Evaluation and prediction of deviation in physico-chemical characteristics of River Ganga

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Abstract: Assessment of physico-chemical parameters of Ganga River water were carried out during 2012 to 2013 at Rishikesh (Uttarakhand) with two different Sites i.e. Site 1 (Shivpuri) control Site and Site 2 (Pashulok Barrage), where river flows with loads of pollution from highly commercial areas and waste water discharge in Rishikesh. During investigation maximum Turbidity (404.00±106.00 JTU), Total Solids (802±132 mgl⁻¹), pH (7.78 ± 0.1), Free CO₂ (1.8 ±0.1 mgl⁻¹), Biochemical Oxygen Demand (3.36 ± 0.264 mgl⁻¹), Chemical Oxygen Demand (7.94 ± 0.406 mgl⁻¹), phosphorus (0.141 ± 0.050 mgl⁻¹), Nitrate (0.058 ± 0.006 mgl⁻¹), Nitrite (0.012 ± 0.001 mgl⁻¹) and Total Hardness (67.79±7.21 mgl⁻¹), while minimum Dissolved Oxygen (7.70 ± 0.23 mgl⁻¹), Velocity (1.33±0.34 ms⁻¹) and Transparency (0.31±0.23 m) were recorded at Site 2 in comparison with Site 1. The mean values of these parameters were compared with WHO and ISI standards and found significant differences (p<0.05) in the mean values of Turbidity, Total solids (TS), pH, Dissolved Oxygen (DO), Free CO₂ and Total Hardness (TH) with sampling Sites. The results indicated that most of the physico-chemical parameters from Gangetic River System were within or at margin in comparison to permissible limit of ISI and WHO for drinking water and therefore, may be suitable for domestic purposes, but it require attention due to drastic changes in climate and increase in pollution in last decade.

Keywords: physico-chemical Characteristics, Ganga River water, pollution, Shivpuri, Pashulok Barrage

Introduction

Ganga occupies a unique position in the cultural ethos of Indians but people all over the world. Legend says that the river has descended from Heaven on earth as a result of the long and arduous prayers of King Bhagirathi for the salvation of his deceased ancestors. From times immemorial, the Ganga has been India's river of faith, devotion and worship. Millions of Hindus accept its water as sacred (Matta, 2010, Matta et. al., 2011, Matta 2014). The mighty River Ganga is no exception (WWF 2012). During its over 2,525 km journey from Gangotri Glacier to Ganga Sagar, there are complex, nested sets of challenges that threaten the very existence of this river revered by millions of Indians. In the upper Himalayan reaches, the flow of river is vulnerable to water abstractions by existing and proposed hydro-power projects proposed hydropower projects. From the time the
river enters the plains, abstractions for agriculture, urban and industrial uses leave the river lean and polluted (Aenab et al. 2014; Matta 2014).

During the decades he Ganges basin is among the most heavily populated areas in the world with an average density of 520 persons per square kilometer. Not only is the river a vital resource for agriculture and industry, it also holds an iconic status in India’s cultural heritage (Das et al. 2012 and M.H.A 2012). But after independence, advancement in industry, urbanization and pressures of population growth have posed higher contamination to water quality of River Ganga causing the invaluable resource into convenient means of waste disposal. The river is also a site for religious bathing, washing and watering of animals, and the disposal of human and animal corpses. Tourism, Kanvar mela and Kumbh mela are major activities, which are engaged in promoting higher pollution load to River Ganga. The permanent restructuring of the environment brought about by a variety of construction activities and replacement of a natural environment by a new built environment has a variety of far reaching and long lasting result, in term of existing biological species and physical conditions in the area (Bhadula et al. 2014). Thus the quality of natural water bodies impacts those using or living within those water bodies (Singh et. al., 2010). Keeping in view the above scenario the present study has been undertaken to assess the impact of seasonal variation on concentration of physico-chemical parameters and impact of the different pollutants discharged into river water, as well as to explore the relative pollution status of the River Ganga.

**Materials and Methods**

**Studied Areas of River Ganga**

The present study has been carried out in Rishikesh to examine pollution status of River Ganga, located in newly carved state of Uttarakhand. Rishikesh is extended from latitude 30°07’ in the north to longitude 78°19’ in the east. It has an average elevation of 372 meters. Rishikesh had a population of 59,671 as per 2001 census of India. During this study period physico-chemical parameters of River Ganges were studied. Water samples were taken from two locations in Rishikesh in foot hills of Garhwal Region of Uttarakhand. The sampling locations are depicted in Fig. 1. Site 1(Shivpuri), is control site for the study 18 Km away from Rishikesh, a naturally ecosystem, no domestic or commercial setups. Water flow in Shivpuri is highly dynamic. It is counted as the last Site where River Ganges starts her journey into plains of India. Just next to sampling location, tourist spots are with hundreds of tourist everyday available for river rafting. Site 2 (Pashulok Barrage – 22Km from Shivpuri) is located in outer part of Rishikesh. After crossing all over from Rishikesh, River Ganga flows from this sampling Site. Fig. 1 shows highly commercial areas with loads of pollution and waste water discharge and detail of sampling sites. Here water level is low in winter season in comparison to summer and monsoon season.
The velocity and water level at Pashulok Barrage depends on seasonal variability. The barrage covers entire pollution load of Rishikesh city and including industrial, domestic and commercial. In a run-of-the-river scheme, the main purpose of the barrage is to divert water into a canal on the east bank of the river which feeds water to the Chilla Power Plant downstream at 29°58′34″N 78°13′11″E, 4 km (2 m) upstream of Haridwar. Therefore, comprehensive river water quality monitoring program is becoming a necessity in order to safeguard public health and to protect the valuable and vulnerable fresh water resources (Kannel et al. 2007 and Singh 2014).

Sample collection procedure

Water samples were collected from River Ganga at Rishikesh during three different seasons viz. winter, summer and monsoon for the period of one year from 2012 to Oct 2013. Water samples were collected from 0.5 m depth from the surface of river using a clean plastic bucket, transferred to clean plastic bottles and transported to the laboratory on ice and stored in a deep freezer (-20°C) till analysis. Samples were collected in triplicate from each Site and average value for each parameter was reported.

Analytical Methods

The physic-chemical parameters like pH, Temperature, DO, Transparency, Velocity, and Free CO₂ were fixed/recorded onsite. The other parameters such as BOD, COD, Nitrate, Nitrite, Phosphorus, Turbidity, TS, and TH were analyzed in laboratory after samples preservation as per Khanna et al., 2011, Bureau of Indian Standards (BIS 1991) and American Public Health Association (APHA 2005) guidelines. The colorimetric analyses were done with UV Spectrophotometer Cary 60.

The statistical analysis was carried out using Minitab 16 to identify the correlation between selected water quality parameters.

Results and Discussion

The physico-chemical characteristics of Site 1 (Shivpuri) control Site and Site 2 (Pashulok Barrage) sampling sites are appended in Table (1) and fig. 2, 3 and 4. The water quality analysis of Ganga River showed that Site 2 was highly polluted because of the influx of sewage and domestic wastes in comparison to Site 1.

Temperature is one of the most important parameters that influence almost all the physical, chemical and biological properties of water and thus the water chemistry. It never remains constant in rivers due to changing environmental conditions (Kumari et al. 2013). Temperature also plays an important role in determining DO in an aquatic body (Khanna et. al., 2012). In present study the mean maximum temperature (20.7°C ± 1.53) of Ganga River was recorded at Site 2 in summer season as compared with Site 1 (Fig. 2). Maximum values of
temperature might be due increasing rates of pollution and wastewater discharged at Site 2. Temperature is known to influence the pH, alkalinity and DO concentration in the water. Bhadula et al. (2014) reported 8.04% increase in temperature between two Sites of Sahasttradhara stream at Dehradun District. The overall lowest and highest mean values of temperature were observed 10.7\(^\circ\)C and 21.7\(^\circ\)C in the month of January and June at the Site - 1 and Site - 2, respectively. Among the selected sites the Site 1, happens to be first site therefore has been treated as reference site. It can also be recorded here that normally there are no tourist at Site 1.

Turbidity of any water sample is the reduction of transparency due to the presence of particulate matter also is an important parameter, which influences the light penetration inside water and thus affects the aquatic life (Verma and Saksena 2010; Tambekar et al. 2013). During the present study maximum turbidity was recorded with Site 2 (404 JTU ±106) in monsoon season as compared with Site 1, while minimum turbidity was observed in winter season (Table 1). Recent study done by Joshi et al. 2009 reported that turbidity in the River Ganga at Haridwar was lowest during winter season. From summer season onwards the water became turbid due to melting of snow and rains. The maximum turbidity 608.15 JTU was observed in monsoon season and minimum 19.15 JTU was observed in winter season from water samples collected from five spots sampling Site A (Bhooma Niketan), sampling Site B (Jai Ram Ashram), Samping Site C (Har-Ki-Pauri), sampling Site D (Prem Nagar Ashram) and sampling Site E (Pul Jatwara).

The clearer the water, the deeper sunlight will penetrate. Transparency has direct bearing on the light penetration of water and depends upon suspended matter and dissolved colored substances. In the present study lowest mean value of transparency was recorded (0.31 m ±0.23) with Site 2 in monsoon season as compared with Site 1. The lower transparency at Site 2 is due to higher pollution load. The higher values were exhibited during winter and summer months, whereas lower values were found in monsoon season (Fig. 3). (Sharma et al. 2010) reported highest values 47cm was at bathing ghat of Sapt rishi during III\(^{rd}\) Royal Bath, while the lowest value 14cm was found at the bathing ghat of Prem Nagar during fourth Royal bath at Haridwar.

Bhadula et al. (2013) reported overall lowest and highest mean value of transparency were observed 1.0cm and 45.7cm in the month of August and January at the Site 2 and Site 1, respectively of Sahashtradhara stream. The study reveals that a relative comparison in transparency showed comprehensive variation in water quality. The maximum transparency was found at the Site 1 during month of January and at Site 2 transparency relatively low due to the touristic activities. The velocity was found to be directly proportional to the flood level and also with gradient of the river stretch. The water level and its velocity started increasing from winter season onwards due to melting of snow at the place of origin of the river. Flow can affect the river’s ability to assimilate pollutants; larger, swiftly-moving streams and rivers can receive pollutants with a diminished negative effect.
Smaller rivers with low flow have less of a capacity to dilute and degrade potentially harmful pollutants (EPA 2012). During the present study the maximum mean velocity of River Ganga at Site 2 was recorded to be (1.33 m/s ±0.34) in monsoon season as compared with Site 1. Maximum velocity of River Ganga was observed in monsoon season at both the sites, but lower velocity was observed at Site 2 in comparison to Site 1 (Fig. 4), might be due to climatic conditions in which water level and its velocity started increasing from winter season onwards due to melting of snow at the place of origin of the river. Joshi et al. (2009) also reported the maximum velocity 2.18 m/s of the Ganga at Haridwar was recorded in monsoon season and the minimum velocity 0.39m/s was observed in winter season.

Total solids (TS) means the total amount total suspended solids (TSS) and total dissolved solids (TDS) in particular sample. The TS are composed of carbonates. The effect of presence of TS is due to silt and organic matter. In the present study maximum TS (802 mg/l ±132) was recorded at Site 2 in monsoon season as compared with Site 1 (Table 1). Higher values of TS were recorded in monsoon season at Site 2 reflects more pollution due to discharge of whole city sewage at this site. Recent studies done by Raja et al., 2008 reported higher level of TS (570.00 mg/l ±155.2) at Chinthamani road bridge than upper anicut and grand anicut Sites of River Kaveri, Tiruchirappalli. Tambekar et al. (2013) also reported Wardha River water sample in pre-monsoon, monsoon and post-monsoon was found to be in the range of 260- 360, 480- 510, 350- 431 mg/l along with concentration of average value with 95% CL value was found to be 283+13.5, 495+11, 385+29 mg/l respectively. The effect of presence of TS is due to silt and organic matter. The maximum value of TS was recorded in monsoon season.

Aquatic organisms are affected by pH, because most of their metabolic activities are pH dependent. Optimal pH range for sustainable aquatic life is pH 6.5-8.2. pH of an aquatic system is an important indicator of the water quality and the extent pollution in the watershed areas (Kumar et al. 2011). During the present study the overall highest mean value of pH were observed (8.1 ± 0.1) at Site 2 in comparison to Site 1. There was not much fluctuation recorded in pH values (Table 1). The highest pH was recorded in the summer seasons than winter and rainy seasons. Higher value of pH in summer season may be due to influx of sewage effluents disposal and low level of water. Recent studies done by Joshi et al. 2009 reported the pH of the Ganga River at Haridwar was slightly alkaline ranged from 7.06 to 8.35.

Oxygen is generally reduced in the water due to bio-chemical activities from the process of respiration to decomposition of organic matter and chemical activities oxygen demanding wastes and inorganic reductant such as hydrogen sulphide, ammonia, nitrites, ferrous iron, etc. (Singh, 2012). In the present study DO reduces during the summer season as compared to winter and monsoon months where as BOD and COD reduces in
monsoon as compared to winters and summers. It may be due to higher temperature, oxygen demanding wastes, inorganic reductant and seasonal variation. In the present study the overall lowest mean value of dissolved oxygen was observed (7.70 mg\textsuperscript{l}^{-1} ± 0.23) with maximum BOD (3.36 mg\textsuperscript{l}^{-1} ± 0.264) and COD (7.94 mg\textsuperscript{l}^{-1} ± 0.406) at Site 2 in comparison to Site 1. The lowest value of DO and highest values of BOD and COD at Site 2 indicates load of pollution in comparison to Site 1 (Table 1). Mishra and Tripathi (2007) reported the mean value of the dissolved oxygen ranged from 1.8 - 5.9 mg\textsuperscript{l}^{-1} in Ganga River in Varanasi, found maximum where minimum discharge of effluent and human activities and lowest DO at the site where maximum discharge of sewage effluent.

Free CO\textsubscript{2} in the present study was recorded maximum (1.80 mg\textsuperscript{l}^{-1} ±0.1) at Site 2 in comparison to Site 1. The lower values of Free CO\textsubscript{2} were observed in winter season and higher values were recorded in monsoon and summer season at Site 2 (Table 1). The increase in carbon dioxide level during these months may be due to decay and decomposition of organic matter due the addition of large amount of sewage, which was the main causal factor for increase in carbon dioxide in the water bodies.Joshi et al. (2009) reported that free carbon dioxide in the Ganga water was invariably present throughout the year. It fluctuated from 1.15 mg\textsuperscript{l}^{-1} in winter season to 5.39 mg\textsuperscript{l}^{-1} in rainy season. The free carbon dioxide was found to be maximum in monsoon season and minimum in winter season.

Hardness of water is not a pollution indicator parameter but indicates water quality mainly in terms of Ca\textsuperscript{2+} and Mg\textsuperscript{2+}, bicarbonate, sulphates, chloride, and nitrates. Water with less than 75 mg\textsuperscript{l}^{-1} of CaCO\textsubscript{3} is considered soft and above 75 mg\textsuperscript{l}^{-1} of CaCO\textsubscript{3} as hard (Kumar et al., 2010; Singh and Chodhary, 2013). It is an important criterion for determining the usability of water for domestic, drinking and many industrial supplies (Mitharwal et al. 2009). In the present study maximum TH (69.46 mg\textsuperscript{l}^{-1} ±5.48) was recorded in monsoon season at Site 2 in comparison to Site 1 (Table 1). This was in accordance with the results of Singh and Chaudhary, 2013 who reported that seasonal behaviors of TH were more or less similar at all the sites. It was lowest at Site 1 (90 ppm) in summer season and even highest at site 1 (200 ppm) in winter and monsoon of Ganga River water at Bhagalpur (Bihar), India respectively. This was due to result from poor dilution owing to low precipitation rate. Khanna et al. (2013) reported that TH of four different Sites of the River Ganga in Haridwar city (Site 1: Harkipauri, Site 2: Birla ghat, Site 3: Mayapur and Site 4: Singhdwar) for a period of 1 year. The maximum (163.52 mg\textsuperscript{l}^{-1}) hardness of water was recorded at second Site and the minimum (60.00 mg\textsuperscript{l}^{-1}) in comparison to other three Sites.

Elevated levels of both nitrogen and phosphorus are main cause of poor water quality and loss of aquatic habitats in the Ganga Basin. Wastewater discharges, including domestic waste and sewage, effluents from
commercial and industrial establishments, and urban run-off, combined with agricultural run-off and aquaculture waste which may also contain fertilizers, are major threats in terms of nutrient pollution (Dubey et al. 2012). Nitrogen-containing compounds act as nutrients in streams and rivers. Nitrate reactions in fresh water can cause oxygen depletion. Thus, aquatic organisms depending on the supply of oxygen in the stream will die. The major routes of entry of nitrogen into bodies of water are municipal and industrial wastewater, septic tanks, feed lot discharges, animal wastes (including birds and fish) and discharges from car exhausts. During the present study the nitrates were ranging between $0.035 \pm 0.002 \text{mg}^{-1}$ to $0.058 \pm 0.006 \text{mg}^{-1}$, while the nitrites between $0.007 \pm 0.001 \text{mg}^{-1}$ to $0.012 \pm 0.001 \text{mg}^{-1}$. Nitrates and nitrites are maximum at Site 2 due to continue discharge of commercial and domestic sewage. Nutrients such as nitrogen and phosphates compounds in water stimulate the growth of algae and other photosynthetic aquatic life, which lead to accelerated eutrophication of water bodies (Dubey et al. 2012). During the study the phosphorus content was also recorded between $0.039 \pm 0.019 \text{mg}^{-1}$ to $0.141 \pm 0.050 \text{mg}^{-1}$ with maximum at Site 2.

**Correlation matrix**

Statistical analysis has been carried out by Pearson’s correlation coefficient between different pairs of water quality parameters of River Ganga to develop the significant correlation among the parameters (Bhandari and Nayal 2008; Joshi et al. 2009). The data analysis yielded an R-value, which is a correlation representing the linear relationship between the data pairs. A linear association implies that as one variable increases, the other increases or decreases linearly. Values of the correlation coefficient close to +1 (positive correlation) imply that as one variable increases, the other increases nearly linearly. On the other hand, a correlation coefficient close to -1 implies that as one variable increases, the other decreases nearly linearly. Values close to 0 imply little linear correlation between the variables or no correlation (Mudgal et al. 2009). When data are truly independent, the correlation between data points is zero. The values of coefficient correlation were determined using MINITAB software version 16 in all the seasons. In the present study the correlation coefficient ($r$) between every parameter for Site 1 and Site 2 is shown in Table 2 and 3 in the form of correlation matrix. Correlation coefficient ($r$) between any two parameters x & y is calculated for parameter such as pH, turbidity, TH, DO, Free CO$_2$ and TS for Ganga River water. The water turbidity has been found to show positive correlations with TS and Free CO$_2$, pH and TH whereas TS have positive correlations with Free CO$_2$, pH and TH at both Site 1 and Site 2. The pH has positive correlation with DO at Site 1, whereas pH has positive correlation with TH at Site 2. DO shows positive correlation with TH at both Site 1 and Site 2. There is a strong positive correlation ($r=0.972/0.993$) between turbidity and TS at Site 1/Site 2. There was also observed significant ($p < 0.05$) positive correlation ($r=0.839/0.894$) between turbidity and Free CO$_2$ at both Site 1 and Site 2. Free CO$_2$ and DO showed a highly significant ($p >0.05$) negative correlation ($r=-0.702/−0.571$) at both Site 1 and Site 2. Nitrate
and nitrite also show highly significant, negative relationship \((r=0.918/-0.427)\) at both Site 1 and Site 2. During the study strong positive relationship was shown by BOD and COD with positive correlation \((r=0.952/0.974)\) at both Site 1 and Site 2. The negative and positive correlation between the parameters shows the seasonal changes in water quality of River Ganga.

**Conclusion**

On the basis of various parameters studied it was concluded that the water quality of River Ganga is not satisfactory. High turbidity can significantly reduce the aesthetic quality of Ganga River water, having a harmful impact on recreation and tourism. It can increase the cost of water treatment for drinking and food processing. It can harm fish and other aquatic life by reducing food supplies, degrading spawning beds, and affecting gill function. Keeping in mind increasing urbanization and pollution loading of rivers, necessary measures should be taken to reduce future contamination loads from entering the river. The study establishes that sewerage, solid and liquid waste contaminants or organic nature are the prime sources of pollution. The analysis report clearly indicates that the water after treatment can be reused in irrigation. Results also indicate that Ganga River with such overloaded situation cannot sustain any further sewage discharge. If proper alternative arrangements like sewage treatment before discharge are not made then the situation may be alarming to the inhabitants in the study area and to the downstream as well. Hence regular monitoring and strict law enforcement is needed to develop a strategy to manage the environmental hazards due to these elements and to improve environmental protection of River Ganga. Our present data should serve as baseline for future reference.

**References**


Fig. 1 Showing the view of Shivpuri (Site 1- control Site) and (Site 2- Pashulok Barrage).
Fig. 2 Showing monthly variations in temperatures (°C) of site 1 and Site 2
Fig. 3 Showing monthly variations in transparency (m) of Site 1 and Site 2
Table 1. Seasonal fluctuation in physico-chemical characteristics of sampling sites in Rishikesh during 2012-2013

<table>
<thead>
<tr>
<th></th>
<th>Site 1 Physico-chemical characteristics</th>
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<th>Site 2 Physico-chemical characteristics</th>
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<tr>
<td></td>
<td>Winter</td>
<td>Summer</td>
<td>Monsoon</td>
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<tr>
<td>Seasons</td>
<td>Turbidity (JTU)</td>
<td>Total Solids (mg/l)</td>
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<tr>
<td>Winter</td>
<td>16.04 ±18.27</td>
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<tr>
<td>Summer</td>
<td>65.25 ±64.02</td>
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<td>Monsoon</td>
<td>308.5 ±183.1</td>
<td>566.44 ±251.84</td>
<td>7.64 ± 0.11</td>
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Fig. 4 Showing monthly variations in velocity (m/s) of Site 1 and Site 2
Table 2. Correlation coefficient (r) values between physico-chemical parameters of Ganga River at Site 1

<table>
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<tr>
<th>Physico-chemical Parameter</th>
<th>Turbidity</th>
<th>Total Solids</th>
<th>pH</th>
<th>DO</th>
<th>Free CO₂</th>
<th>Total Hardness</th>
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<th>BOD</th>
<th>COD</th>
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<td>DO</td>
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<td>Free CO₂</td>
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<td>0.988</td>
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<td>Total Hardness</td>
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<td>Nitrate</td>
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<td>0.005</td>
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<td>0.989</td>
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*Correlation is significant at p < 0.05

Table 3. Correlation coefficient (r) values between physico-chemical parameters of Ganga River at Site 2
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<th>Physico-chemical Parameter</th>
<th>Turbidity</th>
<th>Total Solids</th>
<th>pH</th>
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<th>Free CO₂</th>
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<th>Nitrite</th>
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<td>Free CO₂</td>
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<td>0.387</td>
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<td>0.789</td>
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<td>0.849</td>
<td>0.573</td>
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<tr>
<td>BOD</td>
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<td>-0.842</td>
<td>0.235</td>
<td>0.740</td>
<td>-0.975</td>
<td>0.172</td>
<td>0.335</td>
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<td>-0.932</td>
<td>0.424</td>
<td>0.592</td>
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<td>-0.027</td>
<td>-0.141</td>
<td>-0.835</td>
<td>0.980</td>
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*Correlation is significant at p < 0.05