

Assessment of water quality index of River Ganga and Yamuna in the foothills of Himalayas

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Abstract: Water quality index, a single number or grade, represents the data on various quality parameters into a simpler form which is understandable by public. Overall water quality at certain time and location expressed by water quality index has been used as a criterion for sketching water policies. This study attempts in providing information on the water quality of river Ganga and Yamuna in foothills of Himalayas. The water quality of these rivers is facing great risk from anthropogenic activities like tourist arrival, industrial waste, and closed hydropower projects. In the present study, water quality index has been assessed with the aim of evaluating the water quality for general public consumption, recreational, and ecological purpose. Water quality index has been prepared for four seasons using eleven water quality parameters. The results showed severe drop in water quality. This study found that natural and anthropogenic factors are responsible for deteriorating the water quality of both rivers.

Key words: Water Quality, Ganga, Yamuna, Water Quality Index.

“1. Introduction”

Water plays pivotal role in our life and its availability is essential both in term of quality and quantity for the very existence of the mankind. It is well known fact that potable safe water is absolutely necessary for healthy living. Due to rapid growth of population and the accelerated pace of industrialization, a tremendous pressure has been made on fresh water demand. Water has been the most available sources for domestic purposes and it is getting polluted too. According to World Health Organization report 2004 [47] every year about 1.8 million people, mostly children, die as a result of water related diseases. Ojekunle [1] & Ayeni [4] mentioned that pollution potential in the water body depends on domestic, agricultural, and industrial wastes. Jaiswal [30], Singh [25], Ouyang [50], Shrestha and Kazma [39] reported that due to natural and anthropogenic activities, the quality of water is deteriorating rapidly. Dixit [40] has mentioned that due to anthropogenic contamination of water, it is becoming necessary to do monitoring and assessment of water quality of rivers. Similarly, Ramakrishnaiah [11] has also reported that regular water quality monitoring is important to protect the surface water quality of rivers and aquatic life. River water quality can be assessed by various statistical techniques (such as multivariate analysis), water quality

index (WQI) and water quality modeling. Multivariate techniques help in spatial and temporal analysis of water quality, whereas water quality modeling needs comprehensive data and time. According to Bordalo [3] & Asadi [38] found that WQI is a very useful tool for communicating the information for overall quality of water (both surface water and groundwater) to the concerned citizens and policy makers. Yogendra [26] reported that WQI is mathematical equation in which data is incorporated from various water quality parameters to rate the health of water body in terms of number. Simoes [19] and Liou [36] reported that WQI is one of the simple and important tools available for the water quality management. In the present study weighted arithmetic water quality index is used for assessing the quality of water river and water class. It is calculated by using most commonly measured water quality parameters such as *turbidity, pH, chloride, TDS, TH, Pb, Cu, Fe, Zn, BOD and DO*. Several authors have used weighted arithmetic water quality index for assessing the surface water and ground water quality in different parts of the world [5, 13, 22 and 34].

1.1. Water quality index:

Numerous WQI are developed and applied on surface and groundwater ecosystem throughout the

world. Horton [28] proposed the first formal WQI, which indicates the quality by an index number, representing the overall quality of water for any intended use using 10 water quality variables. Brown [29] formulated a convenient WQI based on expert opinion. It has been accepted by National Sanitation Foundation (NSF), USA, and is widely used in many countries [46]. In 1979, Dunnette [14] developed Oregon WQI (OWQI), later Cude [9] devised OWQI for River Oregon by using 8 water quality parameters. OWQI depends on harmonic averaging concept. Even though, the OWQI assess change in water quality very significantly for in terms of water quality and impacts on it; however, it cannot assess impacts of all types of environmental hazards. Bhargav [15] formulated first Indian WQI for zoning and classification of River Ganga with respect to specific issue of drinking water supply. This index used 4 groups of parameters (concentration of coliform, toxicants and heavy metals, colour, odour and turbidity, sulfide and chloride). In 1987, Smith [16] had developed a hybrid WQI based on Delphi method. In 1990, Ved Prakash has also used NSF WQI after making minor amendments to assess the use of water for different purposes such as agriculture, bathing and drinking as stated by Central Pollution Control Board (CPCB), New Delhi. In 1995 Canadian Ministry of Environment developed British Columbia WQI (BCWQI). It helps in assessing water quality by comparing measured parameters of water quality with the prescribed limits. It is similar to Canadian Council of Ministers of the Environment WQI (CCME WQI) which is more accurate as they have considered more number of samples. Drawback of this WQI is that it does not indicate the water trend until it has maximum deviation from its standard limit. In 2001, Canadian Council of Ministers of the Environment (CCME) developed CCME WQI [10] for assessing water quality to provide information to the water quality executives and local people. The CCMEWQI is easy to calculate, flexible in the selection of parameters, can be used for legal requirements also. Cash [24], Husain [42], Lumb [17], Sharma [43], Khan [18], and Paterson [31] used CCMEWQI for analyzing water quality. For Indian rivers, Sargaonkar and Deshpande [2] built overall index of pollution (OIP). Liou [36] presented Index of water quality which uses multiplicative aggregate function of standardized scores for a number of water quality parameters to assess the health of river body in Taiwan. Tsegaye [44] proposed chemical water quality index to assess the water of lake. Sisodia [33] developed weighed arithmetic WQI for Kalakho Lake based on physico-chemical parameters for 4 different seasons to assess the impacts of industries, agriculture and human activities. Silva [27] used factorial correspondence analysis to build a WQI, to evaluate the impact of the anthropogenic factors on shallow ground water aquifers

by analysing the kriged maps of the values of the index, to identify the areas more sensitive to anthropogenic impact. Rizwan [32] developed WQI for Angul- Talcher region of Orissa to assess spatial and temporal changes in ground water quality. Karbassi [7] developed NSF-WQI to evaluate water quality of River Gorganrood with some modification in NSF weights using Analytical Hierarchy Process (AHP). Akoteyon [21] used Weighted Arithmetic index for urban river Lagos-Nigeria and it was found that water is suitable for human consumption.

2. The study area:

The study area is state of Uttarakhand, India. Uttarakhand have diverse resources in terms of flora and fauna in the foothills of Himalayas. It is also nourished by significant water sources i.e. rivers of India, which include two of the biggest rivers, Ganga and Yamuna. Uttarakhand is bordered by Tibet, Nepal, Himachal Pradesh and Uttar Pradesh on north, east, west and south, respectively. It lies between geo-coordinates from 30°19'48" N to 78°03'36" E. 88 The geographical area is 53566 sq. km, out of which, about 85% is hilly/forest/glacier area and the remaining 15% area buzzes with commercial activities. Uttarakhand is divided into two geographical areas namely, Garhwal and Kumaon area. Garhwal area is nourished by rivers Ganga, Yamuna and Tons; while the rivers Kosi, Ramganga, Gola etc. flow through the Kumaon area. The water samples were collected from 15 and 5 monitoring sites of rivers Ganga and Yamuna, respectively. The Ganga originates from the western Himalayas in the state of Uttarakhand, and flows in the south-east direction through the Gangetic Plain of Northern India (about 2,525 km), thereby converging in the Bay of Bengal. The river Ganga actually arises due to the confluence of Bhagirathi and Alaknanda rivers at Deoprayag. Various rivers contribute to Ganga at different points, namely Bhagirathi at Gangotri, river Alaknanda B/c Nandprayag, river Mandakani B/c Nandprayag, river Alaknanda A/c Nandprayag, river Alaknanda B/c Karanprayag, river Pindar B/c Karanprayag, river Alaknanda A/c Karanprayag, river Bhagirathi Uttarkashi D/s, river Alaknanda Rudraprayag U/s, river Alaknanda Rudraprayag D/s, river Alaknanda B/c Deoprayag, river Bhagirathi B/c Deoprayag and river Ganga A/c Deoprayag. The Ganga receives domestic sewage and heavy effluent discharges from industries such as paper manufacturing, distillery, sugar manufacturing, electroplating and automobiles. The Yamuna originates from the Yamunotri glacier at Banderpoonch peak in the Uttarkashi district of Uttarakhand. The catchment of the river extends to states of Uttarakhand, Uttar Pradesh, Himachal Pradesh, Haryana, Rajasthan, Madhya Pradesh and the entire union territory of Delhi. The river flows 1,367 km from here to its confluence with the Ganga at Allahabad.

Sampling points on river Yamuna are: Yamuna at Yamuntori, river Yamuna Dakpathar U/s, river Yamuna, Vikas Nagar D/s, river Tons D/s Dehradun and river Tons before its confluence with Yamuna. As a result, the Yamuna receives heavy discharge and pollutants from small scale industries including paper, sugar, spices, chemical, leather, distillery, television manufacturing, pharmaceutical, power etc. present in Vikas Nagar and from pesticide industry, which is present before the confluence of river Tons with Yamuna.

3. Sample collection and sample analysis:

Samples were collected in 2000 ml polyethylene sterilized bottles (cleaned with metal free soap, washed with distilled water, soaked in 10% nitric acid for 24 hrs. and finally, rinsed with ultrapure water). Water samples were stored in an insulated, ice cooled container and delivered to the laboratory on the same day. All the samples were kept at 4°C to avoid physico-chemical changes and interference. The sampling, preservation, transportation and analysis of water samples was carried out according to the methods described in APHA-AWWA-WEF (1998). The polyethylene bottles used for storing samples were sealed with tape to make the sample free from air contact. A total of 18 parameters viz. pH, turbidity, dissolved oxygen (DO), electric conductivity (EC), total dissolved solids (TDS) and temperature (Temp.) were measured onsite by portable pH meter, turbidity meter, DO meter, conductivity meter and thermometer; whereas the other parameters viz. total hardness (TH), biochemical oxygen demand (BOD), total alkalinity (TA), total suspended solid (TSS), Cl, Na⁺, K, PO₄ Pb, Cu, Fe and Zn were analysed in laboratory using standard protocol APHA-AWWA-WEF (1998).

4. Calculation of water quality index:

In this study WQI is built using weighted arithmetic index method with the help of eleven most important water quality parameter namely turbidity, pH, chloride, TDS, TH, Pb, Cu, Fe, Zn, BOD and DO. WQI is calculated as per following.

$$WQI = \frac{\sum q_n W_n}{\sum W_n} \text{-----(1)}$$

$$q_n = 100[(V_n - V_{io}) / (S_n - V_{io})] \text{-----(2)}$$

Here, q_n = quality rating for the n th water quality parameter.

V_n = estimated value of the n th parameter at a given sampling station.

S_n = recommended standard or permissible value of n th parameter

V_{io} = ideal value of n th parameter in pure water.

All the ideal values (V_{io}) are taken as zero for drinking water except for pH=7.0 and dissolved oxygen=14.6mg/L.

Unit weight (W_n) for n th parameter is calculated as per following

$$W_n = K/S_n \text{-----(3)}$$

Where K = constant for proportionality.

For the sake of simplicity, the value of K is taken as 1 [35]

For, pH, assuming the same unit weight as that of chloride [12]. The unit weight W_i , obtained from above equation with $K=1$ are shown in table 1

Table 1 : Drinking water standards, recommending agencies and unit weight [8, 20].

Parameters	Indian Standards and Recommended Agency	Unit weight
Turbidity	5 NTU (BIS)	0.2
pH	6.5–8.5 (ICMR/BIS)	.004
Chloride	250 (ICMR)	.004
TDS	500 (BIS)	.002
TH	300 (BIS)	.0033
Pb	.05 (BIS)	20
Cu	.05 (BIS)	20
Fe	.3 (BIS)	3.3
Zn	5 (BIS)	0.2
BOD	5 (ICMR)	0.2
DO	5 (ICMR)	0.2

5. Result and Discussion:

The maximum, minimum and mean values of some selected physico-chemical parameters of water samples collected at different points of river Ganga, Yamuna along with WQI of River Ganga and Yamuna for different season are presented in the Table 2 & 3, respectively.

The mean DO values for River Ganga and Yamuna for all four seasons ranged from 6.4 to 7.4 mg/L & 5.7 - 7.6 mg/l. Maximum DO was observed during January at River Bhagirathi Gangotri, River Alaknanda before confluence at Nandprayag and River Yamuna at Yamunotri, thereafter it started declining gradually and it reached the lowest concentration at River Bhagirathi Uttarkashi Downstream in July because of sediments coming from the erosion of Varunvat mountain. Whereas, in the month of April minimum DO was observed at River Ganga at Haridwar downstream as tourist influx was more during this time which results in the direct disposal of hotel waste into the river body For River Yamuna, it was observed high temperature at River Tons downstream Dehradun due to which oxygen holding capacity of water decreases. pH is an important factor, which help in assessing the suitability of water

quality for different uses. It acts as an index for the pollution. Variation in pH affects taste, corrosion, coagulation and disinfection rate of water. The mean pH values varied between 7.9-8.1 for River Ganga and 7.9-8 for River Yamuna. In the present study, pH values were within the BIS standards (6.5-8.5). In River Ganga and Yamuna, alkaline nature of water was present throughout the study, no seasonal fluctuation was noticed. BOD is an important parameter for water quality assessment. It is the measurement of the amount of biologically oxidizing organic matter present in waste. Disposal of wastewater, agricultural runoff and industrial effluent are the main cause for increased level of BOD in water. High BOD values lead to anaerobic condition causing increase in the concentration of nutrients like nitrogen and phosphorus which leads to eutrophication in river body. Permissible limit for BOD is 5 mg/L. The mean value of BOD for River Ganga and Yamuna were 6.5-8.2 mg/l and 4.7-8.6 mg/l, respectively, indicating water is eutrophic in nature. TDS show presence of various kinds of minerals in water. In the present study, the TDS value varied from 169.8-268.2 mg/l in River Ganga and 155.4-217.6 mg/l in River Yamuna, were found within the permissible limit of BIS in all four seasons. It was observed that in the month of April TDS of River Ganga was recorded more than the standard permissible limit. The possible source of TDS in river Ganga could be erosion from Varun Vat Mountain and shut down H.E projects. For River Ganga and Yamuna, mean turbidity is in between 18-26.4 mg/l and 17.4-34.8 mg/l, respectively. According to NEERI, 2011 report [49] turbidity is a measure of murkiness of water, reflecting the amount of light. If turbidity is more in water it will reduce the amount of light available to plants and animals living under the water thereby affecting the photosynthesis rate of plants and making it difficult for aquatic animals to see their prey. Turbidity was found higher on all sampling sites of River Ganga and Yamuna throughout the year because the direct disposal of hotel waste and cottage industries effluent, erosion, building of roads, hydroelectric projects and industries present along the rivers are responsible for increase in turbid water. Total Hardness for River Ganga and Yamuna were recorded to be under the prescribed limit of BIS. The mean values of hardness for both were 177.7-185.8 mg/l and 176-255.5 mg/l. Chloride (Cl^-) is one of the common elements found in all types of rocks of one form or the other form [37]. The mean chloride values for River Ganga and Yamuna ranged from 8.8-11.9 mg/l and 6.8-10.8 mg/l respectively. Egereonu [45] reported that due to presence of high concentration of chloride in water make it unsuitable for human and livestock consumption. The chloride in River Ganga and Yamuna water was found within the acceptable limit prescribed by BIS i.e. 250 mg/L. Presence of chlorides above the

required acceptable limits is an indicator of pollution by domestic sewage. Concentration of chloride is normally low in natural surface water. The concentration of heavy metals such as lead (Pb), copper (Cu) & iron (Fe) were not within the permissible level of BIS. The mean value of Pb varies from 0.15-0.31 mg/l, Cu varies from 0.64-1 mg/l and Fe varies from 0.23-0.3 mg/l in Ganga River for all four seasons; whereas, in case of Yamuna river, the mean concentration of Cu concentration varies from 0.35-0.59 mg/l, Fe concentration varies from 0.15-0.24 mg/l in all four seasons which is above prescribed limit of BIS. High concentration of lead in River Ganga is attributed due to several factors - natural factors like Uttarkashi valley is rich in radioactive elements and lead is the daughter element of Uranium and anthropogenic factors [49] (Disposal of sewage, industrial effluent). Fe leads to coloration of the water thus initiating sedimentation in the systems, which can result to corrosion. In addition, Fe affects the organoleptic quality of water as do other metals such as copper, aluminum and zinc. The concentration of lead (River Yamuna only) and zinc was found to be within the permissible limits of BIS in both rivers.

The WQIs for four different seasons have been tabulated in Table 3. WQI values in all four seasons were found to be poor and unsuitable for human consumption at all points of River Ganga and Yamuna except at River Bhagirathi at Gangotri and River Yamuna at Yamunotri. but it was observed that both rivers were severely deteriorated following points - River Bhagirathi at Uttarkashi downstream, River Alkananda Rudrapur upstream, River Alkananda Deoprayag before confluence, River Ganga Rishikesh Upstream, River Ganga Haridwar Downstream, River Yamuna Dakphatar upstream, River Yamuna at Vikas Nagar downstream and River Tons downstream Dehradun because at these points - turbidity, BOD, heavy metal concentrations were recorded higher than the prescribed limits. Table 4 explains classification based on WQI criteria, which in turn, indicates that WQI of all sampling location is not within category of good water (50-100) in all four seasons

5.1 Suggestions:

Following are the suggestions recommended to be applied in River Ganga and Yamuna basin

- River front development including bathing ghat
- Interception and diversion (I&D) of sewage, reaching the Ganga and Yamuna Rivers.
- Installing treatment facilities to treat the intercepted sewage. [41]

6. Conclusion:

It is concluded that the water quality of River Ganga and River Yamuna almost at all sites were polluted as indicated by WQI. It has been observed in this study

that WQI is found to be useful in assessing the overall quality of river water and to get rid of judgment on quality of the water. This method appears to be systematic and gives comparative evaluation of the water quality of sampling stations. It is also helpful for public to understand the quality of water as well as being a useful tool in many ways in the field of water quality management.

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Table 2: Descriptive Statistics of river Ganga and Yamuna

		River Ganga				River Yamuna			
Parameter		Jan	April	July	October	Jan	April	July	October
DO	Minimum	4.6	4.2	3.6	4.2	5.6	4.9	3.2	5.8
	Maximum	10.2	9.2	9.6	10.2	8.7	8.9	7.6	8.2
	Mean	7.4	6.9	6.4	7	7.6	7.1	5.7	7.1
pH	Minimum	7.4	7.6	7.5	7.3	7.8	7.8	7.8	7.5
	Maximum	8.9	8.8	8.6	8.4	8.3	8.1	8.5	8.4
	Mean	8	8.1	7.9	7.9	8	7.9	8	7.9
BOD	Minimum	2.1	3.6	3.6	2.8	3.7	3.2	2.2	2.4
	Maximum	15.6	14.3	10.8	9.6	11	15.9	8.4	7.2
	Mean	6.5	8.2	6.6	6.4	7	8.6	5.4	4.7
TH	Minimum	122	136	124	128	136	152	188	224
	Maximum	284	290	268	278	216	224	262	282
	Mean	185.8	201.3	177.7	197	176	187.6	219.2	255.2
TDS	Minimum	122	182	112	146	112	152	142	158
	Maximum	374	548	424	386	196	238	380	308
	Mean	169.8	268.2	228.9	229	155.4	197.4	217.6	212
TSS	Minimum	24	32	45	48	26	36	32	24
	Maximum	468	534	412	366	266	298	384	354
	Mean	118.1	153.2	145.5	146.4	79.8	98.8	146.4	135.6
Cl	Minimum	0	0	0	0	0	0	0	0
	Maximum	21	16	14	17	19	16	12	14
	Mean	11.9	10.5	8.8	10.3	10.8	6.8	8	8.8
Pb	Minimum	0	0	0	0	0	0	0	0
	Maximum	0.66	0.98	0.98	0.84	0.26	0.51	0.36	0.42
	Mean	0.15	0.31	0.22	0.25	0.07	0.16	0.14	0.15
Cu	Minimum	0	0	0	0	0	0	0	0
	Maximum	1.88	2.95	3.6	1.9	0.91	1.22	1.1	0.97
	Mean	0.64	0.99	1	0.83	0.39	0.59	0.36	0.35
Fe	Minimum	0.12	0.16	0.11	0.12	0.11	0.09	0.16	0.1
	Maximum	0.44	0.41	0.66	0.42	0.23	0.25	0.24	0.28
	Mean	0.24	0.27	0.3	0.23	0.15	0.17	0.21	0.24
Zn	Minimum	0	0	0	0	0	0	0	0
	Maximum	0.3	0.34	0.64	0.34	0.08	0.14	0.16	0.08
	Mean	0.06	0.09	0.13	0.1	0.01	0.05	0.06	0.03
Turbidity	Minimum	6	6	14	10	6	6	18	14
	Maximum	42	52	54	46	22	34	54	26
	Mean	18	21.6	26.4	23.8	10.8	16.8	34.8	19.2

Table 3: Computed water quality index values for all sampling locations in all four seasons

WQI of River Ganga at different points					WQI of River Yamuna at different points				
Point	January	April	July	October	Point	January	April	July	October
River Bhagirati Gangotri	4.7	6.3	4.7	4.7	River Yamuna Yamunotri	4.1	3.5	8.4	9.2
River Alaknanda B/c Nandpryag	438.8	802.8	427.6	351.2	River Yamuna Dakpathar Up stream	810	936.9	300.2	513.8
River Mandakani B/c Nanpryag	348.9	559.9	503	511.5	River Yamuna Vikas NagarDown Stream	1064.6	1571.5	1364.8	1264.8
River Alaknanda A/c Nandpryag	196.3	378.4	304.7	268.3	River Tons Down Stream Dehradun	224.2	760.2	553.3	417.2
River Alaknanda B/c Karanpryag	783.8	783.8	494.9	901.9	River Tons before confluence in river Yamuna	5.4	70.8	116.7	124.8
River Pinder B/c Karanpryag	331.1	495	99	279.5					
River Alaknanda A/c Karanpryag	494.8	449.2	170.3	271.4					
River Bhagirathi Uttarkashi Down stream	3548.2	3549	3572.5	2504.7					
River Alaknanda Rudrapryag U/s	1708.2	1708.9	1294	1508.7					
River Alaknanda Rudrapryag D/s	736.1	989	888.7	1003.6					
River Alaknanda B/c Deopryag	1042.4	1701.3	1384.8	1890.3					
River Bhagirati B/c Deopryag	564.1	1134	1624	998.4					
River Ganga A/c Deopryag	66.8	1182	1163.2	811.3					
River Ganga Rishikeshup Stream	1455.7	1854.9	2287	1690.7					
River Ganga Haridwar Down Stream	2008.2	2334.6	2513.7	1936.4					

Table 4: Water quality classification based on WQI value [23]

WQI Value	Water Quality
<50	Excellent
50-100	Good water
100-200	Poor water
200-300	Very poor water
>300	Water unsuitable for drinking