pattern in the physicochemical characteristics of the Budhi Gandak River. S1, representing the upstream region, generally showed the lowest concentrations of turbidity, EC, TDS, BOD, COD, hardness, alkalinity, chloride, sulphate and nitrate, while DO was highest at this site. In contrast, S7, located in the major urban and drainage-influenced section, recorded the highest values for most of these parameters and the lowest DO concentration.

The downstream sites S8-S10 showed a partial reduction in turbidity, EC, TDS, BOD, COD, hardness, chloride, sulphate and nitrate, accompanied by an increase in DO. This pattern indicates some improvement in the physicochemical condition downstream of the principal urban-influenced section. However, the observed changes should be interpreted as spatial variation within the sampled river stretch rather than as evidence of complete recovery.

The general pattern is comparable with observations from other Indian rivers. Gangwar et al. [11] documented spatial variation in turbidity, hardness, alkalinity, DO, BOD and COD in the Ramganga River. Malik et al. [12] reported differences in physicochemical characteristics among lotic systems of South Gujarat. Barai and Kumar [13] observed substantial site-to-site variation in DO, BOD, COD, chloride and nitrate in the Varuna River, while Soni et al. [14] reported deterioration in water quality at downstream locations of the Narmada associated with anthropogenic inputs. These earlier observations support the importance of examining physicochemical parameters at multiple locations along a river rather than relying on a single sampling point. Overall, the present observations indicate that the studied stretch of the Budhi Gandak River was characterized by near-neutral to slightly alkaline pH, moderate dissolved solids and hardness, relatively high turbidity, moderate BOD and COD, and a measurable reduction in DO at the urban-influenced sites. Among the parameters examined, turbidity showed the most evident departure from the corresponding BIS drinking-water limits, whereas pH, TDS, hardness, alkalinity, chloride, sulphate and nitrate remained within their respective limits. Since BIS IS 10500 is intended for drinking water, these comparisons are used only as a reference for interpreting the measured concentrations and should not be considered direct river-water quality standards [10].

4. Conclusion

The present study assessed the physicochemical characteristics of the Budhi Gandak River at ten sampling sites in the Begusarai region of Bihar using fifteen parameters. The results showed that the river water remained neutral to slightly alkaline, with pH values ranging from 7.42 to 7.63. TDS, total hardness, alkalinity, chloride, sulphate and nitrate remained within the corresponding BIS IS 10500:2012 limits, whereas turbidity was comparatively high throughout the studied stretch. The highest turbidity was recorded at the urban and drainage-influenced site, indicating the presence of greater suspended material in this section.

A distinct spatial variation was observed along the river. The upstream site generally exhibited lower turbidity, EC, TDS, BOD, COD, hardness, alkalinity, chloride, sulphate and nitrate, together with higher DO. In contrast, S7 recorded the highest values of most physicochemical parameters and the lowest DO. The simultaneous increase in BOD and COD with a decline in DO at the urban-influenced sites indicates a greater load of organic and oxygen-demanding substances. The subsequent reduction in several parameters and partial increase in DO at S8-S10 suggests some downstream improvement in the measured physicochemical characteristics.

For effective management of the river, direct discharge of untreated domestic wastewater and urban drainage into the Budhi Gandak should be controlled, particularly around the S5-S8 stretch. Existing drains discharging into the river should be identified and regularly monitored, while appropriate sewage collection and treatment facilities should be strengthened in nearby settlements. Agricultural runoff should also be minimized through improved drainage and prudent fertilizer application. Regular monitoring at upstream, urban-influenced and

downstream locations should be undertaken to identify deterioration at an early stage and evaluate the effectiveness of pollution-control measures.

Overall, the studied stretch of the Budhi Gandak River showed moderate influence of local anthropogenic activities, with the most evident deterioration occurring around the urban and drainage-influenced section. The study provides useful baseline information for the Begusarai stretch and highlights the importance of continuous water-quality monitoring, wastewater management and control of pollutant inputs for maintaining the ecological and water-quality condition of the river.

References

1. Kumar S., Sinha U., "Effect of Sewage Discharge on the Planktonic Dynamics of the River Budhi Gandak at Samastipur (Bihar)", *Bulletin of Environmental Sciences*, 2005, 23 (2), 57–61.
2. Kumar S., Choudhary S., "Water Quality and Phytoplankton of River Gandak, Bihar (India)", *Pollution Research*, 2016, 35 (1), 167–176. Note: This was received in September 2015 but published in 2016, so I would not use it in the final 2015 reference list if your cutoff is strictly publication year ≤ 2015 .
3. Sharma D., Choudhary S.K., "Evaluation of Water Quality Index for Assessment of Water Quality of the Budhi Gandak River at Khagaria, Bihar, India", *Pollution Research*, 2014, 33 (4), 715–720.
4. Chaudhary S., Kumar U., Kumar U., "Status of Phytoplankton in Chauras of Begusarai, North Bihar", *Research in Environment and Life Sciences*, 2009, 2 (2), 99–102.
5. Mumtazuddin S., Azad A.K., Kumar M., "Assessment of Water Quality of Budhi Gandak River at Muzaffarpur, Bihar, India", *International Journal of Chemical Sciences*, 2009, 7 (4), 2429–2433.
6. Mumtazuddin S., Azad A.K., Bharti P., Ranjan R., "Physico-Chemical Analysis of Groundwater of the Budhi Gandak Belt in Muzaffarpur District, India", *International Research Journal of Environment Sciences*, 2012, 1 (1), 7–11.
7. Mumtazuddin S., Azad A.K., Kumar M., "Assessment of Some Physico-Chemical Characteristics and Heavy Metals in Some Groundwater Samples Along the Budhi Gandak Belt of Muzaffarpur District During Monsoon Season", *Nature Environment and Pollution Technology*, 2012, 11 (2), 293–296.
8. Kumar M., "Physico-Chemical Characteristics of Water of Budhi Gandak River in Muzaffarpur District of Bihar (India)", *Bulletin of Environment, Pharmacology and Life Sciences*, 2015.
9. American Public Health Association, American Water Works Association, Water Environment Federation, *Standard Methods for the Examination of Water and Wastewater*, 22nd Edition, Washington, D.C., 2012.
10. Bureau of Indian Standards, *IS 10500:2012, Drinking Water: Specification*, Bureau of Indian Standards, New Delhi, 2012.
11. Gangwar, R. K., Khare, P., Singh, J., & Singh, A. P. (2012). Assessment of physico-chemical properties of water: River Ramganga at Bareilly, U.P. *Journal of Chemical and Pharmaceutical Research*, 4(9), 4231-4234.
12. Malik, G. M., Joshi, M. P., Zadafiya, S. K., & Raval, V. H. (2012). Study on physico-chemical characterization of some lotic system of South Gujarat, India. *Research Journal of Chemical Sciences*, 2(1), 83-85.
13. Barai, S. R., & Kumar, S. (2013). Evaluation of the physico-chemical characteristics of river Varuna at Varanasi, India. *Journal of Environmental Biology*, 34(2), 259-265.
14. Soni, V. K., Visavadia, M., Gosai, C., Hussain, M. D., Mewada, M. S., Gor, S., & Salahuddin, K. (2013). Evaluation of physico-chemical and microbial parameters on water quality of Narmada River, India. *African Journal of Environmental Science and Technology*, 7(6), 496-503.