

MICROBIAL CHARACTERIZATION OF GANGA RIVER



CENTRAL POLLUTION CONTROL BOARD

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1.0 INTRODUCTION

Ganga is the largest river of Indian subcontinent in terms of discharge potential. The river is most sacred and holy river of India. Considering the importance and various features of Ganga River, the river has been declared as 'National River' of India. River Bhagirathi is the source Stream of Ganga River which originates from the place called Gaumukh located at a height of about 3892 meters above sea level on southern slope of Himalayas in Uttarkashi district of Uttarakhand state. The highest place from where a river receives the water is generally considered the source of that river. According to this definition Tapovan, located at an elevation of about 4463 meters and about 5 kilometers from Gaumukh is also considered as the main source of river Bhagirathi. From tapovan to Gaumukh the river flows beneath the Gangotri glacier and appears on surface at Gaumukh only. The river after traveling a distance of about 205 kilometers reaches at Devprayag to join with another Himalayan river called Alkananda. It is after their confluence the united stream is known as Ganga River. The river after passing through five states and after receiving numerous tributaries terminates in Bay of Bengal at Ganga Sagar.

As a result of increasing anthropogenic activities especially in Gangetic plain, Ganga River water quality has declined over the years. To restore quality of the river, Government of India taken various efforts under the scheme called National Mission for Clean Ganga (NMCG). The success of these efforts depends on careful identifications of water quality issues and accordingly implementation of effective water quality projects. Microbial contaminations especially pathogens is a major and critical issue in all the riverine system of the country including river Ganga. An effort is being made through the present the present study to evaluate a profile of river Ganga not in terms of indicator microbes of pathogens but also in terms of few common pathogens having significance considering the human health.

2.0 NEED OF THE STUDY

Ancient religious books describe the qualities of Ganga River water as cool, sweet, transparent, ability to remove evils, high tonic property, wholesomeness, potability, ability to resuscitate from swoon caused by dehydration, having digestive property, ability to help retain wisdom. However, besides these characteristics, the river is also famous worldwide for its unique characteristics e.g. no deteriorating effect in Ganga water even after prolonged storage period, significantly high bactericidal capacity etc. This is the reason that most Indians preserve a bottle of Ganga water in their house

for use in every important puja / ritual and also sip water directly from the river. These characteristics confirmed by several scientific studies in the past. However, during the recent past when the river water quality deteriorated significantly that too from the sources that causes significant microbial contamination of river water, no such investigation being carried out reflecting the impact of pollution on these special quality of Ganga River water. The pollution in the river is mainly assessed through the traditional approach of physico –chemical analysis only and accordingly emphasis has been given to these parameters while planning and launching of various Ganga River water quality restoration schemes. The microbial contamination even if assessed in the river is assessed generally through pathogen indicator groups i.e. Total and fecal coliform only. In the recent time when pollution in the river is increasing significantly and that too from domestic sources and when there is lot of confusion about the characteristics of Ganga river water quality for which it is known, there is an urgent need to carry out the study to innumerate the microbial population not only in terms of indicators but also in terms of few common pathogens responsible for water borne diseases. The significance of microbial contamination is also reflected in the early history of human civilization where water borne diseases such as typhoid, cholera, amoebiasis and gastroenteritis etc. are listed as common threats. According to WHO report about 80% diseases worldwide are associated with contaminated drinking water. Based on these facts also assessment of microbial contamination in water is essential while evaluating water quality of any river.

3.0 THE STUDY

To evaluate the microbiological profile of Gang River, around 1350 Km. long river stretch from Gangotri to downstream of Varanasi, representing about 53% of the total river stretch was selected for the study with following objectives:

- To innumerate pathogenic and nonpathogenic (mainly indicators of pathogens) bacteria at various locations of the river.
- To find out the impact of various towns/bathing Ghats on the concentration of various selected microbes.
- To find out the source of microbial contamination in River Ganga.
- Identifications of river locations where instream use of water may lead to water borne disease.

Considering the significance, thirty eight locations as depicted in Table 1 and Figure 1, were identified on the said Ganga River stretch for the study besides these locations, two other locations were also studied, which are situated at Alaknanda River and upper

Ganga canal . Considering the expertise in analyzing pathogens in water samples, the study was undertaken in collaboration with Department of microbiology and Department of microbiology, Institute of Medical sciences, Banaras Hindu University (IMS, BHU), Varanasi and All India Institute of Medical Science (AIIMS), Rishikes.

Seven groups of microbes and one protozoa identified for the study are as follows:

- **Total Coliform** - Total coliforms are the bacteria that are found in the soil, in water that has been influenced by surface water, and in human or animal waste. These bacteria themselves are not normally causes any serious illness, however, their presence is used to indicate that other [pathogenic](#) organisms of fecal origin may be present in water.
- **Fecal Coliform** - The group of the total coliforms that are considered to be present specifically in the gut and feces of warm-blooded animals. The presence of fecal coliform in [aquatic environments](#) may indicate that the water has been contaminated with the fecal material of humans or other animals. Fecal coliform bacteria can enter [rivers](#) through direct discharge of human [sewage](#).
- **Fecal streptococci** – These bacteria are not only present in present in human and animal intestines, but also present in the stomach. Many species of streptococcus are pathogenic. They cause diseases such as bacterial pneumonia, ear infection and bacterial meningitis. The fecal streptococci is generally been used with fecal coliforms to differentiate human fecal contamination from that of other warm blooded animals. The ratio of Fecal coliform and Fecal streptococci could provide information, though not accurately, about the source of contamination. A ratio of greater than 4 is considered indicative of human fecal contamination whereas, a ratio of less than 0.7 is indicative of non-human contamination.
- **Escherichia coli** - *Escherichia coli* also known as *E. coli* is commonly found in the lower [intestine](#) of [warm-blooded](#) organisms and is more potential indicator of fecal contamination. These bacteria can benefit their hosts by producing [Vitamin K₂](#), and preventing colonization of the intestine with [pathogenic bacteria](#), having a symbiotic relationship. However , if these bacteria penetrate to kidney or other part of the body in such case they can cause [gastroenteritis](#), [urinary tract infections](#), [neonatal meningitis](#), hemorrhagic colitis, and [Crohn's disease](#).
- **Salmonella** – This bacteria present in human feces and urine and cause illnesses such as [typhoid fever](#), [paratyphoid fever](#) and [food poisoning](#).

- **Shigella** – Present in human feces and is one of the leading bacterial causes of diarrhea worldwide. It is in the top four pathogens that cause moderate-to-severe diarrhea in African and South Asian children.
- **Vibrio cholerae** – Released in environment through human feces and responsible for the disease called cholera.
- **Cryptosporidium**- *Cryptosporidium* is a parasitic protozoa, which is present in mammals, birds, reptiles and fishes. The protozoa cause respiratory (persistent cough) and gastrointestinal (watery diarrhea) diseases in human.

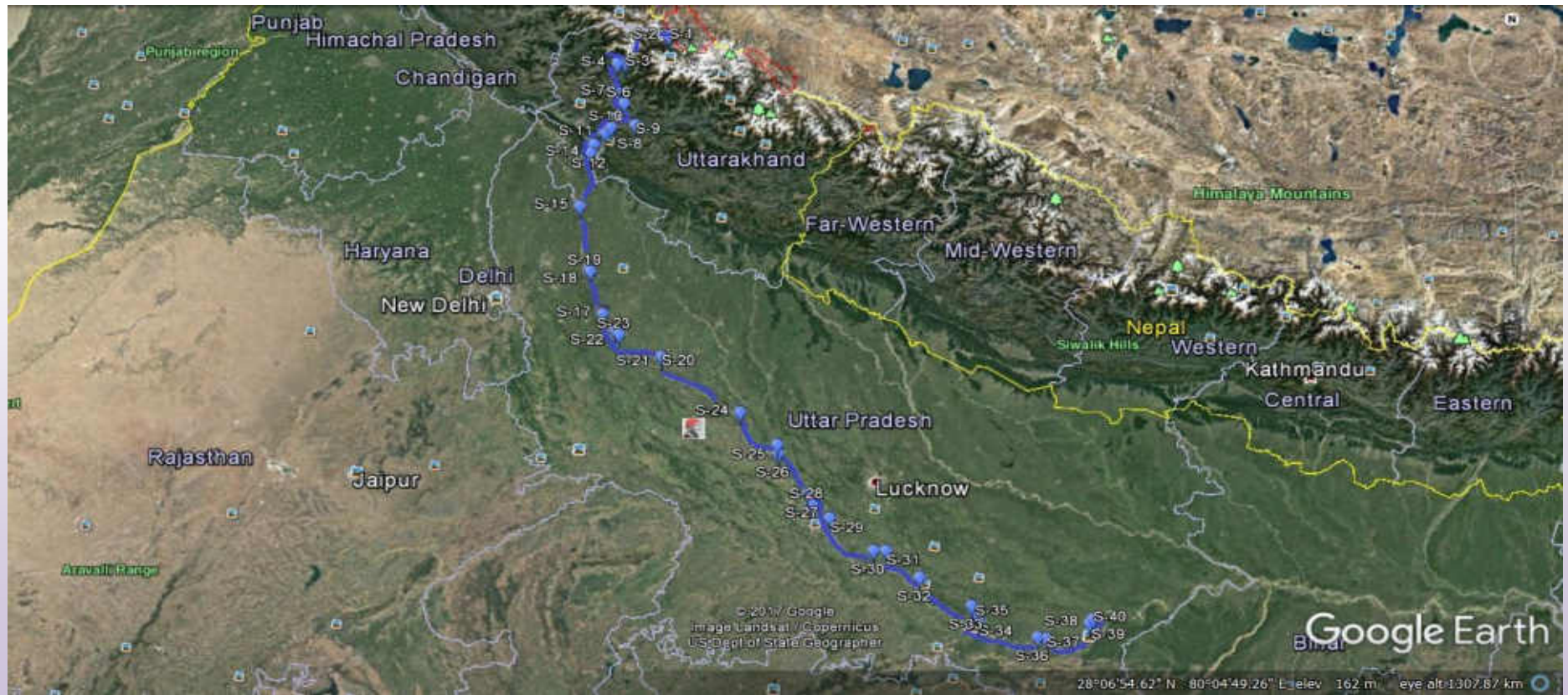
4.0 METHODOLOGY

Three samples (right bank, left bank and mid-stream) of Ganga River water were collected from each location with few locations. Sampling locations, where the water is well mixed or where boat etc. is not available only one or two samples were collected from the banks only as detailed in Table 1. Sterilized bottles were used to collect 2.0 liter of samples. Samples were collected directly from the river without using any sampling device and all the prescribed precautions were taken to avoid any contamination during sampling. The samples were preserved in ice immediately after collection. The samples were collected during the period 9th June to 15th June, 2017. Samples collected from Gangotri to Kachla Ghat were handed over to AIIMS, Rishikesh and remaining samples given to IMS, BHU for further processing. The samples concentrated through centrifuge method and analyzed for individual microbes as per Standard Methods for the examination of water and waste water, APHA (22nd edition and Practical medical microbiology, 14th ed. McCarty).

Table 1: Sampling locations and sites on Ganga River

Location code (U/S to D/S)	Location name	Sampling Site		
		Left bank	Right bank	Mid-stream
Locations on river stretch of Ganga				
S-1	Gangotri U/S (before bathing Ghat)	X	✓	X
S-2	Gangotri D/S (after bathing Ghat)	X	✓	X
S-3	Uttarkashi U/S (upstream Netala)	X	✓	X
S-4	Uttarkashi D/S (Uttarkashi Bypass Bridge)	X	✓	X
S-5	Chinyalisaur D/S (after the town)	X	✓	X
S-6	Tehri Dam U/S (near the Barrage)	✓	X	X
S-7	Tehri Dam D/S (at zero point)	X	✓	X
S-8	Bhagirathi at Dev Prayag (before confluence with Alaknanda)	✓	X	X
S-10	Rishikesh U/S (near bridge at Garurchatti)	✓	X	X

S-11	Rishikesh D/s (Chilla Barrage)-	X	✓	X
S-12	Haridwar U/s (Bhimgaura Barrage)	X	✓	X
S-14	Haridwar D/S (Bal Kumari temple D/s Ajeetpur)	X	✓	X
S-15	Ganga Barrage, Bijnore	✓	X	X
S-16	Brij Ghat U/S (before bathing Ghat)	✓	✓	✓
S-17	Brij Ghat D/ S (after bathing Ghat)	✓	✓	✓
S-18	Anoopsahar U/S (at Ganga bridge)	✓	✓	✓
S-19	Anoopsahar D/S (mastram ghat)	✓	✓	✓
S-20	Naroga Barrage, Narora	✓	✓	X
S-21	Gandhi Ghat, Narora	✓	✓	✓
S-22	Kachla Ghat U/S (before Bathing Ghat)	✓	✓	✓
S-23	Kachla Ghat D/S (after Bathing Ghat)	✓	✓	✓
S-24	Panchal Ghat, Farukhabad	✓	✓	✓
S-25	Raj Ghat, Kannauj	✓	✓	✓
S-26	Kannauj D/s (Mehndi Ghat D/s, Durjanpur village)	✓	✓	✓
S-27	Bithoor (Brahmavart ghat)	✓	✓	✓
S-28	Kanpur U/s (Shuklaganj barrage)	✓	✓	X
S-29	Kanpur D/s (Dodi ghat)	✓	✓	✓
S-30	Dalmau (near Palace), Raibareli	✓	✓	✓
S-31	Kalakankar, Raibareli	✓	✓	✓
S-32	Gegasu Ghat (Asni) Fatehpur	✓	✓	✓
S-33	Allahabad U/S (Rasoolabad)	✓	✓	✓
S-34	Ganga before confluence with Yamuna at Allahabad	✓	✓	✓
S-35	Ganga after Sangam (Chatkana Village), Allahabad	X	✓	X
S-36	Mirzapur U/S (Ramgaya Ghat), Vindhyanchal	✓	✓	✓
S-37	Mirzapur D/S (Kacheri Ghat), Vindhyanchal	✓	✓	✓
S-38	Varanasi U/S (Balua Ghat), Near Ramnagar Qila	✓	✓	✓
S-39	Assi Ghat, Varanasi	✓	✓	✓
S-40	Varanasi D/S after confluence With R. Varuna (Rajghat)	✓	✓	✓
Location on Alaknanda River				
S-9	Alkananda at Dev Prayag (before confluence with Bhagirathi)	X	✓	X
Location on Upper Ganga Canal				
S-13	Har ki Pauri D/S (Bathing Ghat), Haridwar	✓	✓	X




 S-n; where, S= Sampling locations of River Ganga, n=1-40 is the number of locations as given in Table 1

Figure: 1 Locations of River Ganga for Microbiological Monitoring



Gangotri U/S Bathing Ghat



Bhagirathi at Dev Prayag



Confluence of Bhagirathi and Alaknanda at
Devprayag












Rishikesh D/S (Chilla Barrage)









Harkipaouri D/S



	
<p>Brijghat, UP</p>	<p>Bathing at Brijghat, UP</p>
	
<p>Bijnour, U.P.</p>	<p>Anoop Shaher</p>
	
<p>Cattle wedding near Mehndi Ghat at Durjanapur D/s Kannauj</p>	<p>Collection of sample at D/s Kannauj near Mehndi Ghat at Durjanapur</p>

	
<p>Recreation activities on the bank of Ganga at Dalmau, Raibareilly</p>	<p>Bathing at Gegasu Ghat, Near Asni, Fatehpur</p>
	
<p>Shuklaganj (Barrage) Kanpur</p>	<p>Kalakankar, Pratapgarh</p>
	
<p>Mirzapur D/S Vindhyachal</p>	<p>Varanasi U/S</p>

	
<p>Rasulabad drain joining Ganga at Allahabad</p>	<p>Fish Mortality in River Ganga, Varanasi U/S</p>
	
<p>Collection of Sample in River Ganga after confluence with Yamuna at Allahabad</p>	<p>Bathing in River Ganga at Assighat, Varanasi</p>
	
<p>Varanasi D/s A/c with Varuna</p>	<p>Varanasi U/S</p>

5.0 OBSERVATIONS AND DISCUSSION

Total 85 samples were collected from the selected 38 locations in the studied stretch of Ganga River. Out of total collected samples, 34 samples were drawn from right bank, 32 samples were collected from midstream and remaining 22 samples were collected from left bank of the river. From Alaknanda River, sample was drawn from Right bank only,

whereas samples were drawn from upper Ganga canal from left and right bank both. The detail results are given in Table 2. The findings of the study are described below:

- Total coliform (TC) and fecal coliform (FC) were found at all studied 40 locations.
- TC and FC were found in the range of 5 to >1800 MPN/100 and minimum were observed at Gangotri U/S. At Alaknanda TC and FC were 84 and 63 MPN/100ml, respectively, whereas, at Harki Pauri D/S, TC and FC were around 50MPN/100ml.
- TC was found violating prescribed standard of 500 MPN/100ml at 18 locations out of 38 locations of Ganga River Stretch. The violation of Standard was observed after Rishikesh. The value of this parameter was meeting the standard.
- FC was found meeting desirable standards of 500 MPN/100ml at 21 locations of Ganga River, Alaknanda River and Harki Pauri at Haridwar. At 5 locations, the value of this parameter is exceeding desirable limit but reflecting uncertainty as the values reflecting >1600 or >1800 MPN/100ml over maximum permissible limit of 2500MPN/100ml.
- In the remaining 12 locations, samples collected from different sites either meeting desirable limit or permissible standard or violating permissible standards or there is uncertainty for permissible standard.
- No other studied microbes were present in the Ganga stretch from Gangotri U/S to Uttarkashi D/S.
- The *results of Escherichia coli (E. coli)* are depicted at Figure 2. *E. coli* were observed at all locations except five locations i.e. Gangotri U/S, Gangotri D/S, Uttarkashi U/S, Uttarkashi D/S and Tehri Dam U/S, where, the probability of presence this bacteria in the sample is nil. In River Alaknanda, the probability of these bacteria found nil, whereas at Harki Pauri D/S, the number observed were 47 MPN/100ml. The range of *E. coli* is 1.8 MPN/100ml to >1800 MPN/100ml. Among the locations where three samples were drawn, there are three locations i.e. Ram Ghat, Narora, Mirjapur D/S and Varanasi U/S, where all the three samples not reflect the probability of presence of bacteria.

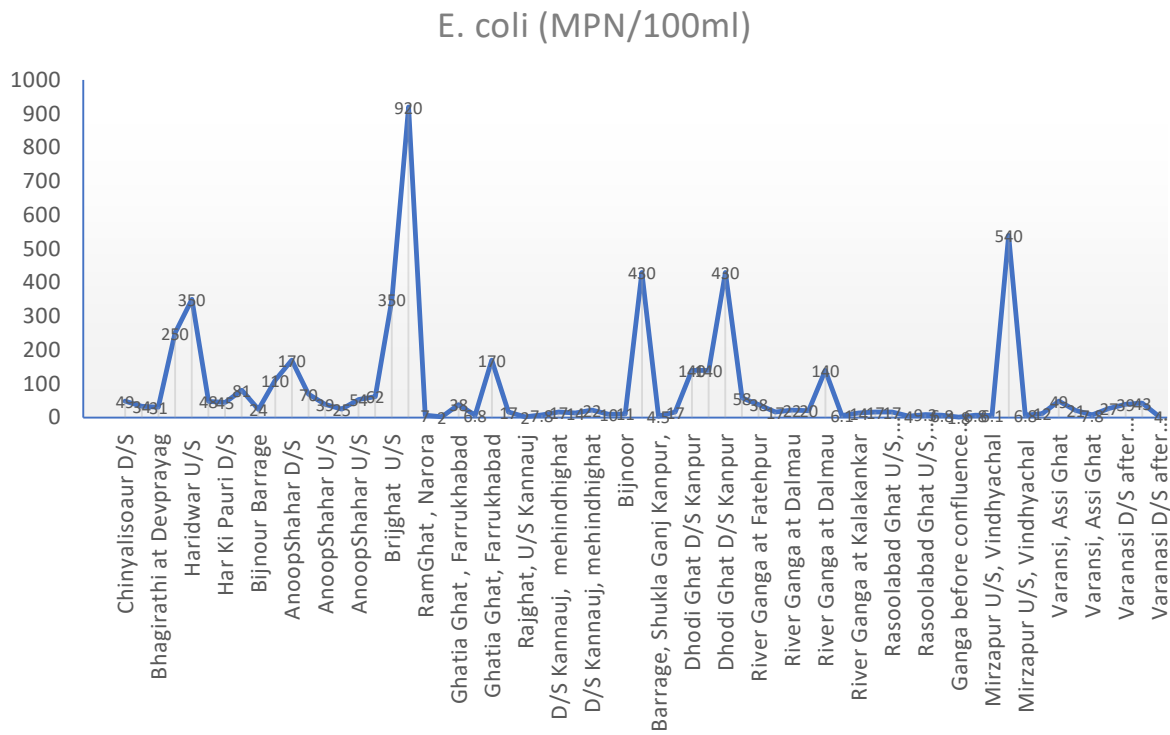


Figure 2: Profile of *E. coli* in Ganga River, Alaknanda River and Harki Pauri

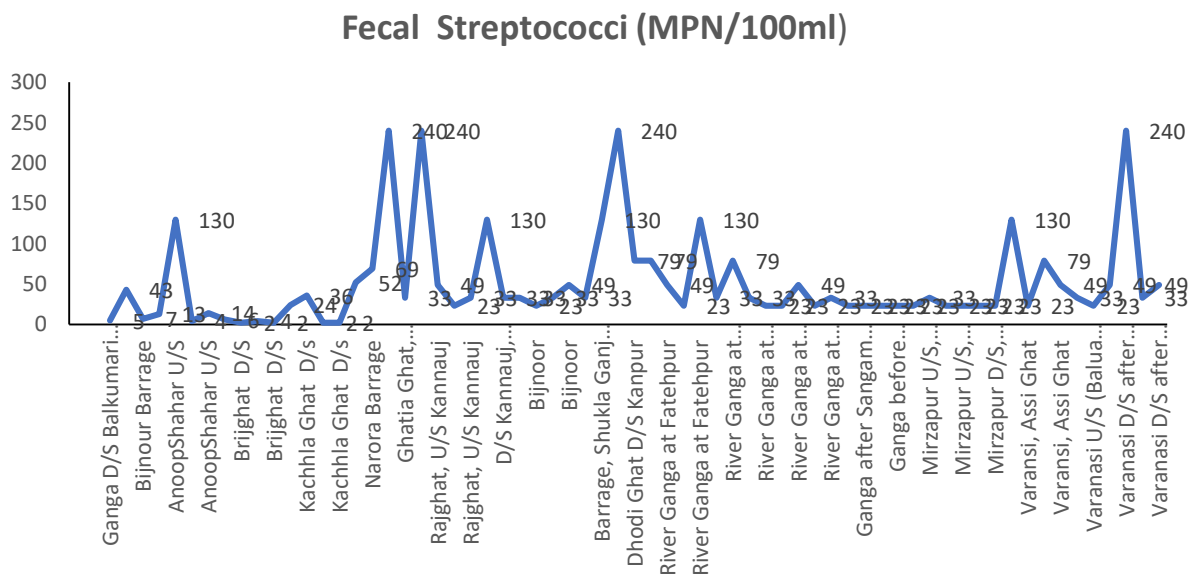


Figure 3: Profile of *Fecal Streptococci* in Ganga River, Alaknanda River and Harki Pauri

- The results of *Fecal streptococci* (FS) are depicted at Figure 3. In the River stretch from Gangotri to Haridwar U/S the probability of presence of *Fecal streptococci* (FS) was nil at 11 locations. In the remaining stretch, FS was present except at Ramghat, Narora, where, the probability of presence was found nil in all the three collected samples. The maximum number (240MPN/100ml) of *Fecal*

streptococci were recorded at three locations i.e. Gatia ghat (Farrukhabad), Kanpur D/S and Varanasi D/S.

- Desirable standard (100MPN/100ml) for FS is meeting at 32 locations and at remaining locations, samples collected from 1 or 2 sites only reflecting violation of this standard.
- Qualitative analysis was performed for pathogens (*Salmonella*, *Shigella* V. *Chlorae*) as in stressed condition (natural environment) quantitative analysis of these pathogens is viable but not culturable in water samples (APHA, 22nd ed., 2012).
- Among the studied pathogens only *Salmonella* was present at six locations that to at one samples out of three collected samples from each location. These locations, where the *Salmonella* were present are Ghatia Ghat, Farrukhabad (right), Dodighat D/S Kanpur (Middle), River Ganga at Kalakankar (Left), Rasoolabad U/S (Right), Mirzapur D/S (Left) and Varanasi Assighat (Left). The reason behind presence of pathogens in some locations is low survival rate (Inactive phase) or higher stressed rate of these bacteria in natural environment and this rate is lowest in case of *V. Chlorae*.
- *Cryptosporidium* was analyzed in river stretch from Farrukhabad to Varanasi D/S only. The Presence of this Protozoa was noticed in 13 locations as depicted in Table 3.

Table 3: List of locations where *Cryptosporidium* were found

S.No.	Name of location
1.	Panchal ghat (right)
2.	D/S Kannuj (left)
3.	Dodighat D/S Kanpur (Middle)
4.	River Ganga at Dalmau (Middle)
5.	River Ganga at Kalakankar (Middle)
6.	Rasoolabad U/S (Right)
7.	Rasoolabad U/S (Left)
8.	R. Ganga after Sangam D/S (Right)
9.	R. Ganga before confluence with Yamuna (Left and Middle)
10.	Mirzapur D/S (Left)
11.	Varanasi U/S (Left)
12.	Varanasi Assighat
13.	Varanasi D/S after confluence with R. Varuna

- FC/FS ratio used by various scientists to differentiate the sources of microbial contamination i.e. human or animal. Various references indicating value of this ratio for various sources are summarized at Table 4. According to the references in general, FC/FS ratio >4 indicates human source, 1-4, uncertain, 0.1 to 0.7, domestic animals and <0.1 indicates contamination from wild animals.

Table 4: Information of FC/FS ratio to give information about the source/type of waste

S.No.	FC/FS Ratio	Type of waste	Reference
1.	>4	Human waste	Fecal coliform and fecal streptococci ratio as a tool for assessment of waste contamination. A case Study of river Sokoto, Northwestern Nigeria. Raji M.I.O, Abraham Y.K.E, Tytler B.A., Ehinmidu T.O, et al
	0.1-0.6	Domestic animal waste	
	<0.1	Wild animal waste	
2.	>4	Human waste	The fecal coliform /Fecal streptococci ratio (FS/ FC) and water quality in the blue grass Region of Kentucky. Mark S. Coyne, and J. M. Howell, <i>University of Kentucky</i>
	0.1-0.6	Cattle waste	
	<0.1	Wild animal waste	
3.	4	Human waste	Science fair Water (sciencefairwater.com/biological-water.../ fecal- coliformfecal-streptococci-ratios/)
	1-2	Uncertain interpretation	
	<0.1	Animal waste	
4.	>=7	Human waste	Significance of fecal coliform and fecal streptococci in water pollution Monitoring. Linhai, Cai hongdao- <i>Acta Academic Medicine Wuhan</i> , December 1982, 2:251
	<1	Animal waste	
5.	>4	Human waste	www.westminister.edu/staff/orathrock/limnology/everything/
	<0.7	Animal waste	

- FC/FS ratio is not applicable at 13 locations (12 upper most locations and 1 Gandhi ghat, Narora) as the probability of FS was nil at these locations. In majority of other locations, the value of FC/FS ratio indicates microbial contamination from human sources with exceptions.

Table 2: Pathogens at various locations of the River Ganga from Gangotri to Varanasi

S.No	Sampling location details with latitude and longitude	Sample point	Date of sampling/ Time of sampling	Total Coliform (MPN/100ml)	Fecal Coliform (MPN/100ml)	<i>E. coli</i> (MPN/100ml)	F. Streptococci (MPN/100ml)	<i>Salmonella</i>	<i>Shigella</i>	<i>V. cholerae</i>	FC/FS ratio
Standard				500*	500 (desirable) - 2500 (max. permissible) ** 500**		100 (desirable)- 500 (max. permissible) **	-	-	-	-
Locations in river stretch of Ganga											
1	Gangotri U/S	Right	13/06/2017	5	5	<1.8	<1.8	NF	NF	NF	-
2	Gangotri D/S	Right	13/06/2017	34	34	<1.8	<1.8	NF	NF	NF	-
3	Uttarkashi U/S	Right	13/06/2017	8	8	<1.8	<1.8	NF	NF	NF	-
4	Uttarkashi D/S	Right	13/06/2017	56	39	<1.8	<1.8	NF	NF	NF	-
5	Chinyalisoaur D/S	Right	13/06/2017	79	79	49	<1.8	NF	NF	NF	-
6	Tehri Dam U/S	Left	14/06/2017	19	19	<1.8	<1.8	NF	NF	NF	-
7	Tehri Dam D/S	Right	14/06/2017	130	130	34	<1.8	NF	NF	NF	-
8	Bhagirathi, Devprayag	Left	14/06/2017	120	120	31	<1.8	NF	NF	NF	-
9	Rishikesh U/S	Left	14/06/2017	430	430	250	<1.8	NF	NF	NF	-
10	Rishikesh D/S	Right	14/06/2017	>1800	>1800	>1800	<1.8	NF	NF	NF	-
11	Haridwar U/S (Bhimgaura Barrage)	Right	15/06/2017	540	540	350	<1.8	NF	NF	NF	-
12	Haridwar D/S, Ajeetpur	Right	15/06/2017	>1800	81	81	05	NF	NF	NF	16.2
13	Ganga Barrage, Bijnour	Left	09.06.2017	210	44	24	43	NF	NF	NF	1.0
14	Brijghat U/S	Left	11.06.2017	>1800	>1800	62	<1.8	NF	NF	NF	-
		Right	11.06.2017	>1800	>1800	350	14	NF	NF	NF	128.6
		Middle	11.06.2017	>1800	>1800	>1800	06	NF	NF	NF	>300
15	Brijghat D/S	Left	11.06.2017	>1800	>1800	>1800	02	NF	NF	NF	>900
		Right	11.06.2017	>1800	>1800	>1800	04	NF	NF	NF	>450

		Middle	11.06.2017	>1800	>1800	>1800	<1.8	NF	NF	NF	-
16	Anoop Shahr U/S	Left	11.06.2017	220	140	39	130	NF	NF	NF	1.0
		Right	11.06.2017	>1800	1800	25	<1.8	NF	NF	NF	-
		Middle	11.06.2017	1600	1600	54	4	NF	NF	NF	400
17	Anoop Shahr D/S	Left	10.06.2017	350	170	110	<1.8	NF	NF	NF	-
		Right	10.06.2017	540	220	170	07	NF	NF	NF	31.4
		Middle	10.06.2017	910	140	70	13	NF	NF	NF	10.8

NF: Not found, < 1.8 MPN/100ml indicated, the probability of presence of bacteria in the sample is nil.

* Outdoor bathing-organized; Source (Primary water quality criteria for river): Adsorbs/3/1978-79(CPCB Publication)

** Primary water quality criteria for bathing water; Source Standards for Emission and discharge of Environmental Pollutants (EPA, 1986, Schedule 1(Rule 3))

S.No	Sampling location details with latitude and longitude	Sample point	Date of sampling/ Time of sampling	Total Coliform (MPN/100ml)	Fecal Coliform (MPN/100ml)	<i>E. coli</i> (MPN/100ml)	F. Streptococci (MPN/100ml)	<i>Salmonella</i>	<i>Shigella</i>	<i>V. cholerae</i>	FC/FS ratio
Standard				500*	500 (desirable) - 2500 (max. permissible) ** 500**		100 (desirable)- 500 (max. permissible) **	-	-	-	-
18	Narora Barrage	Left	11.06.2017	>1800	>1800	>1800	52	NF	NF	NF	>35
		Right	11.06.2017	>1800	>1800	>1800	69	NF	NF	NF	>26
19	Ghandhi Ghat , Narora	Left	11.06.2017	>1800	1600	07	<1.8	NF	NF	NF	-
		Right	11.06.2017	25	25	<1.8	<1.8	NF	NF	NF	-
		Middle	11.06.2017	430	120	02	<1.8	NF	NF	NF	-
20	Kachhla Ghat U/S	Left	11.06.2017	>1800	>1800	>1800	<1.8	NF	NF	NF	-
		Middle	11.06.2017	>1800	>1800	>1800	02	NF	NF	NF	>900
		Right	11.06.2017	>1800	>1800	>1800	24	NF	NF	NF	>75
21	Kachhla Ghat D/S	Left	11.06.2017	>1800	>1800	>1800	36	NF	NF	NF	>50
		Right	11.06.2017	>1800	>1800	>1800	02	NF	NF	NF	>900

		Middle	11.06.2017	>1800	1600	920	02	NF	NF	NF	800
22	Panehal Ghat, Farrukhabad	Left	13/06/2017	>1600	>1600	38	240	NF	NF	NF	>6.6
		Middle	13/06/2017	49	49	6.8	33	NF	NF	NF	1.5
		Right	13/06/2017	>1600	>1600	170	240	+ve	NF	NF	>6.6
23	Rajghat, Kannauj	Left	13/06/2017	140	140	17	49	NF	NF	NF	2.8
		Middle	13/06/2017	33	33	02	23	NF	NF	NF	1.4
		Right	13/06/2017	79	79	7.8	33	NF	NF	NF	2.4
24	Kannauj, D/S Near Durjapur village	Left	13/06/2017	79	79	17	130	NF	NF	NF	0.6
		Middle	13/06/2017	110	110	14	33	NF	NF	NF	3.3
		Right	13/06/2017	130	130	22	33	NF	NF	NF	3.9
25	Bithoor (Brahmvrat ghat)	Left	13/06/2017	49	49	10	23	NF	NF	NF	2.1
		Middle	13/06/2017	49	49	11	33	NF	NF	NF	1.5
		Right	13/06/2017	>1600	>1600	430	49	NF	NF	NF	>32.6
26	Kanpur U/S , Shukla Ganj Kanpur,	Left	13/06/2017	49	49	4.5	33	NF	NF	NF	1.5
		Right	13/06/2017	140	140	17	130	NF	NF	NF	1.1
27	Kanpur D/S, Dhodi Ghat	Left	13/06/2017	>1600	>1600	140	240	NF	NF	NF	>6.7
		Middle	13/06/2017	>1600	>1600	140	79	NF	NF	NF	>20.2
		Right	13/06/2017	>1600	>1600	430	79	+ve	NF	NF	20.2

NF: Not found, < 1.8 MPN/100ml indicated, the probability of presence of bacteria in the sample is nil.

* Outdoor bathing-organized; Source (Primary water quality criteria for river): Adsorbs/3/1978-79(CPCB Publication)

** Primary water quality criteria for bathing water; Source Standards for Emission and discharge of Environmental Pollutants (EPA, 1986, Schedule 1(Rule 3))

S.No	Sampling location	Sample point	Date of sampling/ Time of sampling	Total Coliform (MPN/100ml)	Fecal Coliform (MPN/100ml)	<i>E. coli</i> (MPN/100ml)	F. Streptococci (MPN/100ml)	<i>Salmonella</i>	<i>Shigella</i>	<i>V. chlorae</i>	FC/FS Ratio
Standard				500*	500 (desirable) - 2500 (max. permissible) ** 500**	-	100 (desirable)- 500 (max. permissible) **	-	-	-	-
28	Dalmau, Raibareilly,	Left	14/06/2017	220	220	22	33	NF	NF	NF	6.7
		Middle	14/06/2017	>1600	>1600	20	79	NF	NF	NF	>20.2
		Right	14/06/2017	540	540	140	33	NF	NF	NF	16.4
29	Kalakankar, Pratapgarh	Left	14/06/2017	46	46	6.1	23	+ve	NF	NF	2.0
		Middle	14/06/2017	79	79	14	23	NF	NF	NF	3.4
		Right	14/06/2017	110	110	17	49	NF	NF	NF	2.2
30	Gegasu Ghat (Asni), Fatehpur	Left	14/06/2017	920	920	58	49	NF	NF	NF	18.8
		Middle	14/06/2017	920	920	38	23	NF	NF	NF	-
		Right	14/06/2017	140	140	17	130	NF	NF	NF	1.1
31	Allahabad U/S (Rasoolabad Ghat)	Left	10/06/2017	79	79	17	23	NF	NF	NF	3.4
		Middle	10/06/2017	33	33	04	33	NF	NF	NF	1.0
		Right	10/06/2017	>1600	>1600	>1600	23	+ve	NF	NF	>69.6
32	Ganga before confluence with Yamuna,	Left	10/06/2017	70	70	6.8	23	NF	NF	NF	3.0
		Middle	10/06/2017	23	23	1.8	23	NF	NF	NF	1.0
		Right	10/06/2017	49	49	6.8	23	NF	NF	NF	2.1
33	Ganga after Sangam, Allahabad	Right	10/06/2017	49	49	9.3	23	NF	NF	NF	2.1

34	Mirzapur U/S, Vindhyachal (Ram Gaya Ghat)	Left	11/06/2017	33	33	6.1	33	NF	NF	NF	1.0
		Middle	11/06/2017	540	540	540	23	NF	NF	NF	23.5
		Right	11/06/2017	49	49	6.8	23	NF	NF	NF	2.1
35	Mirzapur D/S, vindhychal (Kaccheri Ghat)	Left	11/06/2017	23	23	<1.8	23	+ve	NF	NF	1.0
		Middle	11/06/2017	23	23	<1.8	23	NF	NF	NF	1.0
		Right	11/06/2017	70	70	12	130	NF	NF	NF	1.0
36	Varansi, Assi Ghat	Left	12/06/2017	240	240	49	23	+ve	NF	NF	10.4
		Middle	12/06/2017	170	170	21	79	NF	NF	NF	2.2
		Right	12/06/2017	79	79	7.8	49	NF	NF	NF	1.6

NF: Not found, < 1.8 MPN/100ml indicated, the probability of presence of bacteria in the sample is nil.

* Outdoor bathing-organized; Source (Primary water quality criteria for river): Adsorbs/3/1978-79(CPCB Publication)

** Primary water quality criteria for bathing water; Source Standards for Emission and discharge of Environmental Pollutants (EPA, 1986, Schedule 1(Rule 3))

S.No	Sampling location details with latitude and longitude	Sample point	Date of sampling/ Time of sampling	Total Coliform (MPN/100m l)	Fecal Coliform (MPN/100m l)	<i>E. coli</i> (MPN/100m l)	F. Streptococci (MPN/100ml)	<i>Salmonella</i>	<i>Shigella</i>	<i>V. cholerae</i>	FC/FS Ratio
Standard				500*	500 (desirable) - 2500 (max. permissible) ** 500**	-	100 (desirable)- 500 (max. permissible) **	-	-	-	-
37	Varanasi U/S (Balua Ghat) (Near Ram Nagar Qila)	Left	12/06/2017	23	23	<1.8	33	NF	NF	NF	0.7
		Middle	12/06/2017	23	23	<1.8	23	NF	NF	NF	1.0
		Right	12/06/2017	130	130	27	49	NF	NF	NF	2.6
38	Varanasi D/S after confluence with Varuna (Raj Ghat)	Left	12/06/2017	430	430	39	240	NF	NF	NF	1.8
		Middle	12/06/2017	540	540	43	33	NF	NF	NF	16.4
		Right	12/06/2017	33	33	04	49	NF	NF	NF	0.7
Location in Alaknanda River											
39	Alkananda, Devprayag	Right	14/06/2017	84	63	<1.8	<1.8	NF	NF	NF	-
Location in Upper Ganga Canal											
40	Har Ki Pauri D/S Bathing ghat	Left	15/06/2017	56	56	48	<1.8	NF	NF	NF	-
		Right	15/06/2017	45	45	45	<1.8	NF	NF	NF	-

NF: Not found, < 1.8 MPN/100ml indicated, the probability of presence of bacteria in the sample is nil.

* Outdoor bathing-organized; Source (Primary water quality criteria for river): Adsorbs/3/1978-79(CPCB Publication)

** Primary water quality criteria for bathing water; Source Standards for Emission and discharge of Environmental Pollutants (EPA, 1986, Schedule 1(Rule 3)

6.0 CONCLUSION

In nature, it is extremely difficult to differentiate the sources of microbiological contamination (i.e. from human or animal) in water bodies. To identify the sources and severity of contaminations, indicator microbes identified and used worldwide. The pathogenic indicator microbes generally reflect contamination predominantly from human sources, but cover the contamination from other animals also. Further, contamination from animal is also significant, considering the fact that the bacterial pathogen from animal sources may infect human also. Therefore, identification of contamination sources may not provide any significant and realistic information. Further, identifying of particular sources of contamination is exhausted, time consuming and expensive and as such may not be practiced on regular basis. This is one of the main reasons behind the application of indicator microbes in water system for pathogenic contamination. In the present study, among the selected indicator species, *E. coli* predominantly contributed from human sources whereas *fecal streptococci* contributed from animal sources. Though, FC/FS ratio and *E. coli* has limitations and may not provide correct information but still generally used to identify the sources. Based on these two parameters, it may be concluded that in studied river stretch from Gangotri to Uttarkashi and in Alaknanda river at Devprayag, the probability of microbial contamination is nil. Whereas, in remaining stretch, at majority of locations including Harki pauri at Haridwar, there is a probability of human contamination besides contamination of animals exists. At 13 locations situated in the river stretch from Farrukhabad to Varanasi, six locations of Ganga River, where presence of *Salmonella*/*Cryptosporidium* were observed are the most severely contaminated locations and in stream use of river water at these locations may cause [typhoid fever](#), [paratyphoid fever](#) and [diarrhea](#).

7.0 RECOMMENDATION

- The present study was conducted in summer season; it will be better to extend the study for other seasons also for two-three years to get more realistic information.
- Steps required to be taken in the river stretch from Rishikesh onwards to check fecal contamination from human and animal sources, so as to minimize bacterial contamination.
- At 13 severely contaminated sites, warning boards regarding health risk of in stream use of river water should be displayed.
- More attentions are required to be paid at the thirteen locations where Salmonella and Cryptosporidium were present.
- Open defecation is also a major source of microbial/protozoan contamination of river water. Priority should be given to the Human settlements located on the banks of River Ganga for implementation of government initiatives to check this activity.
- The results of several samples reflects values >1600MPN/100ml and >1800MPN/100ml to get the exact probable numbers, higher dilution should be used if require, more than three dilution series may be taken for analysis.