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Seasonal and Temporal Variations in Physico-chemical and Bacteriological Characteristics of River Ganga in Varanasi

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ABSTRACT: Various physico chemical characteristics of the river Ganga in Varanasi were studied in the Oct 2005 to Nov 2006. Ecological parameters like dissolved oxygen(DO), pH, nitrate(NO_3^-), PO_4^{3-} and bacterial population were analyzed and compared with standard permissible limits to assess the best designated use of the river water for various purposes. Study revealed that the water quality at Varanasi was not safe for human use. Result shows that Fecal coliform (20.9×10^3/100mL), Fecal streptococci (93/100mL), Total bacterial density (1.43×10^3/L), Total coliform (25.4×10^3/100mL) *Escherichia coli* (6.9×10^3/100mL) and *Clostridium perfringens* (396/100mL) were substantially high and much beyond the permissible limit of ISI and WHO. There were a marked correlation observed between physico-chemical quality of water and bacterial density. Some pathogenic bacteria Actinomyces *sp., Aerobacter aerogenes, A. Cloacae, Micrococcus* sp., *Salmonella sp., Staphylococcus aureus, Bacillus* sp. and *Shigella sp.,* that indicate the higher level of fecal contamination in water. These untreated water sources are used for drinking and domestic purposes and pose a serious threat to the health of the consumers and therefore calls for urgent intervention by government.

Key words: Coliform, Fecal, Contamination, Indicator, Bacteria, River Ganga

INTRODUCTION

Rivers are the most important natural resource for human development but it is being polluted by indiscriminate disposal of sewage, industrial waste and plethora of human activities, which affects its physicochemical and microbiological quality (Koshy and Nayar, 1999). The potential cause of degradation of river water quality due to various point and nonpoint sources (Berankova *et al.*, 1996, Carpenter *et al.*, 1998). Increasing problem of deterioration of river water quality, it is necessary to monitoring of water quality to evaluate the production capacity.

The Ganga River is one of the most sacred river in India is being polluted by many sources. The main sources of pollution of river Ganga at Varanasi are industrial effluents, domestic sewage and cremation of dead bodies. At Varanasi 190 MLD of domestic sewage and 80 MLD untreated sewage and industrial effluent along with excreta by human being and various warm blooded animal are directly or indirectly discharged into the river Ganga which have adversely affects the physicochemical and biological quality of river. Approximately 60,000 human dead bodies and about 15,000 incomplete burnt dead human and animal bodies annually dumped in the river. In addition to this variety of other human activities also contributes significantly increase the bacterial concentration in the river. Many of these bacteria are pathogenic and spread the disease like typhoid, paratyphoid, gastroenteritis. Surface waters may play an important role in the transmission of pathogenic agents discharged through feces.

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Prevention of river pollution requires effective monitoring of physicochemical and microbiological parameters (Bonde, 1977; Ramteke *et al*, 1994). DO and BOD is used to state the pollution status of aquatic system. Nevertheless, the concentration of DO in water always is a reliable factor to indicate the pollution state of aquatic system (Voznaya, 1983). Redox potential (E_h) and Oxidation Reduction Index (rH_2) is one of the important indicators of pollution state of river. Redox potential is considerably influenced by the ambient temperature and hydrogen ion concentration. A positive E_h value results from a state tending towards oxidation, while a negative E_h indicates a system causing reduction (Sinha, 1995). The E_h considered as useful physical parameters that governs several microbial processes (Lynch etal, 1988)). Water with an E_h lower than 0.1 to 0.2 V is generally called reducing (Mortimer, 1942). In natural water and mud, the apparent potential difference is usually between -0.1V (oxygen free) and +0.5V (oxygen saturated). Water saturated with oxygen should have a value of about 0.8V. (Golterman, *et al.*, 1978) The oxidation-reduction index (rH_2) used to assess the pollution status in aquatic system. Negative correlation between the rH_2 and the BOD (Gautam *et al.*, 1989) showed the higher pollution state in the river.Oxidation-reduction index (rH_2) is calculated by computing the E_h and pH of the water bodies following the equation:

$$\mathbf{rH_2 = E_h/0.029+2pH}$$

The neutral point of rH_2 is assumed 28.00 (Voznaya, 1983). Lower than 28.00 indicate a pollution state. In aquatic body, low values of E_h and rH_2 values increase the growth and multiplication of aerobic microorganism. Detection and enumeration of indicator organism are of primary importance for the monitoring of sanitary and microbiological quality of water (Gunnison, 1999: Kataria *et al.*, 1997). The bacterial growth also regulated by physico-chemical quality of water. The elevated turbidities are often associated with the possibility of microbiological contamination as high turbidity makes it difficult to disinfect water properly (Van Loon, 1982; Quality of Domestic Water Supplies, 1998). Coliform is the major microbial indicator of monitoring water quality (Brenner *et al.*, 1993, Grant, 1997). Total Coliform (TC) and fecal coliform (FC) counts are the most widely used bacteriological procedures for assessment of the quality of drinking and surface waters (Mcdaniels. *et al*, 1985).The TC bacteria test is a primary indicator of potability, suitability for consumption of drinking water. It measures the concentration of TC bacteria associated with the possible presence of disease causing organisms(Craun,1978) FC are selected members of the coli form group of bacteria are fairly specific for the feces of warm blooded animals and are commonly used as indicators of fecal pollution in waters such as waste water effluents, rivers and raw sources of drinking water supplies (Geldraich,1978) Variety of human activities contributes significantly to raising the bacterial concentration in the river. Many of these bacteria are pathogenic and agents of diseases like typhoid, paratyphoid, gastroenteritis, dysentery, diarrhea, etc (LeChevellier and Mc Feters, 1985, Kumar, 1992).In the present study, an attempt has been made to assess the impact of seasonal changes on concentration of pathogenic and nonpathogenic bacteria and impact of the different pollutants discharged into river water, as well as to explore the relative pollution states of the river Ganga.

MATERIALS & METHODS

Study area covered in the urban fringe area of Varanasi city, situated in the Eastern Gangetic plain (82^0 15'E to 84^0 30'E and 24^0 35 'N to 25^0 30'N) of Northern India. Total five sites, namely Raj Ghat (site1), Assi ghat (site2), Harischandra Ghat (site3), Shiwala Ghat (site4) and Samne Ghat (site5) were selected for river quality monitoring. Each site was reasonably representing the water quality of the river system. The first site is most polluted and receives much of the sewage of the town. Site 2, 3, and 4 are fall in midstream region. Site 5 is located in the area of relatively low river pollution and upstream of the Varanasi city.

Pollution sources at selected sites:

- Samne ghat near Samne ghat drain.
- Assi ghat nala from the southern boundary of the city opening near Assi ghat.
- Shiwala ghat nala opening in the upstream near Shiwala ghat.
- Harishchandra ghat nala located near Harishchandra ghat, opening before the burning place.

• Raj ghat nala , the point of maximum sewage discharge into the river Ganga, is situated at downstream before the river confluence of river Varuna, with this river marks the end of northern border of the city.

Water samples were collected in Jan, March, May, July, Sept, Nov across in the river width at all the 5 sites with a view to monitor changes caused by anthropogenic sources.Sampling, preservation and transportation of the water samples to the laboratory were as per standard methods (APHA, 1998). All samples were transported in cold packs to the laboratory and were analyzed within 7h of collection. The pH was determined by a portable pH meter at a collection site immediately after sampling since the biological and chemical reactions between the atmosphere and the sample could readily alter the pH (Hutton, 1983). The E_h was determined through the following equation
$E_h = E_0 - 0.058\ pH + 0.0145\ log pO_2$ where E_0 is the standard electrode potential and a function of pH; PO2 is the partial pressure of the oxygen dissolved in water (Voznaya, 1983).

For bacterial analysis samples were collected in sterile bottles at each site and were kept cold ice packed cooler boxes in the field where, possible, being returned to laboratory for analysis as soon as possible. In bacterial analysis, Hi media were used. Qualitative analysis was carried by multiple tube fermentation technique (APHA, 1998) for members of the coliform group. Coliform were detected by presumptive inoculation into tubes of MacConkey broth and their incubation at 37 ± 2^0C for 48h Gram characters were also observed by gram staining. MPN of coliform were found in terms of index/100 ml by using standards tubes. For confirmation of indicator bacterial species other test tubes like IMVic, fermentation, VP, nitrate, oxides, citrate, H_2S tests etc were performed by using specific media and indicators(Sirockin and Cullimore, 1969, WHO 1985, APHA, 1998**).** The correlation coefficient analyses were done between different parameters to assess the significance of observed data.

RESULTS & DISCUSSION

The physico-chemical analysis carried out from the different site during different season has been presented in (Figs.1 to 9). Temperature is the most important factor, which influences chemical, physical and biological characteristics of water bodies. A study revealed that temperature varied from 23.8 to 25.3 where maximum at Site 1 and minimum at Site 5. Similar pattern were observed for Electric Conductivity. The pH values did not show remarkable differences between sampling sites and ranged 7.4 to 8.1. The value of DO is remarkable in determine the water quality criteria of an aquatic system. In the system where the rates of respiration and organic decomposition are high, the DO values usually remain lower than those of the system, where the rate of photosynthesis is high. The mean value of the dissolved oxygen ranged between 1.8 to 5.8 mg/L. Highest DO at the Site 5 where minimum discharge of effluent and human activities. Lowest DO at the Site 1 where maximum discharge of sewage effluent from the town. In opposite BOD is minimum at Site 5 and maximum at Site 1 followed by Site 2, 4 and 3. The nitrate concentration were high ranging from 1.38 to 2.6 mg/L. Highest mean concentration were observed at sampling Site 1 and Site2 (2.6 and 1.58 mg/L respectively). Plotting the monthly values of nitrate concentration verses time, maxima at the end of winter and during the summer are obtained (Vega *et al.*, 1998).

The highest concentration was probably partially a result of rainfall, washing out nitrate from fertilizers. Same pattern were also observed for phosphate. PO_4 values in river Ganga ranged between 3.56 to 5.79 mg/L where maximum value in sampling site 1 followed by Site2 and 4. Average concentration of PO_4 is 3.9, which is considered as the lower limit for river waters to pose a risk of eutrophication (Mourkidas *et al.*, 1990). Fig. 9. showed the value of E_h and rH_2 at different Sites. In natural water might have a range from -0.1 V (oxygen free) to + 0.8V (oxygen saturated). The neutral point of E_h in natural water might be taken as +0.35V [0.5(0.8V-0.1V)] the value below this would indicate a pollution state. Present study revealed that Ganga water in a reducing state (E_h always remained above +0.2V). The rH_2 is an objective characteristic of the process occurring in a given body of water (Voznaya, 1983).

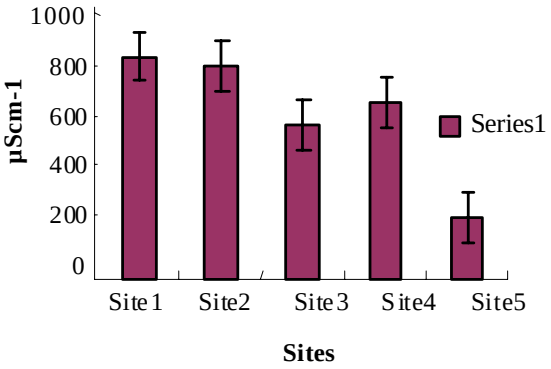

Fig. 1. Variation in EC

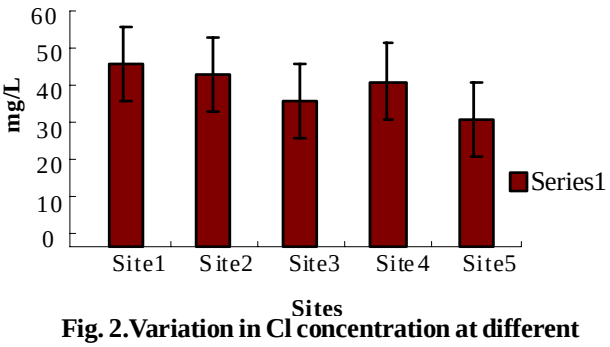

Fig. 2.Variation in Cl concentration at different sites

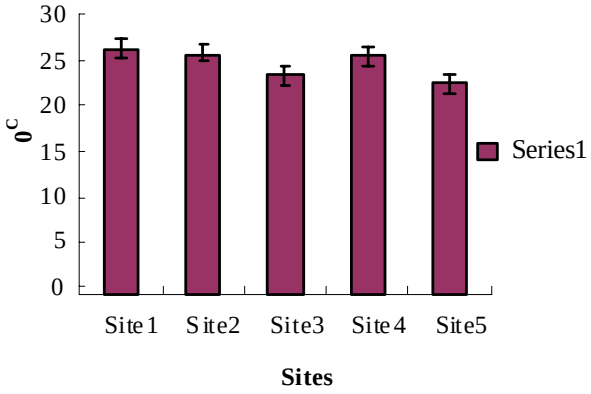

Fig. 3. Tempurature variation at different site

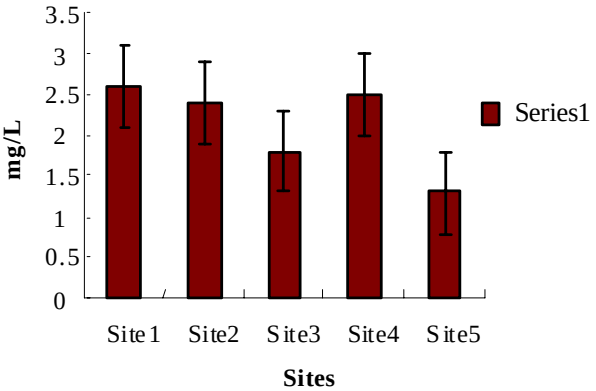

Fig. 4. Variation in Nitrate concentration at different site

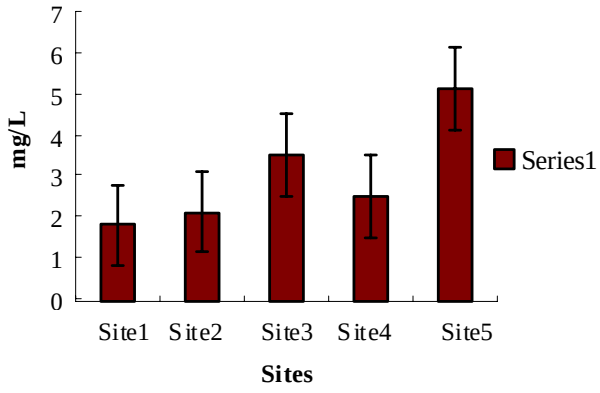

Fig. 5.Variation in DO at different sites

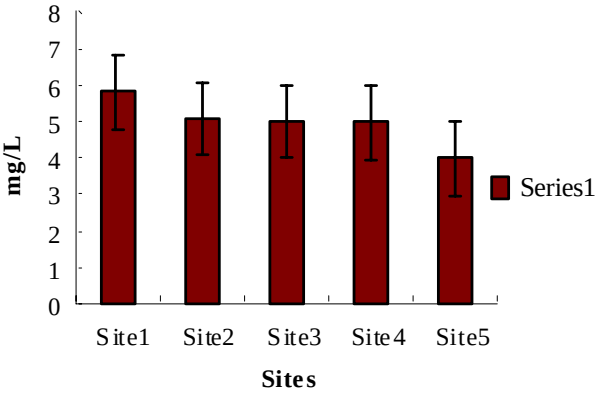

Fig. 6.Variation in Phosphate concentration at different sites

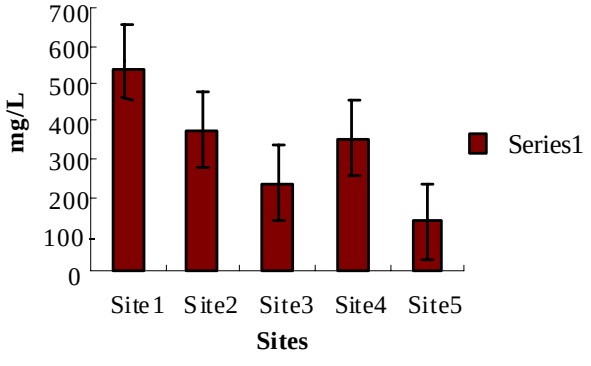

Fig. 7. Variation in BOD at different sites

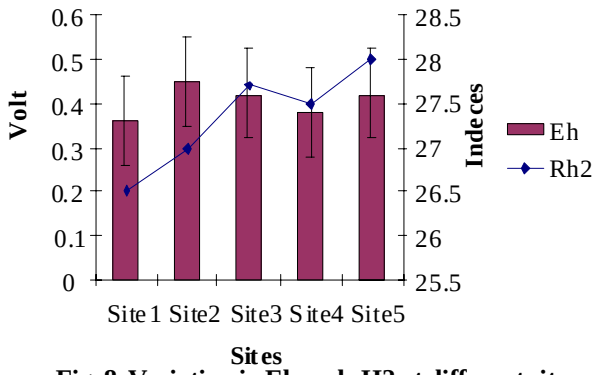

Fig. 8. Variation in Eh and rH2 at different sites

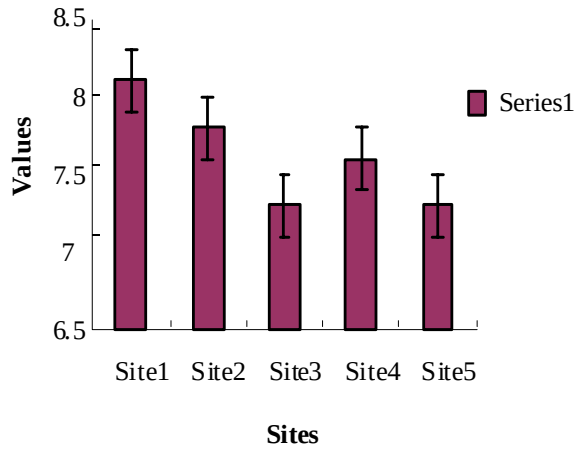

Fig. 9. Temporal variation in pH

At almost all sites values of rH_2 in river Ganga, is lower than 28, which point to the pollution in river. The addition of organic matter in water increased the concentration of the reduced from of chemical substances and lowered the ambient E_h and rH_2 values.

Bacteria are the chief decomposer and indicator of organic pollution (Table 1). Showed the bacterial concentration (TBD, FC, EC, TC, and CP) at different Sites and season. Total bacterial density (TBD) were maximum at Site 1. Bacterial population had affected by seasonal variations. Maximum concentration of (TBD, TC, FC, EC, and CP) was found in July due to favorable temperature, high turbidity and addition of more sewage and fecal matter through surface runoff.In January minimum bacterial concentration were observed due to low temperature and low input of organic matter. The irregular variation in the coliform bacterial population was due to seasonal change. (Legendra *et al.*, 1984, Barcina, 1986 and Ramanibai, 1996).

Total bacterial count can be a reliable indicator of water quality since the number of bacteria present depends upon the degree of contamination (Bilgrammi, 1998). The quantitative values of bacteria were invariable highest at Site 1 followed by 2, 4, 3 and 5 due to the discharge of sewage along with human and animal excreta and hospital refuge, open defecation near bank, allowing of cattle and other human activities. Bacterial population concentration has been noted to be directly related with the outbreaks of water borne diseases (Muller *et al.*, 1977).

Coliform bacteria are reliable indicator of organic pollution because they are unable to survive in clean water beyond a limited time (Rai and Hill 1978, Hiraishi *et al.*, 1987). Table1. shows the different concentration range of coliform, FC, E.coli and CP at different months. FC group is supposed to be more reliable indicator of fecal pollution of water than E. coli (Kennar, 1978) because they are unable to multiply outside the body of human and other warm blooded animals (Mathur and Ramanathan 1966) and also because their survival is more prolonged in surface water than other coliform types(WHO, 1991). Clostridium perfringens is an important bacterial species which survive in water for a comparatively longer period as compared to other fecal bacteria. Their presence in river water is an indicator of fecal contamination of remote time (Droop and Jannash, 1977, Sinha and Banerjee, 1987). Table 2 shows the correlation coefficient between physico-chemical and bacterial parameters of river Ganga at Varanasi. Statistically significant positive correlation were observed between Temperature, BOD, NO_3, PO_4 correlation were found between DO, EC, pH, Cl and bacterial population. Table 3 and 4 show the correlation coefficient between DO and BOD, E_h, rH_2.

Table 5 Shows the qualitatively 11 bacterial species were identified from the Ganga River at Varanasi. Maximum bacterial species were prominent in rainy season because organic matters enhance the bacterial growth and multiplication. E.coli is prevalent in every season. The existence of other members of FC group (Klebesiella, Enterobacter) has been reported for the non-fecal origin (Alonso *et al.*, 1998). Presence of pathogenic bacteria like Actinomyces, Proteus vulgaris, Pseudomonas aerogenosa, Salmonella typhi, S. paratyphi, Staphylococcus in water may cause acute to severe disease on getting suitable host and condition.

Table 1. Average monthly and seasonally variation in different bacterial parameters at different sampling sites at Varanasi

	Site1					Site2					Site3					Site4					Site 5				
Months	TBD	TC	FC	EC	CP	TBD	TC	FC	EC	CP	TBD	TC	FC	EC	CP	TBD	TC	FC	EC	CP	TBD	TC	FC	EC	CP
Nov	8.26	136.4	116	113	2560	6.45	234.8	134	456	1867	5.28	263.4	164	59.6	1960	4.87	34.8	18.7	83.8	328	4.26	32.6	18.6	19.6	392
Jan	7.26	66.3	76.4	95.4	1630	5.89	5.4	3.8	48	453	5.63	43.6	49.3	26.3	930	1.86	1.8	1.4	0.8	123	3.62	2.6	1.9	6.9	196
March	14.1	54.6	68.6	63.2	2820	8.45	23	27	107	1134	8.98	36.4	29.6	34.6	1365	7.56	23.8	17.9	256	1450	8.63	26.3	16.3	19.3	862
May	13.21	948.3	184.3	204.3	6250	8.6	34.7	24.6	250	3500	12.9	61.3	48.3	53.4	3780	9.76	34.7	25.6	281	1860	8.96	38.4	24.3	26.3	1085
July	21.63	1189	1242	1260	32300	18.96	1264	1380	3480	34000	19.34	1563	1396	256	34630	17.68	1280	980	2540	19000	16.42	1195.2	928	194.1	13400
Sept	18.41	1320	1640	1736	16850	13.8	1360	658	985	8950	16.95	1230	983	150	22140	9.19	435	360	445	9400	8.42	549.6	353	84.2	15800

Table 2. Correlation Coefficient between physico chemical and bacterial parameters of river Ganga at Varanasi

	Site1					Site2					Site3				
	TBD	TC	FC	EC	CP	TBD	TC	FC	EC	CP	TBD	TC	FC	EC	CP
Temp	0.634*	0.511	0.363	0.363	0.464	0.723*	0.312	0.316	0.416	0.456	0.735*	0.345	0.293	0.316	0.384
Turbidity	0.796**	0.815**	0.963**	0.963**	0.952**	0.746*	0.912**	0.926**	0.971**	0.924**	0.843**	0.934**	0.985**	0.956**	0.912**
EC	-0.693*	-0.764*	-0.763*	-0.793*	-0.743*	-0.61*	-0.901**	-0.899**	-0.81**	-0.856*	-0.623*	-0.856**	-0.893**	-0.815**	-0.746*
Ph	-0.412	-0.623*	-0.623*	-0.625*	-0.643*	-0.221	-0.627*	-0.62*	-0.523	-0.523	-0.31	-0.643*	-0.626*	-0.594	-0.585
DO	-0.823**	-0.726*	-0.726**	-0.725*	-0.71*	-0.756*	-0.863**	-0.843**	-0.953**	-0.887**	-0.926**	-0.884**	-0.812**	-0.893**	-0.894**
NO3	0.421	0.654*	0.653*	0.692*	0.695*	0.632*	0.932**	0.926**	0.892**	0.853**	0.426	0.864**	0.793	0.765*	0.61*
PO4	0.613*	0.854**	0.864**	0.823**	0.864**	0.623*	0.916**	-0.996**	0.916**	0.846**	0.619*	0.943**	0.936**	0.865**	0.726*
Cl	-0.076	-0.436	-0.436	-0.428	-0.413	-0.169	-0.167	-0.653*	-0.496	-0.564	-0.005	-0.549	-0.534	-0.325	-0.415

	Site4					Sites 5				
	TBD	TC	FC	EC	CP	TBD	TC	FC	EC	CP
Temp	0.654*	0.432	0.327	0.356	0.398	0.673*	0.456	0.42	0.534	0.421
Turbidity	0.796*	0.897**	0.834**	0.896**	0.843**	0.876**	0.897**	0.823**	0.865**	0.984**
EC	-0.61*	-0.783*	-0.768*	-0.689*	-0.71**	-0.438	-0.689*	-0.79*	-0.653*	-0.695*
Ph	-0.31	-0.589	-0.679*	-0.654*	-0.568	-0.875**	-0.793*	-0.731*	-0.856**	-0.784*
DO	-0.789*	-0.723*	-0.679*	-0.638*	-0.689**	-0.764*	-0.753*	-0.843**	-0.638*	-0.675*
NO3	0.345	0.679*	0.654*	0.621*	0.634**	0.378	0.864**	0.745*	0.567	0.713*
PO4	0.635*	0.83	0.798*	0.687*	0.79*	0.578	0.89**	0.953**	0.734*	0.756*
Cl	-0.069	-0.409	-0.453	-0.43	-0.414	-0.005	-0.547	-0.435	-0.267	-0.543

***Significant at 1%, ** Significant at 0.1%**

TBD = total bacterial density: TC = total coliform; FS= feacal streptococci, EC = Escherichia coli; CP =Clostridium perfringens

Table 3. Correlation coefficient (r) between DO and other parameters (BOD, E_h and rH2)

	Site1	Site2	Site3	Site4	Site5
Parameters	**DO**	**DO**	**DO**	**DO**	**DO**
BOD	0.4357	0.3012	0.1360	0.4389	0.3478
E_h	0.4356	0.4568	0.0065	0.4674	0.2345
Rh2	0.2356	0.0098	0.2400	0.2456	0.3145

Table 4. Correlation Coefficients(r) between BOD and other parameters (E_h and rH_2) in the river Ganga

	Site1	Site2	Site3	Site4	Site5
Parameters	**BOD**	**BOD**	**BOD**	**BOD**	**BOD**
E_h	0.9870**	-0.5160	-0.9890**	-0.5106	-0.6540
Rh2	-0.9841**	-0.4560	-0.9840**	-0.4560	-0.5600

**** Significance at 1% level**

Table 5. Bacterial Species isolated from Ganga Water at Varanasi

Bacteria	Summer	Rainy	Winter
Actinomyces sp	+	+++	+
Streptococus faeclis	++	+++	++
Shigella sp	+	++	+
Salmonella paratyphi	-	+++	-
Salmonella typhi	++	++	-
Clostridium perfirgens	+++	+++	++
Esherichia coli	+++	+++	++
Psuedomonas aeruginosa	+	+++	+
Klebsiella pneumoniae	+	++	-
Bacillus anthracis	-	++	+
Aerobacter aerogenes	+	+++	-

CONCLUSION

The river Ganga which is holiest river of India is frequently used for different purposes. Present study revealed the high level of bacterial population and E_h and rH_2 indicate pollution state of river Ganga. The concentration of different physico chemical and bacterial parameters is much beyond the permissible limit prescribed by WHO. Hence, direct consumption of untreated Ganga water and bathing in the Varanasi reason is at high risk for human health.

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