



“Sacred Ganga River and Triveni Sangam Water”: Assessment of water Quality and Suitability

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Abstract

Background: The river Ganga, a support for millions, drains one of the world's insignificant, and most heavily and continuously occupied watersheds. The river is exploited for drinking, power generation, irrigation, fish production, and religious pilgrimages. The Ganges is the most sacred river to Hindus. It is worshipped as the goddess Ganga in Hinduism. Millions of pilgrims take holy dip and take bottles of it to their homes. Triveni Sangam is the confluence of the Ganges (Ganga), the Yamuna, and the legendary Saraswati River. Triveni Sangam is located at Prayag - the area of Prayag raj. The present investigation was to study the water quality of river Ganga and Triveni Sangam with reference to physicochemical and heavy metal characterization.

Results: Ganga River water and Triveni Sangam water has a rich mineral composition. The result revealed that among the different sampling sites, the maximum value of Magnesium (11.06 mg/L), Calcium (43.68 ± 0.3 mg/L), Sodium (43.65 ± 0.1 mg/L), Potassium (5.409 ± 0.2 mg/L), Sulphate (40 ± 0.1 mg/L), Nitrate (1.6 ± 0.1 mg/L), Phosphorous (0.26 ± 0.1 mg/L) were recorded higher at Triveni Sangam water (TSW) in comparison to Ganga water (GW) sampling sites which showed maximum value of Aluminum (0.0174 ± 0.3 mg/L), Zinc (0.0058 ± 0.2 mg/L), Silver (0.0011 ± 0.2 mg/L). Experimental studies indicate that Ganga River water and Triveni Sangam water is safe.

Conclusion: During the study, it was observed that the water quality of River Ganga was good at most of the locations, even over the years, increased industrial activities and urban growth along the rivers and lakes have resulted in increased load over the water bodies. But the upper segment of Ganga and Triveni Sangam had good quality of water to be used for drinking with minimal treatment but after disinfection. Even the concentration of heavy metals was either non-detectable or within the safe limits. In conclusion the results of present study indicated that Ganga River water and Triveni Sangam are alkaline mineral water, unpolluted by heavy metals and pesticides, and is safe for use.

Keywords: Metallic profile; ICP-OES analysis; minerals; gas chromatograph mass spectrometer

Abbreviations: SD: Standard Deviation; TSW: Triveni Sangam water; ND: Not Detected; PPM: parts per million; PPT: parts per trillion; BIS: Bureau of Indian standard; GW: Ganga Water

Introduction

India has a distinctive place due to its religious, political, historical, geographical, environmental, socio-cultural, and as an emerging economic power not only in South Asian Countries, but also in the world [1]. All the communities as Hindus, Muslims, Sikh, and Christians are residing together and celebrated their auspicious events of happiness and sorrows together. Rivers have a great

significance and place in Indian civilization. These are considered as live entity and having a place as mother in the life of people in India. The Ganges, one of the most sacred rivers to Hindus. Ganga River originates from Gangotri glacier. It is a valley-type glacier with a length of 30.20 km, and width varying from 0.5 to 2.5 km [2] situated in the Uttarkashi district of Garhwal Himalaya. Ganga river

basin is the largest among river basins in India and the fourth largest in the world. River Ganga water is used for irrigation primarily, and as a source for drinking water and industrial applications. It, therefore, becomes imperative to assess the suitability of water for different uses.

Ganga River Rishikesh

The Ganges flows through Rishikesh in its course from the Shivalik Hills of the Himalayas to the plains of northern India with temples built along the banks. People take baths into the

holy river and perform their rituals [3]. Rishikesh, unlike other cities, is the first pilgrimage cum tourist destination after the river enters plains, and upstream-located industrial/anthropogenic sources of pollution which may affect the water quality are absent. Any addition upstream of Rishikesh (Figure 1) may be treated as natural. For Hindus in India, the Ganges is not just a river but a mother, a goddess, a tradition, a culture and much more. Some Hindus also believe life is incomplete without bathing in the Ganges at least once in your lifetime.



Figure 1: Ganga River (Google image).

Triveni Sangam Prayagraj

Triveni Sangam is the confluence of the Ganges (Ganga), the Yamuna, and the legendary Saraswati River. Triveni Sangam is located at Prayag, the area of Prayagraj neighbouring the confluence; for this reason, the confluence is also sometimes referred to as Prayag [4]. At Triveni Sangam (Figure 2), the Ganges and the Yamuna can be identified by their different colours – the water of the Ganges is clear while that of the Yamuna is greenish in colour [5]. The third river, the mythical Saraswati, is called invisible.

The auspiciousness of the confluence of two rivers is referred to in the Rigveda, which says, “Those who bathe at the place where the two rivers, white and dark, flow together, rise up to heaven [6]. Therefore, regular monitoring of the water quality of these sacred water bodies is essential to maintain their ecological esthetic and recreational significance. Keeping in view the present case study was undertaken to assess the water quality of River Ganga and Triveni Sangam with reference to physico-chemical, pesticides, and heavy metal characteristics.



Figure 2: Triveni Sangam, the confluence of the Ganges, Yamuna and a sacred third river, the Saraswati, at Prayag.

Material and methods

Study Area

River Ganga and Triveni Sangam water was selected for the present study to determine the contamination of heavy metals, pesticides and physico-chemical characteristics in the water. The samples were collected during March 2023 to December 2023 selecting four sampling sites, two samples from each city viz., Rishikesh, Uttarakhand and Prayagraj (Triveni Sangam), Uttar Pradesh.

Reagents

All reagents and chemicals used in this study were of analytical grade. Ultrapure deionized water (Merck Millipore, USA) was used for preparation of reagents and dilution throughout the work. For instrument calibration and standard solutions were purchased from Analytic Jena, Germany. Chemicals used were

purchased from Merck (Darmstadt, Germany) and Sigma- Aldrich (St. Louis, MO, USA). GCMS calibration and standard solutions were purchased from Shimadzu, Japan. Nutrient analysis kits e.g., nitrate, phosphorous, sulphate, total hardness, chloride was purchased from HACH, USA.

Sample Collection

Total four Samples were collected from four different sites, two samples from each city i.e. Rishikesh, Uttarakhand and Prayagraj, Uttar Pradesh. Two locations were selected from Rishikesh city to collect samples viz. Muni ki Reti and Shivpuri (GW1 and GW2). The another two samples were collected from Triveni Sangam of Prayagraj (TSW1 and TSW2), where the “three-river confluence” the Ganges, Yamuna, and the mythical Sarasvati. The four samples were collected in 1 L bottles; labelled and stored in room temperature (Figure 3).

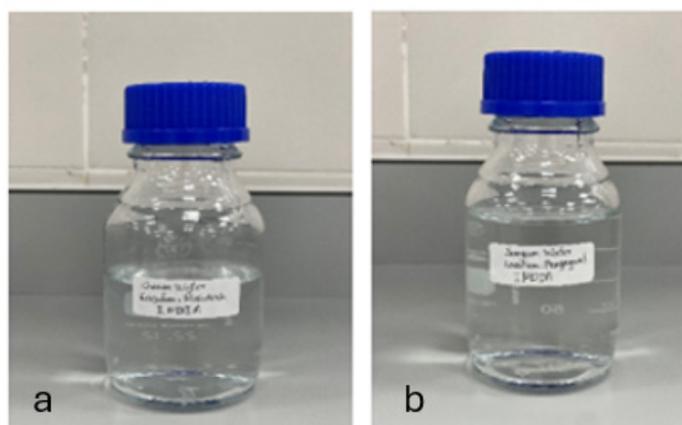


Figure 3: (a) Ganga River water (b) Triveni Sangam water.

Sample Preparation

After collection, each water samples were divided into two portions. The first was used for determination of pH, Total Dissolved Salts (TDS) and levels of chloride, total hardness, sulphate, nitrate, and phosphorous. The second part was processed for heavy metal and pesticide analysis. All analyses were carried out within a week of sample collection.

Physicochemical, Metallic Profile and Pesticides Analysis

All water samples were analysed for pH, salinity, Nitrate, Sulphate, Phosphorous, heavy metal concentration, and pesticides. The pH, salinity, TDS, conductivity was measured with WTW 3430 multimeter, Germany. Nitrate, Sulphate, Phosphorous, total hardness, chloride concentration was measured by using HACH spectrophotometer DR 3900, USA. Heavy metal concentration was analysed by using ICP-OES Plasma Quant PQ 9000 (Analytic Jena, Germany). Pesticide analysis was performed by using Gas Chromatograph Mass Spectrometer GCMS-QP2020 NX (Shimadzu, Japan).

Quality Control Procedure

All reagents used were of analytical-reagent grade. Reference solutions used in calibration range were prepared from 1000 mg/L standard solutions (Analytic Jena, Germany) [7]. In case of GCMS, Certified Reference Material for pesticide (Shimadzu, Japan) was used to control the quality of measurements. This reference material was analyzed at regular intervals (monthly) during sample analysis to assess the accuracy. Triplicate measurements of each sample were done. The precision of analysis was assessed by calculation of relative standard deviations (RSD). Recovery of the analyte from spiked samples was used to evaluate accuracy of the procedure.

Statistical Analysis

The experiments were performed in triplicates. Data are expressed as mean. Pair wise comparisons were performed. Experimental error was determined for triplicate and expressed as standard deviation (SD).

Results

This study provided a valuable data concerning the assessment and awareness of quality of Ganga River and Triveni Sangam water with nutrient, metallic profile, and pesticides.

Physicochemical characteristics of Ganga River and Triveni Sangam water

According to our research analysis, the average concentrations of all analytes (water samples) were within the permissible limits of the BIS standard (Table 1). Ganga River water and Triveni Sangam has a rich mineral composition. The result revealed that among the different sampling sites, the maximum value of Magnesium (11.06 mg/L), Calcium (43.68 ± 0.3 mg/L), Sodium (43.65 ± 0.1 mg/L), Potassium (5.409 ± 0.2 mg/L), Sulphate (40 ± 0.1 mg/L), Nitrate (1.6 ± 0.1 mg/L), Phosphorous (0.26 ± 0.1 mg/L) were recorded higher at Triveni Sangam Water (TSW) in comparison to Ganga Water (GW) sampling sites which showed maximum value of Aluminium (0.0174 ± 0.3 mg/L), Zinc (0.0058 ± 0.2 mg/L), Silver (0.0011 ± 0.2 mg/L). Heavy metals like Lead, Indium, nickel, manganese, cadmium, cobalt, chromium was not detected (Table 1).

Pesticides analysis of Ganga River and Triveni Sangam water

According to our research analysis GCMS was used for pesticides detection i.e. α -BHC, γ -BHC (Lindane), β -BHC, δ -BHC, Heptachlor, Aldrin, Heptachlor epoxide (isomer B), cis-Chlordane, trans-Chlordane, 4,4'-DDD, 4,4'-DDE, 4,4'-DDT, Dieldrin, Endosulfan I, Endosulfan II, Endosulfan sulfate, Endrin, Endrin aldehyde, Endrin ketone, Methoxychlor but, no pesticides were detected in all the four water samples.

Discussion

The present study was conducted for the multi-elemental, pesticide analysis of Ganga River water and Triveni Sangam water which was analyzed by Inductively Coupled Plasma Optical Emission spectroscopy (ICP-OES), nutrient analysis by HACH spectrophotometer DR 3900, pesticides by GCMS. The results of the present study pointed that chemical composition of GW and TSW are acceptable according to guidelines of Bureau of Indian standard for drinking water. Differences among studies could be explained by many factors such as differences in the laboratory methods used for water analysis, material used due to variable water samples, ways of collection, season, or the preservation of water in bottles and the source of the samples. According to the present research work, it was found that the pH values of Ganga River water and TSW were in the range of 7.16–7.29 indicating that the water is slightly alkaline, at different sampling sites and it was likely due to the use of detergents by the pilgrims during the holy bath which is similar in result with [8] several studies have conferred the process by which alkaline water promotes healing.

For example, [9] stated that alkaline drinking water plays an important part in get ridding the toxins from the body. The more acidic the body is, the more it holds onto (heavy) metals. Heavy metals in turn create a high oxidative stress that acidifies the

body. Subsequently, alkaline water has been used for improving bone density and healing [10]; controlling gastric functions [11]; improving capacity for aerobic activities and flushing toxins and acidic waste [12,13]. Electrical conductivity (EC) represents the concentration of different ions present. In our research findings, EC varied from 315 to 578 $\mu\text{S}/\text{cm}$. Conductivity serve as an indicator of water quality problems. Similar research results of EC agreed with [14] who reported the changes in EC of water of river Ganga during at Haridwar, [15] India. The TDS ranged from 142.0 to 290.0 mg/L. Higher values of TDS at location #TSW1 and #TSW2 may be attributed to addition of sewage, suspension of ashes and flowers used for worship and offering to the deities, near the locations.

The desirable limit for TDS in drinking water is 500 mg/L. Kumar et al., 2018 reported similar results stated that among different sampling sites the most values of TS (545 mg/L), TDS (320 mg/L) and TSS (225 mg/L). Salinity (%) ranged from 0.001074 to 0.010699. Alkalinity of the water exhibited more variation and ranged from 36.0 to 80.0 mg/L. Similar resulted were reported by [16] 2014 stated that Alkalinity of the water exhibited more variation and ranged from 32.0 to 144.0 mg/L. As per the Bureau of Indian Standards (BIS) standards (2012) (Table 1), the limit of alkalinity in drinking water is 200 mg/L. The Total Hardness (TH) in river water is primarily regulated by the carbonates, bicarbonates, chlorides, sulphates, etc. of calcium and magnesium chiefly, whereas there are certain other chemical entities accounting for it. The hardness levels varied from 103.24 to 176.35 mg/L. The observations revealed that the major source of hardness ions is the wastewater from domestic use. The desirable limit for total hardness in drinking water, as per BIS, India is 200 mg/L.

These results revealed that wastewater from domestic use had a fair proportion of calcium bound ions adding to total hardness. The contribution of carbonate ions towards hardness was analyzed (Table 1). In the present study, the values of chloride observed at different sites are varied from 11 mg/L to 50 mg/L which is in the range of BIS standard (2012), the limit of chloride in drinking water is 250 mg/L. Higher value of chloride were found in TSW 1 and TSW2. Similar work was done by, studied that the values of chloride (118.36-124.50 mg/L), hardness (221.00-232.54 mg/L) and alkalinity (146.37-158.36 mg/L) was ranged at different sampling sites as Har ki Pauri (HKP), Vishnu Ghat (VG), Daksh Mandir (DM), Pul Jatwara (PJ). In the present study, the values of nitrate (0.77-1.6 mg/L) and sulphate (25-40 mg/L) was ranged at different sampling sites. The values of nitrate and sulphate are in the standard range of BIS drinking water which is 45 mg/L and 200 mg/L.

Heavy metal Characteristics of Ganga River water and Triveni Sangam water

The heavy metals are at very low concentrations in the natural environment, and they are typically introduced to surface waters as waste from human activities. Heavy metal is another class of pollutants responsible for many of the diseases in exposed organisms. Some of the metals of concern for human and aquatic health are cadmium, lead, copper, mercury, selenium, and chromium etc. Nickel, cobalt, cadmium, Iron, lead, indium, manganese, chromium was not detected in the collected water samples (Table

1). Copper was below the detection limit in all the samples. Copper was present at all the locations and ranged from 0.0062 to 0.0119 mg/L with a limit value of 0.05 mg/L. Maximum concentration was reported in lower stretch TSW1 and TSW2. Similar results were reported by Haritash et al., 2014 which says that Copper was present at all the locations and ranged from 0.0321 to 0.0581 mg/L with an average value of 0.0386 mg/L. [17] stated similar results

align with our research, stated that the maximum concentration of copper (0.043 mg/L) [18] who reported the higher contents of copper in abandoned old Ganga canal at Haridwar (Uttarakhand), India [19] also reported higher concentration of copper in the water of sub canal of upper Ganga canal at Haridwar (Uttarakhand), India due to the discharge of untreated textile effluent.

Table 1: summarizes the metallic and nutritional profile content in Ganga water (GW) and Triveni Sangam water (TSW) as well as the recommended values available according to the Bureau of Indian Standards (2012). Specification for drinking water. 1S: 10500, *Bureau of Indian Standards*, New Delhi.

Parameters	GW 1	GW 2	TSW 1	TSW 2	BIS, Indian Standard Reference, 2012
pH	7.16	7.18	7.29	7.28	6.5-8.5
Salinity (%)	0.001092	0.001074	0.010699	0.010624	-
Conductivity (S/cm)	315	324	578	575	-
TDS (ppm)	156	142	290	276	Max 500
Total alkalinity (as calcium carbonate, ppm)	36	38	80	76	Max 200
Total hardness (as calcium carbonate, ppm)	105.76	103.24	176.35	171.52	Max 200
Silver (ppm)	0.0011±0.2	0.0002±0.1	Not detected	Not detected	Max 0.1
Aluminium (ppm)	0.0171±0.1	0.0174±0.3	0.0109±0.2	0.0112±0.4	Max 0.03
Boron (ppm)	0.0126±0.3	0.0123±0.2	0.0506±0.2	0.0492±0.1	Max 0.5
Barium (ppm)	0.0151±0.2	0.0159±0.3	0.0579±0.1	0.0573±0.2	Max 0.7
Bismuth (ppm)	0.0019±0.1	0.0012±0.3	0.0017±0.2	0.0005±0.3	-
Cadmium (ppm)	Not detected	Not detected	Not detected	Not detected	Max 0.003
Cobalt (ppm)	Not detected	Not detected	Not detected	Not detected	-
Chromium (ppm)	Not detected	Not detected	Not detected	Not detected	-
Copper (ppm)	0.0062±0.2	0.0069±0.1	0.0119±0.1	0.0110±0.2	Max 0.05
Iron (ppm)	Not detected	Not detected	Not detected	Not detected	Max 0.3
Gallium (ppm)	0.0106±0.3	0.0098±0.1	0.0095±0.2	0.0093±0.1	-
Indium (ppm)	Not detected	Not detected	Not detected	Not detected	-
Manganese (ppm)	Not detected	Not detected	Not detected	Not detected	Max 0.1
Nickel (ppm)	Not detected	Not detected	Not detected	Not detected	Max 0.02
Lead (ppm)	Not detected	Not detected	Not detected	Not detected	Max 0.01
Calcium (ppm)	26.66±0.1	27.07±0.1	43.07±0.2	43.68±0.3	Max 75
Strontium (ppm)	0.0985±0.2	0.1013±0.2	0.2855±0.3	0.2846±0.1	-
Potassium (ppm)	2.299±0.1	2.279±0.4	5.409±0.2	5.362±0.3	-
Thallium (ppm)	0.0100±0.2	0.0111±0.1	0.0134±0.1	0.0113±0.3	-
Magnesium (ppm)	8.953±0.4	8.993±0.3	11.06±0.1	10.98±0.2	Max 30
Lithium (ppm)	0.0008±0.1	0.0006±0.2	0.0014±0.1	0.0013±0.4	-
Sodium (ppm)	4.3±0.2	4.215±0.4	42.50±0.2	43.65±0.1	-
Zinc (ppm)	0.0055±0.1	0.0058±0.2	0.0005±0.1	0.0006±0.2	Max 5
Phosphorous(ppm)	0.10±0.1	0.13±0.2	0.26±0.1	0.25±0.1	-
Sulphate(ppm)	25±0.2	28±0.1	40±0.1	37±0.2	200 mg/L
Nitrate(ppm)	0.8±0.1	0.77±0.1	1.6±0.1	1.4±0.2	45 mg/L
Chloride(ppm)	14±0.2	11±0.3	50±0.1	47±0.1	250 mg/L

Contrary results were reported by which studied that the values of Cu (0.164-0.171 mg/L), Cr (1.434-1.503 mg/L), Fe (3.501-3.642 mg/L) and Mn (0.627-0.644 mg/L) were ranged at different sampling sites. In our research finding, Zinc concentration varied from 0.0005 to 0.0058 mg/L (Table 1) which is below the [20] standard of drinking water i.e. 5mg/L. Reported minimum zinc concentration as 0.008 mg/L Whereas, maximum zinc value was detected as 0.127 mg/L and it might also be due to a number of anthropogenic activities like mass bathing, discharge of urban waste and runoff etc. as also reported earlier by, In our research findings in all water samples, chromium was not detected. Chromium is considered as one of the essential nutrients for several living organisms only in trace amount [21,22]. The concentration of chromium in drinking water is usually found only at trace level, but chromium (VI) in exceeded concentration is extremely toxic to the consumers from health point of view [23]. Our research findings were similar to which stated that chromium was detected 0.001 mg/L as minimum concentration at all the study sites. The BIS (2012) has prescribed its desirable limit up to 0.05 mg/L, but there is no relaxation beyond this range.

Conclusion

The results of the present study concluded that Ganga River water and Triveni Sangam water has a rich mineral composition. It contains maximum value of Magnesium (11.06 mg/L), Calcium (43.68 ± 0.3 mg/L), Sodium (43.65 ± 0.1 mg/L), Potassium (5.409 ± 0.2 mg/L), Sulphate (40 ± 0.1 mg/L), Nitrate (1.6 ± 0.1 mg/L), Phosphorous (0.26 ± 0.1 mg/L) were recorded higher at Triveni Sangam water (TSW) in comparison to Ganga water (GW) sampling sites which showed maximum value of Aluminium (0.0174 ± 0.3 mg/L), Zinc (0.0058± 0.2 mg/L), Silver (0.0011± 0.2 mg/L). Heavy metals like Lead, Indium, nickel, manganese, cadmium, cobalt, chromium was not detected. No pesticides were detected. During the study, it was observed that the water quality of River Ganga was good at most of the locations in Rishikesh town. The upper segment of Ganga had good quality of water to be used for drinking with minimal treatment but after disinfection. Even the concentration of heavy metals was either non-detectable or within the safe limits. Ganga River water and Triveni Sangam water are alkaline in nature, unpolluted by heavy metals and is safe for use. All metal concentrations in the studied samples were within the acceptable limits according to the Bureau of Indian Standard of drinking water. Efforts are made by the Indian government, [24,25] (National mission for Clean Ganga) and local authorities. More comprehensive research work is required to accomplish the twin objectives of effective abatement of pollution, conservation, and rejuvenation of National River Ganga; To maintain minimum ecological flows in the river Ganga with the aim of ensuring water quality and environmentally sustainable development.

Ethics Approval and Consent to Participate

Not applicable.

Consent for Publication

Not applicable.

Availability of Data and Materials

The relevant data and materials are available in the present study.

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Declaration of Competing interests

The authors declare that they have no competing interests. All procedures followed were in accordance with the ethical standards (institutional and national). The author declared that there is no specific conflicting financial interest or personal partnership that could have influenced the work presented in article.

Credit Authors' statement

Dr. Vibha Bhardwaj performed all the experiments. VB analysed the data and wrote the manuscript. Conceptualization, Methodology, Validation, Formal analysis, Investigation, Resources, Supervision, Data curation, writing original draft, Writing review & editing, Visualization.

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