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Status of River Water in India: A Review

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Authors' contributions

Both authors contributed to the study conception and design equally. Inception of idea, material and data collection was done by authors PK and MSJ. The first draft of the manuscript was written by author PK. Both the authors and corresponding author has read and approved the final manuscript.

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Review Article

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ABSTRACT

Water means life which is a cyclic, inexhaustible, renewable prime natural resource. It is both a basic human need and a valued asset possessed by all living creatures. Hydrosphere, cryosphere, atmosphere, lithosphere and biosphere are all sources of water around the world. Water covers 71 % of the earth's surface but only 1% of water is potable. Rivers like the Ganga, Yamuna and Sabarmati are revered throughout India. River water is critical for commercial and industrial development, hydroelectric power generation, agriculture, new multipurpose dams and tourism attractions. However, the presence of different contaminants such as pesticides, heavy metals, organic waste, chemical waste and direct sewage discharge has harmed the river's water quality. In India, river water pollution is a major issue that has harmed not only human and animal health, but also the economy of the country. In this review, a substantial number of studies on river water pollution in India are examined. Data on various physical, chemical, and biological characteristics are carefully analysed and interpreted, and it is discovered that river water in India is severely polluted. Furthermore, after careful interpretation of data and discussions published in research articles, this review explains the interrelationships among distinct physical and chemical parameters. EC and TDS are complementary to each other and temperature has a direct impact on

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pH and DO levels. Also, BOD and DO are reciprocally related with each other. This review provides a concise set of guidelines for assessing river water pollution and calculation of water quality index.

Keywords: Importance; water pollution; parameters; interrelationship; water quality index.

1. INTRODUCTION

No water, no life; hence water is the elixir of life. Water and water resources are essential for ensuring continue food supply and a healthy environment for all living species. Water has always been a major factor in the evolution of civilizations and a key component in development of the residential regions [1]. Human beings cannot survive more than few days if they do not have access to water [2] as it ranges in human tissues from 20% in bones to 85% in brain cells. More than 70% of our total body weight is water [3]. According to estimates, each individual requires 20 to 50 litres of clean, safe water every day for drinking, cooking basic hygiene, etc. [1]. Water is a colourless, odourless and tasteless liquid at ambient temperature and pressure. It is formed by two H-atoms and one O- atom resulting in a V- shaped triangular dipole molecule. Due to a small negative charge on O-atom and positive charge on H- atoms, the polarity gives it many peculiar physical and chemical properties which have permitted living things to appear, survive and to evolve on this planet [4,5]. It has highest specific heat, is universal solvent and medium for the most of chemical reactions and is the only substance that occurs naturally in all three states of matter [6,7].

Despite the fact that water covers a large portion of the Earth (71%), just a small portion of it can be exploited for various human activities [7]. Atmosphere, hydrosphere, cryosphere, lithosphere and biosphere are all sources of water over globe. Hydrological cycle circulates water among these sources whereas some of it is present as underground water [1]. Oceans occupy 97% of the planet’s water, 3% of water on the earth is available as freshwater, out of this, 69% lies in glaciers, 30% underground and less than 1% is located in rivers, lakes and swamps. Human beings can access only 1% percent of the water on the Earth’s surface while 99% of the usable quantity is located underground [6]. Rivers, among all sources of water are most important and valuable as they make a network of regular water supply and are considered as the arteries of human civilization [8]. Including domestic use, river water is also critical for commercial and industrial development, hydroelectric power generation, agricultural applications, new multipurpose dams and tourism attractions [1]. Numerous anthropogenic activities, continuously degrading the river water quality and quantity [8,9]. Industries including chemical, dyeing- bleaching, pharmaceutical, textiles, paper-pulp etc. require a large amount of water, which in turn discharges chemicals, effluents and toxic metals in water bodies, soil and ground resulting in degradation of these natural sources leading to serious health issues as millions of people continue to rely on these resources [10,11,12]. Pollution of rivers has harmed the populations of both surface and aquatic animals, putting their lives in jeopardy and has impacted their reproductive ability [13].

The present review examines the available works on river water pollution in India and highlights not only the sources and effects of water pollution as well as the interrelationship among various parameters and calculation of water quality index.

2. SOURCES AND EFFECTS OF WATER POLLUTION

There are numerous sources of river water pollutants. For example, domestic and industrial sources are well defined sources discharging effluents and pollutants through a single point directly into water bodies. These are known as point sources and are easier to check, control and manage. Pollutants coming from vast and wide areas like run-off from agriculture farms, construction sites, abandoned mines etc. are known as non-point sources. Controlling and managing these sources is quite difficult. Natural sources include siltation of water bodies and sources due to human activities are called anthropogenic sources. Any change in water quality from permissible limit cause many water-borne diseases like typhoid, cholera, hepatitis etc. leading to huge life and economy disruption. Also, the food chain gets disrupted, when toxins and pollutants enter in it through polluted water, primary and secondary carriers and then to human beings. Being highly dynamic in nature, the ecosystem responds to even small changes in the surroundings; water pollution can lead to the collapse of an entire ecosystem if left unchecked, for example eutrophication [14].

3. WATER QUALITY PARAMETERS AND THEIR PERMISSIBLE LIMIT

Water quality standards have been established by a number of national and international organizations like BIS [15] (Table 1). If the water in rivers and other water bodies meet these quality criteria, then only it is safe for drinking and other purposes [16].

4. EVALUATION OF WATER QUALITY

Water quality of any water body can be evaluated by physical, chemical and biological assessment.

4.1 Physical Parameters

The physical status of any water body is evaluated by its electrical conductance (EC), temperature, total dissolved solids (TDS) and turbidity. Electrical conductance provides the concentration of ions in a given volume of water. More the ions present, higher will be the conductance and vice-versa. Therefore, EC and TDS are complementary to each other [17]. Temperature is an important parameter for assessing the water quality as it has a direct impact on pH and dissolved oxygen (DO) levels (Saikh and Yeragi, 2003). Panda et al. [18] found lower pH of Salandi river water in May which may be due to the liberation of CO_2 from the decomposition of organic matters at high temperature. Saxena and Singh [19] while assessing the water quality and river health of the River Ganga at Varanasi discovered that pH and DO are at lowest levels during summer season (16March-15May) (presented in Table 2). The increased microbial activity involved in the decomposition of organic wastes due to high temperature in summers causes the DO and pH to decline. Total dissolved solids is a measurement of total solids in a water body including inorganic salt, organic compounds and other soluble substances [20,21]. TDS is higher in rainy and post-rainy seasons due to the entry of agricultural wastes, domestic wastes, forest run off, industrial wastes, mining wastes and soil erosion. And the lower TDS value in summer is due to silt and settling of dissolved materials [22-24] in River Narmada found higher TDS during the rainy season and lower during winter season. Also, Sharma et al. [25] in River Yamuna found highest TDS value during rainy season (July) and the lowest value in the month of October (Table 3). Turbidity is the measure of the transparency and cleanliness of any water body and is higher in the rainy season due to soil erosion and floating particles, whereas it is lower in the summer and winter due to settling of floating materials [22,23]. Panda et al. [24] observed higher turbidity in rainy season and lower in the summer season in river Salandi (Table 4). Similar results were also found by Sharma et al. [26] in river Sutlej.

Table 1. Water quality parameters and their permissible limit

Water quality parameters	Bureau of Indian standards
pH	6.5- 8.5
Dissolved oxygen (DO) (mg/l)	-
Biochemical oxygen demand (BOD) (mg/l)	-
Chemical oxygen demand (COD) (mg/l)	-
Turbidity (NTU)	5
Total Dissolved Solids (mg/l)	2000
Nitrate (mg/l)	45
Phosphate (mg/l)	-
Calcium (mg/l)	200
Magnesium (mg/l)	100
Chloride (mg/l)	1000
Fluoride (mg/l)	1.5
Total hardness CaCo3 (mg/l)	600
Total Coliform Bacteria	Nil/100ml

Source: (Bureau of Indian Standards, 2012)

Table 2. Seasonal range of parameters observed in River Ganga near Varanasi during year 2017- 2018

Parameters	Unit	Post Monsoon (16Sep-15Nov)	Winter (16Nov-15Jan)	Spring (16Jan-15Mar)	Summer (16Mar-15May)	Inference
Temperature	°C	23.4-24.9	17.1-18.0	22.3-23.8	27.3-28.2	Low pH and DO values are in summer. High BOD values are in post-monsoon season.
pH		7.8-8.3	8.1-8.6	7.9-8.6	7.5-8.0	
EC	µmhos/cm	572-650	293-372	332-390	420-1100	
DO	mg/L	4.2-6.7	4.6-6.5	4.2-6.3	2.9-5.9	
BOD	mg/L	4.7-6.8	3.9-6.0	4.0-6.4	4.4-6.9	
COD	mg/L	40-68	42-78	52-80	52-110	
FC	MPN/100 mL	1200-3100	1200-2200	1200-1900	1600-3300	

Table 3. Analysis of physical and chemical parameters for River Yamuna at Dehradun in year 2019

Parameters	January	April	July	October	Remarks
pH	7.82	7.78	7.62	7.72	
DO	8.6	8.6	8.6	9	
BOD (mg/L)	1.2	1	1	1	
COD (mg/L)	6	1	4	6	Highest TDS value is found in month of July
TDS	76	72	105	82	Maximum COD is found in January and October; minimum COD is found in May and July
Chlorides	6	5	7	5	
Calcium as CaCO3	44	36	46	38	
Magnesium as CaCO3	30	32	36	32	
Hardness as CaCO3	74	68	82	70	

Table 4. Water quality of river Salandi in 2015

Parameters	May	August	October	December	Inference
pH	7	7.1	7.1	6.9	
Turbidity (mg/L)	6	11	10	7	Higher turbidity is found in August and lower in May
DO (mg/L)	7.2	7.2	7.0	7.2	
BOD (mg/L)	2.6	5.0	5.2	5.0	

4.2 Chemical Parameters

In order to study the chemical quality of water the parameters like pH, total hardness, Ca and Mg hardness, DO, BOD, COD, chloride, nitrate, phosphate, fluoride and heavy metals have to be considered.

4.2.1 pH, Ca, Mg and total hardness

Knowledge of the pH is a critical parameter for maintenance and management of any water body [27,28]. While studying the water quality of the river Mahanadi, Atharabanki and Taladanda, Samantray et al. (2009) found comparatively lower value of pH during summer season than post-monsoon and winter season, which they attribute to organic matter breakdown at high temperatures and low water flow during the summer [29]. Similar results were obtained for Salandi river by Panda et al. [18]. Panigrahi et al. [30] observed a greater value of Mg^{2+} (6.40 mg/l) than Ca^{2+} (6.33 mg/l) in river Mahanadi at Cuttack city in the downstream during summer season. Panda et al. (2017) found higher concentration of Ca in the rainy and post-rainy seasons and higher concentration of Mg than Ca during the summer season (April and May) in the river Salandi. It may be due to greater CO_2 content in May, which is the result of breakdown of organic matter at high temperature forming soluble Magnesium bicarbonate from insoluble Magnesium carbonate, that rises Magnesium hardness in the summer compared to Calcium hardness. Due to lesser solubility of calcium compounds and the fact that magnesium compounds are often more soluble than calcium compounds, the same thing is unlikely to occur in the case of calcium [18].

4.2.2 DO, Biological oxygen demand (BOD) and chemical oxygen demand (COD)

The amount of DO decides the health of aquatic ecosystem. Agricultural runoff, sewage, soil and other organic pollutants can lower the DO level which impacts the lives of aquatic organisms [31] Samantray *et al*. [29] in Mahandi (Table 5) river water found lower DO in summer season than in rainy and winter seasons. Panda *et al*. [18] found lower DO during summer season in Salandi river. The reason for this may be low flow of water, evaporation due to high temperature, low rate of photosynthesis by autotrops and after all low rate of dissolution of atmospheric oxygen in summers. Sharma et al. [25] in Yamuna River found maximum value of DO in summer season (April) and the minimum value in rainy season (July). BOD is the amount of oxygen required by micro-organisms for stabilizing biologically decomposable organic matter under aerobic conditions which is being used to assess the level of water pollution [5]. Moza et al. [32] analyzed the water quality of the river Beas at Talawara (Table 6) during pre-monsoon, monsoon and post-monsoon seasons and found that BOD decreases in monsoon and increases in post monsoon which may be due to the increase in hardness than in monsoon and pre monsoon seasons. Singh et al. [33] found higher BOD values during the rainy season in the river Iril and Nambul of Manipur. The higher value during the rainy and post-rainy seasons can be due to heavy flood and rain water that transports forest run-off, mining discharges, industrial effluents, urban wastes, agricultural waste and massive residential wastes in the rivers. Mishra and Tripathy (2007) found highest mean value of BOD (589.0 mg/L) during summer and lowest during winter season in Ganga [34]. Similar results were found by Singh et al. [35] for Narmada. Higher oxygen consumption rate and a higher pollution load are both indicative of higher BOD values. While summer maximums are caused by the quick oxidation of oxygen at higher temperatures, low BOD in winters is primarily due to improved oxygen solubility at low temperatures. The COD value determines the degree of water pollution and river's ability to purify itself which is required to oxidize the organic and inorganic pollutants. COD for given water sample is always higher than the BOD but must be less than 20 mg/L [17]. Singh et al. [35] reported lowest COD value (8.6 mg/l) in winter and highest in summer season (64 mg/l) for Narmada due to mixing of wastewater. While Sharma et al. (2020) in Yamuna (Table 3) found maximum COD in January and October and minimum in April and July [25].

4.2.3 Chloride, fluoride, nitrate and phosphate

Chlorides in river water are present in the form of soluble salts of Sodium and Magnesium. Domestic sewage, industrial discharges, urban waste materials, fertilizer and pesticides, bleaching chemicals, septic tank effluents, and animal feeds are the main sources of chloride [27]. Joshi et al. [31] found maximum concentration of chloride (13.48 mg/l) in rainy season and minimum (1.97 mg/l) in winter season in Ganga. While Kalavathy et al. [36]

found higher concentration of chloride during the summer season (94-100 mg/L) than the winter season (Table 7) in Cauvery. Fluoride is a crucial criterion for determining the quality of potable water as it causes fluorosis when exceeds from 0.6 to 1.5 mg/L [15]. The principal sources of fluoride are sodium fluoride (NaF), fluorosilisic acid (H_2SiF_6), CaF_2, cryolite (Na_3AlF_6) and phosphate fertilizers [37,17].

Haritash et al. [37,38] analyzed the water quality of Ganga in Rishikesh and found fairly low value of fluoride than the standard limit of 1.0 mg/l. Kaur and Singh (2012) found concentration of nitrate and phosphate highest during the monsoon in river Yamuna at Delhi which may be due to the flow of mining effluents, agricultural runoff, forest runoff, industrial wastes and urban wastes to the river water [39]. Mishra et al. [34] reported higher NO^{3-} and $PO_4{}^{3-}$ during summer than rainy and winter seasons in the Ganga at Varanasi. Chakravarty and Gupta [40] found the highest concentrations of $PO_4{}^{3-}$ during post monsoon season in rivers of south Assam. High values of nitrate and phosphate during summers and post monsoon seasons may be attributed to low flow in rivers which can enhance the chances of eutrophication.

Table 5. Seasonal water quality of the river Mahandi

Season	pH	BOD (mg/L)	DO (mg/L)	Inference
Summer	6.85	5.0	5.9	The DO is low and BOD is high in summer than
Post monsoon	7.07	4.7	6.3	winter and post-monsoon season.
Winter	7.0	4.8	6.1	pH is low during summer than winter & post – monsoon season.

Table 6. Seasonal water quality of the Beas at Talwara

Station	Season	Parameters	Content (mg/L)	Inference
	Pre-monsoon	DO	8.7	
		BOD	9.0 mg/L	
	Monsoon	DO	7.9 mg/L	Decreases
Talwara		BOD	3.83 mg/L	Decreases
	Post- monsoon	DO	7.3 mg/L	Decreases
		BOD	6.4 mg/L	Increases
	Winter	DO	9.0 mg/L	Increases (Highest)
		BOD	12.0mg/L	Increases

Table 7. Monthly water quality of the river Cauvery at Pettavaithalai

Parameters (mg/l except pH)	January	February	March	Inference
pH	8.4	8.8	8.6	
Chloride	51	86	94	Maximum Chloride is found in March and
Nitrate	0.01	0.15	0.1	minimum in January
Total Hardness	169	162	160	

Table 8. Heavy metal concentration in river Kali

Heavy metals	Water quality (Mean± S.D)		Inference
	Pre-monsoon	Post-monsoon	
Fe	1.77±0.87	1.53±0.75	
Cr	0.09±0.03	0.06±0.02	Minimum cumulative concentration of heavy
Cd	0.08±0.03	0.06±0.03	metals is during the post-monsoon season and
Zn	29.71±7.59	24.71±6.42	maximum during the pre-monsoon season
Pb	0.19±0.13	0.13±0.07	

4.2.4 Heavy metals

Singh and Pandey [33] found highest heavy metal concentrations during winter season in the Ganga. Mishra et al. [41] reported lowest cumulative concentration of heavy metals during the post-monsoon and highest during the pre-monsoon season in river Kali (Table 8). Setia et al. [42] assessed ten metals (Zn, Cu, Fe, Mn, Ni, Cd, Pb, Co, Cr, and As) in Sutlej water and found highest average concentration of Fe among all the metals during pre-monsoon and post-monsoon seasons. They also observed highest Zn, Cu, Fe, Cr, and Co concentrations in pre-monsoon and lowest in the post-monsoon season.

4.3 Biological Assessment

Mishra et al. [34] observed the presence of *Actinomycetes*, *Streptococcus, Salmonella typhi, Escherichia coli*, *Pseudomonas aeruginosa* and *Bacillus anthracis* bacteria in the river Ganga at Varanasi. The amount of bacteria was more in rainy season than summer and winter seasons. Similar results were found by Singh and Kumar [43] for river Gomati and Sharma et al. for the river Bhagirathi [26].

Table 9. The standard values of water quality index (WQI) using weight arithmetic water quality index method

Grading	WQI value	Water quality rating
A	0–25	Excellent
B	26–50	Good
C	51–75	Poor
D	76–100	Very poor
E	Above 100	Unsuitable for drinking

Source: [25]

5. WATER QUALITY INDEX (WQI) MODEL

Globally, the WQI model has been applied to evaluate water quality (surface water and groundwater) based on local water quality criteria [44]. It is a dimensionless number achieved by studying many parameters affecting water quality into a single number [45]. Sangani and Manoj (2020) computed WQI for river Tapi (presented in Table 10) and found that the average value of WQI at upstream reference site fell under category of good water quality, whereas spatial variations in water quality were observed with WQI>100 indicating poor quality of water [46].

5.1 Calculation of Water Quality Index

WQI is calculated on the basis of several physical and chemical parameters which are then multiplied by a weighing factor and the final aggregate is obtained using arithmetic mean [46].

$WQI = \sum W_iQ_i / W_i$

Where,

Q_i = Quality rating
W_i = Unit weight

The quality Rating (Qi) scale for each parameter can be calculated by using the formula:

$Qi = 100\ [(Vn-Vi)/\ (Vs-vi)]$

Where;

Vn = Estimated value of parameter in sample

Vi= Ideal value in pure water

Vs= Standard unit

Wi (Unit weight) = K/Si

K (Proportionality constant) = $\frac{1}{\sum 1/Si}$

Si= Standard value

6. DISCUSSION

In light of the above study it can be concluded that the level of water pollution in Indian rivers has reached the alarming stage. The quality of water in most of the rivers has degraded in terms of physical, chemical and biological properties. The work shows that temperature is an important parameter for assessing the water quality as it has a direct impact on pH and dissolved oxygen levels. The DO is related with temperature, photosynthesis, respiration and turbidity. DO is lower during summer season due to high temperature and higher during winter season due to low temperature. Hence temperature and DO are inversely related. Also, EC and TDS are complementary to each other and BOD and DO are reciprocally related with each other. In addition, higher turbidity is found in monsoon than in pre-monsoon and post- monsoon season. The study of these parameters is important for proper assessment of water quality as their concentration above the permissible limits deteriorates the quality of water and makes it unfit for drinking and other purposes.

Table 10. Water quality parameters and water quality index at three different sites along the stretch of Tapi

Parameters	Annual Average (Vi)			Ideal value	Std. value		Wi	Qi			Wi* Qi		
	G	**U**	**AK**	**Vo**	**Si**			**G**	**U**	**AK**	**G**	**U**	**AK**
Temp.	24.35	24.73	224.78	0.0	30.0	0.0333	0.00356	81.167	82.444	82.611	0.289	0.294	0.295
pH	7.616	7.920	7.907	7.0	8.5	0.1176	0.01258	41.056	61.333	60.444	0.517	0.772	0.761
DO	7.551	6.829	6.520	14.6	5.0	0.2000	0.02140	73.432	80.944	84.167	1.571	1.732	1.801
NO_3	1.865	4.457	5.313	0.0	50.0	0.0200	0.00214	3.729	8.914	10.625	0.008	0.019	0.023
NO_2	0.024	0.054	0.052	0.0	0.5	2.0000	0.21400	4.767	10.867	10.483	1.020	2.325	2.243
NH_4	0.295	0.456	0.532	0.0	0.2	5.0000	0.53500	147.250	228.042	266.083	78.779	122.002	142.355
PO_4	0.170	0.442	0.480	0.0	0.5	2.0000	0.21400	34.050	88.333	95.900	7.287	18.903	20.523
TC	2958.3	5025.0	5508.3	0.0	5000	0.0002	0.00002	59.167	100.500	110.167	0.001	0.002	0.002
FC	264.1	400.0	426.6	0.0	1000	0.0010	0.00010	26.417	40.000	42.667	0.003	0.004	0.005
FS	356.6	181.6	220.8	0.0	200	0.0050	0.00053	178.333	90.833	110.417	0.095	0.049	0.059
						9.3438					**89.571**	**145.975**	**167.937**
					K	**0.107**	**1.003**			**WQI**	**89.271**	**145.616**	**167.524**

Source: Sangani and Manoj (2020)

7. CONCLUSION

Rivers are the main lifeline of India. Many cities are located around river banks. Rivers also play a vital role for the biodiversity. River water pollution is a major issue in India and severity of the problem varies from place to place. Due to the inflow of pollutants from diverse sources such as industry, mines, agricultural, urban, domestic, and medicals, the present review indicates that river water is severely polluted in terms of physical, chemical, and bacteriological properties. The quality of river water is crucial for the aquatic ecosystem as, a variety of zooplankton, phytoplankton, bacteria, fishes, and mollusk kinds establish their habitat in these ecosystems. Algae, small animals, insects, small fish, and giant fish all play a role in the river food chain. As river pollution is increasing on a daily basis, various heavy metals such as Pb, Cd, and Zn enter into fish body and find their way into the food chain; thus disturbing the balance of the environment. Moreover, this review also establishes a link among several physical and chemical parameters. EC and TDS are complementary to each other and temperature has a direct impact on pH and DO levels. Also, the review finds that BOD and DO are reciprocally related with each other. Furthermore, this review gives detail about water quality index and its calculation for evaluating the water quality so as to study and check the water pollution for the benefit of the society as a whole.

AVAILABILITY OF DATA AND MATERIALS

All the data and material was collected from various research papers.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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