CIBTech Journal of Zoology ISSN: 2319–3883
An Online International Journal, Available at http://www.cibtech.org/cjz.htm
2025 Vol.14, pp.157-173/Shailu and Rakesh
Research Article

EVALUATION OF DRINKING WATER QUALITY BASED ON PHYSICOCHEMICAL AND MICROBIAL PARAMETERS IN COMMUNITY SOURCES OF PITHORAGARH, UTTARAKHAND

Shailu Garkoti and Rakesh Verma*
Department of Zoology, S.S.J. University, L.S.M. Campus Pithoragarh Uttarakhand, India
**Author for Correspondence: rv.pith@gmail.com*

ABSTRACT
Water is a vital resource for all forms of life, offering essential health benefits and supporting the survival and well-being of living organisms. Ensuring access to clean and safe drinking water is crucial, particularly in remote and ecologically sensitive regions. This study focuses on the physicochemical assessment of community water sources in the Himalayan region of Pithoragarh, Uttarakhand, India. The primary objective was to evaluate the seasonal variations in water quality through monthly analysis of various physicochemical parameters over one year. Water samples were collected from multiple community sources and tested for pH (6.0-7.9), water temperature (7-21°C), air temperature (10-22°C), total dissolved solids 332-498 mg/L, dissolved oxygen 5.2-7.9 mg/L, carbon dioxide 0.4-2.6 mg/L, alklinity 59-287 mg/L, biological oxygen demand 0.8-3.1 mg/L, and electrical conductivity 308-799 µS/cm. After that, find out the statistically significant differences between the various parameters, as shown by p-values less than 0.05. These parameters showed noticeable fluctuations throughout the year, indicating the influence of seasonal and environmental factors on water quality. In addition to chemical analysis, microbiological examination revealed the presence of bacteria in several water sources, such as *E. coli, Salmonella, Shigella, Clostridium* & *Campylobacter.* After that, we observed the different bacterial characteristics, such as colour, shape, and surface. The presence of bacteria raises the possibility of waterborne illnesses in this area and suggests possible faecal contamination. This study highlights the necessity of routine monitoring, better sanitation procedures, and efficient water management techniques for drinking water safety. Furthermore, identifying different microorganisms' points to persistent biological contamination that endangers public health.

Keywords: *Physicochemical, Microbiological, Contamination, Waterborne Diseases*

INTRODUCTION
Water is essential for sustaining life, yet only 2.6% of Earth's water is freshwater. Of this, 76.4% is locked in glaciers and polar ice caps, and much remains underground or as atmospheric moisture. Only about 0.3% is accessible as surface water in rivers and lakes. This limited availability highlights the urgent need for sustainable water management (Oliveira, 2017). A basic human right is the availability of clean drinking water; yet, consumers may experience health issues if the water is contaminated with opportunistic pathogenic environmental bacteria (WHO, 2004). They may get polluted with bacteria as a result of interactions between these exposed water sources and sewage effluents, animal waste, and agricultural runoff (Obi *et al*., 2002; Sharma *et al.,* 2005). The rate at which water supplies are being misused and deteriorating is concerning. This reduction is caused in part by population expansion, industrialisation, and urbanisation. Numerous microorganisms are currently contaminating clean water sources. In these unfavourable circumstances, their inherent biological traits are changing (Singh *et al.,* 2010). Knowing the physicochemical characteristics of water is necessary to evaluate its quality and suitability for different applications. Both human activity and natural forces have an impact on these attributes. Such understanding is necessary for the efficient use and management of water resources

(Gorde & Jadhav, 2013). In Pithoragarh, Uttarakhand, traditional water sources like "naula" and "dhara" are still essential to the local population. Because of their ease of use and accessibility, these sources have been trusted for many generations. Concerns over the water's quality, however, have increased recently. Due to the presence of harmful bacteria, residents are now concerned about their health and safety (Johnston *et al.,* 2001).

Throughout the year, seasonal changes in physico-chemical parameters impact the quality of drinking water. Both human activity and natural processes are responsible for these changes. Water safety and usability may be greatly impacted by such variations major health risks associated with contaminated water at specific seasons. Consuming it can lead to gastrointestinal infections, typhoid, diarrhoea, and dysentery caused by different types of bacteria such as *E. coli, Salmonella, Shigella, etc* (Fazal-ur-Rehman, 2019). The World Health Organization estimates that 1.1 billion people globally drink contaminated water. 88% of all diarrheal illness cases worldwide are caused by unsafe water, inadequate sanitation, and poor hygiene (WHO, 2002). Ten to twenty million people die each year from waterborne illnesses, which also cause about 250 million infections (Zamxaka *et al*., 2004). In many parts of the world, waterborne illnesses continue to be a serious health concern. Every year, they are to blame for about 4 billion instances of diarrhoea. These conditions comprised 5.7% of the world's disease burden in 2000. This demonstrates the continuous harm to public health caused by contaminated water and inadequate sanitation (WHO, 2002).

The aim of conducting a physico-chemical assessment of community water sources in the Himalayan region of Pithoragarh, Uttarakhand, India. The primary objective of the study is to analyze the water quality of the community water sources and analyzed the microbial examination revealed the presence of bacteria in several water sources, such as *E. coli, Salmonella, Shigella, Clostridium* & *Campylobacter.* This investigation holds significant importance in guiding public health interventions and policy decisions related to water quality management, helping to prevent and control waterborne diseases and promoting safe drinking water access for the local community.

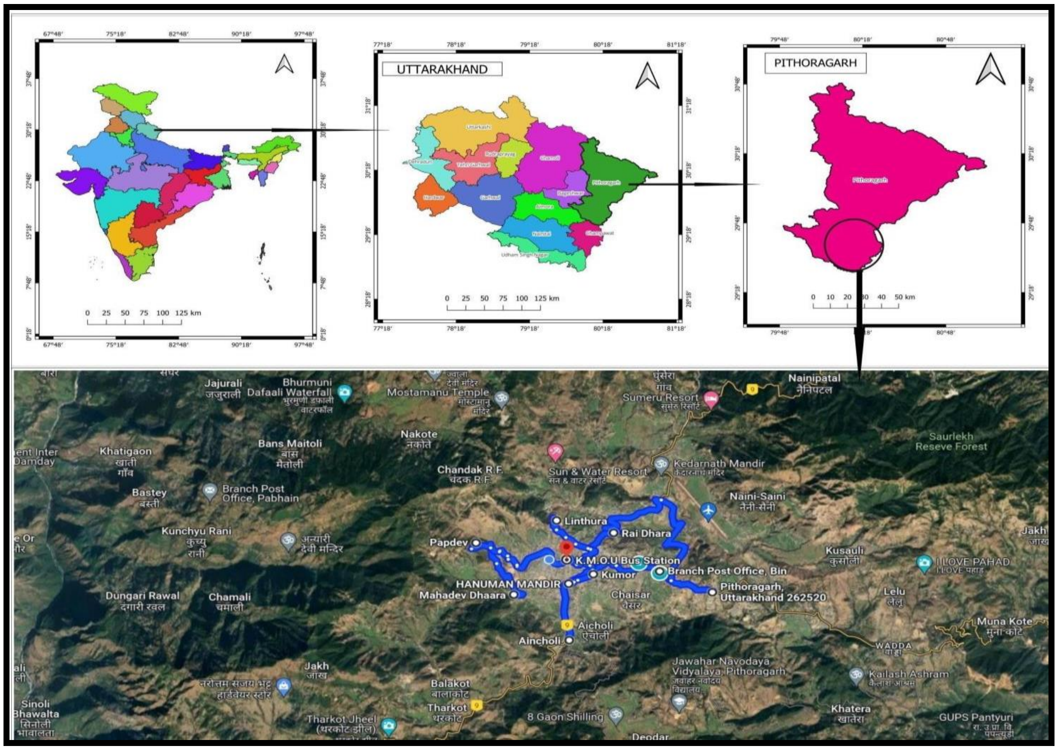
MATERIALS AND METHODS

Sample collection: Water samples were taken from traditional drinking water sources at ten distinct study locations close to Pithoragarh City, which is situated in the northern Indian state of Uttarakhand at 29.5829º N, 80.2182º E. Shive Dhara (SD), Hanuman Mandir Dhara (HD), Rai Dhara (RD), Linthura Dhara (LD), Bin Naula (BN), Chungi Dhara (CD), Kumor Naula (KN), Ancholi Dhara (AD), Pavdeev Dhara (PD), and Mahadev Dhara (MD) are the locations for these studies (Photograph 1). Several sterile conical flasks covered with aluminium foil were filled with the samples. The neck was then filled around 30 cm below the water's surface after the cap cover was gently replaced. The sample location name, date, and time were then written on each bottle. The samples were promptly taken to the laboratory for bacteriological investigation after being stored in an icebox. All water sampling was done according to APHA (2012).

Physico-chemical analysis: Several crucial parameters, including hydrogen ion concentration (pH), water temperature (WT), atmospheric temperature (AT), total dissolved solids (TDS), dissolved oxygen (DO), carbon dioxide (CO_2), total alkalinity (TA), biological oxygen demand (BOD), and electric conductivity (EC), were used to evaluate the water quality after the sample was aseptically collected in 1000 ml sterile bottles with the method of APHA, 2012.

Microbial analysis: The components of selective media help target organisms flourish while preventing undesirable microorganisms from growing. The various bacteria have their own set of selective media produced. Xylose lysin deoxycholate agar media for *Shigella* (Gaurav *et al.,* 2013), lactose gelatin media for *Clostridium* (Lin & Labbe, 2003), skirrow's campylobacter media for *Campylobacter* (Bi *et al.,* 2013), l brilliant green agar media for *Salmonella* (Murchie et al., 2008), eosin methylene blue agar media for *Escherichia coli* (Leininger *et al.,* 2001), and cefsulodin irgasan novobiocin media for *Yersinia* (Schiemann, 1979) were used. After that observed the bacterial characteristics morphology such as color, shape, and surface were observed and calculated, according to Singh & Sao, (2015); Jan *et al.,* (2016) and Batra *et al.,* (2018).

Statistical analysis: The annual data summary statistical analysis was examined using the mean, standard deviation, PAST program 4.08 version (Hammer & Harper, 2001), MS Excel data analysis software, and ANOVA (Heiberger & Neuwirth, 2009).



Photograph 1: Map of the study area showing the location of different sampling sites

RESULTS

Monthly analyses of drinking water's physicochemical properties from various sources were conducted in this study to evaluate fluctuations in water quality. The average pH, which ranged from 6.0 to 7.9, stayed rather alkaline at all sampling locations. The temperature of the water varied very little, from 7 °C (AD) to 21 °C (BN and KN), suggesting thermal profiles that were very constant. The air temperature varied slightly from 10 °C to 22 °C. Concentrations of Total Dissolved Solids (TDS) ranged from 232 mg/L to 498 mg/L, showing significant variance. While the concentrations of carbon dioxide (CO_2) stayed low, reaching a maximum of 287 mg/L, the amounts of dissolved oxygen (DO) ranged from 5.2 mg/L to 7.9 mg/L. Biochemical Oxygen Demand (BOD) varied from 0.8 mg/L to 3.1 mg/L. Ion concentration was indicated by Electrical Conductivity (EC), which varied from 308 to 799 µS/cm, demonstrating considerable variation in mineral composition between sources shown in Table 1.

Table 2 demonstrates that, with p-values less than 0.05, all examined parameters showed statistically significant differences. WT/pH, WT/TDS, and WT/EC all had high F-values, indicating significant variation between groups, with WT/TDS displaying the most pronounced variations. To highlight spatial variability, mean square (MS) values for between-group variation were larger than within-group values. This implies that the water quality varies greatly depending on the area. Particularly significant statistical results were found for parameters such as WT/AT, WT/CO_2, WT/DO, WT/BOD, and WT/alkalinity.

Microbial contamination was examined at ten selected drinking water sources using various selective agar media to detect specific pathogenic bacteria. The study consistently identified *E. coli*, *Salmonella*, *Shigella*, *Campylobacter*, and *Clostridium* across all seasons, indicating continuous contamination. A significant rise in bacterial colonies was observed during the summer, which enhances microbial growth. Conversely, the lowest contamination levels were recorded during winter, suggesting seasonal variation in bacterial activity. Notably, *Yersinia* was completely absent from all sampling sites throughout the study, indicated in Table 3-8.

The bacterial culture characteristics of *E. coli*, *Shigella*, *Salmonella*, *Campylobacter*, and *Clostridium* showed distinct morphological patterns across months and locations. *E. coli* colonies were mostly white, round, and smooth, but some showed a metallic sheen or rough texture in certain months (Table 9). *Shigella* formed primarily yellow colonies with irregular shapes, though round forms also appeared; surfaces remained smooth (Table 10). *Salmonella* colonies were consistently pink, round, and smooth, indicating stable growth across all months (Table 11). *Campylobacter* colonies were usually white, occasionally turning grey, and maintained a round shape with smooth surfaces (Table 12). Color shifts in *Campylobacter* likely reflected metabolic changes. *Clostridium* colonies were mainly white but sometimes turned yellow, possibly due to metabolic variation (Table 13). These colonies were round and smooth regardless of color changes. Overall, each bacterium exhibited characteristic colony color, shape, and surface, as shown in Figure 1.

DISCUSSION

Our analysis of the physico-chemical parameters of various drinking water sources in this study is consistent with the findings of Patil (2010), Jasmin and Mallikarjuna (2014), and Qureshi *et al*., (2021), who investigated the physico-chemical characteristics of groundwater quality parameters. The current study found that the water's temperature fluctuates with the seasons, which is consistent with the results of studies by Menberg *et al*., (2014) and Gunawardhana and Kazama (2011) that examined the effects of climate change on groundwater temperature. In the present study, we analyzed the physicochemical properties of groundwater, which were similar to Robinson *et al.,* (1998) and Jasechko *et al*., (2014), which worked on the seasonal differences in the groundwater recharge ratio, defined here as the ratio of groundwater recharge to precipitation.

In our study findings, the site-wise ANOVA analysis of various parameters revealed that p-values less than 0.05 for all parameters under investigation indicated statistical significance. This was comparable to the study conducted by Shenai-Tirodkar *et al.,* (2016), which focused on the assessment of water and sediment quality and discovered significant seasonal and site-wise variations of physicochemical parameters ($P < 0.05$). In our study, Tyagi *et al.,* (2015) investigated site-wise variation under ANOVA analysis between the major physicochemical characteristics. They looked at variations in drinking water sources across time and space. Using analysis of variance (ANOVA) to interpret their results, Jha *et al*., (2013) and Bhardwaj *et al*., (2018) carried out a thorough comparative examination of water quality metrics across various research locations.

According to Dinakaran et al., (2023) findings, we also examined the presence of several bacteria in various water samples in our study by looking at the colonies across a variety of selective media. Zhang *et al*., (2019) also observed the *E. coli* colonies on EMB agar displaying a metallic sheen color. In line with McConn *et al*., (2024), *Salmonella* colonies were isolated on brilliant green agar, demonstrating the efficacy of the medium. According to Bolton & Robertson (1982), *Campylobacter* was effectively isolated using Skirrow's medium. The appearance of *Clostridium* colonies on selected gelatin agar was consistent with Wohlsen *et al.,* (2006) observations. In contrast to Cheyne *et al.,* (2009), we did not discover *Yersinia* while using CIN media, indicating environmental heterogeneity.

In this study, we observed the different morphology characteristics of different bacteria such as color, shape, and surface, which were similar to the observation of Singh & Sao (2015), and Batra (2018). We observed distinct culture characteristics of various bacterial species on selective media, which aligned with the findings of Paul *et al*., (2010); Kannahi & Sivasankari (2014) whose work focused on isolating and characterizing bacteria from selected areas, and reported similar observations to our study. In our study, we observed the cultured morphology of bacteria, which was similar to the findings of Chigbu & Sobolev (2007); Chouhan (2015) and Kim *et al*., (2019), who isolated the colony morphology from drinking water sources and identified their distinct colony morphologies, findings that align with our observations.

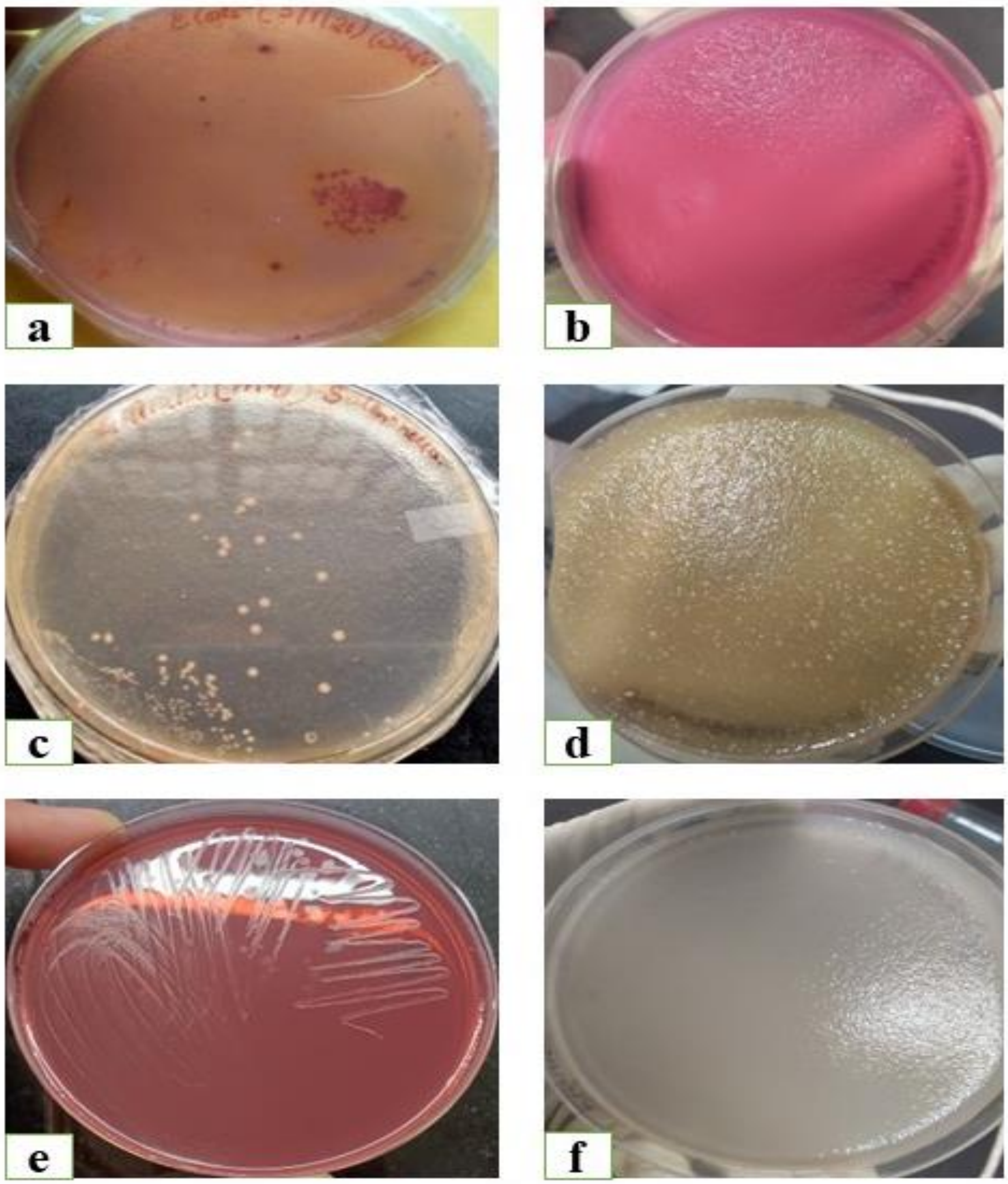


Figure 1: Showing the colony of different bacteria on selective agar media (a) *E. coli*, (b) *Shigella,* (c) *Salmonella,* (d) *Campylobacter*, (e) *Clostridium,* and (f) *Yersinia* (No growth)

Table 1: Annual variations of all physicochemical parameters in all spots

Name of sites	pH	WT (ºC)	AT (ºC)	TDS (mg/l)	DO (mg/l)	CO_2 (mg/l)	Alkalinity (mg/l)	BOD (mg/l)	EC (µs/cm)
SD	6.6-7.7 7.10±0.39	10-20 15.16±3.12	12-20 16.75±2.56	232-489 389.41±65.67	5.9-7.5 6.35±0.48	0.7-2.5 1.55±0.49	98-187 134.08±30.844	1.3-2.7 2.1±0.36	423-759 605.08±129.06
HM	6.4-7.7 6.98±0.43	9-20 15.08±3.36	11-21 16.83±3.53	321-489 399.75±53.48	5.5-7.3 6.44±0.47	0.9-2.6 1.78±0.56	92-186 137.16±30.12	1.2-3 2.01±0.55	434-759 621.25±124.19
RD	6.4-7.6 7.11±0.39	9-19 17.33±3.07	12-21 17.33±3.08	294-480 403.25±56.44	5.2-7.2 6.25±0.51	0.5-2.3 1.44±0.59	76-201 139.41±40.53	1.5-3.1 2.14±0.40	338-765 593.16±146.88
LD	6-7.8 7.05±0.54	9-19 16±3.13	12-21 17.08±3.55	348-491 436.16±44.44	6-7.9 6.77±0.62	0.4-2.3 1.48±0.58	152-287 195.58±41.72	1.2-2.6 2.05±0.39	354-729 568.16±117.62
BN	6.3-7.9 7.1±0.52	10-21 15.75±3.67	12-20 16.83±2.94	328-480 417.41±35.68	6-7.9 6.55±0.55	0.6-2.6 1.45±0.62	107-199 162.75±30.98	1.6-2.5 2.15±0.31	358-779 604.25±150.55
CD	6.1-7.3 6.92±0.43	9-18 14.33±3.02	12-20 16.83±2.85	314-490 403.91±46.52	5.9-7.2 6.47±0.42	0.8-2.2 1.61±0.49	59-198 127±43.38	1.7-2.7 2.10±0.31	308-799 595.41±142.07
KN	6.4-7.8 7.10±0.51	10-21 16±3.43	10-21 16.41±3.75	344-498 413.74±47.62	5.7-7.1 6.35±0.37	0.8-2.3 1.42±0.51	102-207 145.5±39.75	1.3-2.9 2.13±0.40	338-751 587.41±143.53
AD	6.1-7.9 7.07±0.49	7-19 14.58±3.50	10-22 17±3.64	300-490 377.91±66.31	5.8-7.1 6.45±0.38	0.6-2.4 1.61±0.62	117-189 153.08±24.94	1.4-2.4 2.05±0.32	341-737 558.33±142.81
MD	6.2-7.4 6.94±0.45	9-19 14.66±3.36	10-20 16.66±3.20	304-460 382.16±52.16	6-7.4 6.42±0.44	0.5-2.3 1.48±0.65	106-220 162.166±37.59	0.8-2.7 1.89±0.52	329-740 580.25±149.80
PD	6-7.6 7±0.56	10-20 15.91±3.34	12-22 18.33±3.70	342-473 402.08±45.75	6-7.9 6.67±0.58	1-2 1.61±0.33	102-188 142.33±28.46	1.2-2.8 1.95±0.47	418-748 580.91±124.87

Table 2: Site-wise analysis of variance test between different parameters

S. No.	Variation between different parameters	BG WG T	Sum of Squares (SS)	df	Mean Square (MS)	F	P value	Sig.
1	WT/ AT	BG	11.628125	1	11.628125	21.3899747	0.0002104	***
		WG	9.78525	18	0.543625			
		T	21.413375	19				
2	WT/ pH	BG	356.421245	1	356.421245	874.699869	1.03123E-16	***
		WG	7.33461	18	0.407478333			
		T	363.755855	19				
3	WT/ TDS	BG	749224.308	1	749224.308	5015.46613	1.77674E-23	***
		WG	2688.89016	18	149.3827867			
		T	751913.1982	19				
4	WT/ CO_2	BG	971.199845	1	971.199845	2362.24712	1.50526E-20	***
		WG	7.40041	18	0.411133889			
		T	978.600255	19				
5	WT/DO	BG	405.72032	1	405.72032	972.981518	4.02455E-17	***
		WG	7.50576	18	0.416986667			
		T	413.22608	19				
6	WT/ BOD	BG	900.884645	1	900.884645	2204.86519	2.78675E-20	***
		WG	7.35461	18	0.408589444			
		T	908.239255	19				
7	WT/Alkalinity	BG	90351.20968	1	90351.20968	458.980511	2.92905E-14	***
		WG	3543.335142	18	196.8519524			
		T	93894.54482	19				
8	WT/EC	BG	1647041.357	1	1647041.357	9518.65369	5.64329E-26	***
		WG	3114.59429	18	173.0330161			
		T	1650155.952	19				

Table 3: *E. coli* colonies on selective agar media

S. no.	Sampling sites	Name of the months											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1.	SD	+	+	+	+	+	+	+	+	+	+	-	+
2.	HM	-	+	-	-	+	+	+	+	-	+	-	-
3.	RD	+	-	+	+	+	+	+	+	+	+	+	+
4.	LD	-	+	+	+	+	+	+	+	+	+	+	+
5.	CD	+	-	-	+	+	+	+	+	+	+	-	+
6.	BN	+	+	+	+	+	+	+	+	+	-	+	+
7.	KN	+	+	+	+	+	+	+	+	-	+	+	+
8.	AD	-	+	+	+	+	+	+	+	+	+	-	+
9.	MD	+	-	+	+	+	+	+	+	-	+	+	+
10.	PD	+	+	-	+	+	+	+	+	+	+	+	+

(+) = Presence, (-) = Absence

Table 4: *Shigella* colonies on selective agar media

S.no.	Sampling sites	Name of the months											
		Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1.	**SD**	+	-	-	+	+	+	+	+	+	+	+	-
2.	**HM**	+	-	+	+	-	+	+	+	-	+	-	-
3.	**RD**	-	+	+	+	+	+	-	+	+	+	-	+
4.	**LD**	+	+	+	+	+	+	+	+	+	+	-	+
5.	**CD**	-	-	-	+	-	+	+	+	+	+	+	-
6.	**BN**	+	+	+	+	+	+	+	+	+	+	+	+
7.	**KN**	+	+	+	+	+	+	+	+	+	+	+	+
8.	**AD**	+	-	+	+	+	+	+	-	+	+	-	-
9.	**MD**	-	-	+	+	+	+	+	+	+	+	+	+
10.	**PD**	+	-	+	+	-	+	+	+	-	+	-	+

(+) = Presence, (-) = Absence

Table 5: *Salmonella* colonies on selective agar media

S.no.	Sampling sites	Name of the months											
		Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1.	**SD**	+	-	+	-	+	+	+	+	+	-	+	-
2.	**HM**	-	+	-	+	-	-	+	-	+	+	-	+
3.	**RD**	+	+	+	-	+	+	+	+	+	+	+	-
4.	**LD**	+	-	+	+	+	+	+	-	-	+	-	-
5.	**CD**	+	+	-	-	+	-	-	+	+	-	-	-
6.	**BN**	+	+	+	+	+	+	+	+	+	+	+	+
7.	**KN**	+	+	+	+	+	+	+	+	+	+	-	+
8.	**AD**	-	+	+	+	-	+	+	+	+	+	-	+
9.	**MD**	+	+	-	+	+	+	+	+	-	+	+	+
10.	**PD**	-	+	+	+	-	+	+	+	+	-	+	-

(+) = Presence, (-) = Absence

Table 6: *Campylobacter* colonies on selective agar media

S.no.	Sampling sites	Name of the months											
		Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1.	**SD**	+	-	+	-	+	+	+	+	+	-	-	-
2.	**HM**	-	+	-	+	+	+	+	-	-	+	+	-
3.	**RD**	+	+	+	+	+	+	+	+	+	+	+	+
4.	**LD**	+	-	-	+	-	+	+	+	+	-	+	-
5.	**CD**	-	+	-	+	+	+	+	-	+	-	+	+
6.	**BN**	+	+	+	+	+	+	+	+	+	+	+	+
7.	**KN**	+	+	+	+	+	+	+	-	+	+	+	+
8.	**AD**	+	-	-	+	-	+	+	+	+	+	-	-
9.	**MD**	-	+	-	+	+	+	+	+	-	+	-	+
10.	**PD**	+	-	+	+	+	+	+	+	-	+	-	+

(+) = Presence, (-) = Absence

Table 7: *Clostridium* colonies on selective agar media

S.no.	Sampling sites	Name of the months											
		Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1.	**SD**	+	-	+	+	+	+	+	+	+	+	-	+
2.	**HM**	-	+	-	+	+	+	+	+	-	+	-	-
3.	**RD**	+	-	+	-	+	+	+	+	+	-	+	-
4.	**LD**	+	+	+	+	+	+	+	+	+	+	+	+
5.	**CD**	-	+	-	+	+	+	-	+	-	+	-	+
6.	**BN**	+	-	+	+	+	+	+	+	+	+	+	+
7.	**KN**	+	+	+	+	+	+	+	+	+	+	-	+
8.	**AD**	+	-	-	+	+	+	+	+	-	+	+	-
9.	**MD**	+	+	+	+	+	+	+	+	-	-	-	+
10.	**PD**	-	+	-	+	+	+	-	+	+	+	+	+

(+) = Presence, (-) = Absence

Table 8: *Yersinia* colonies on selective agar media

S.no.	Sampling sites	Name of the months											
		Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1.	**SD**	-	-	-	-	-	-	-	-	-	-	-	-
2.	**HM**	-	-	-	-	-	-	-	-	-	-	-	-
3.	**RD**	-	-	-	-	-	-	-	-	-	-	-	-
4.	**LD**	-	-	-	-	-	-	-	-	-	-	-	-
5.	**CD**	-	-	-	-	-	-	-	-	-	-	-	-
6.	**BN**	-	-	-	-	-	-	-	-	-	-	-	-
7.	**KN**	-	-	-	-	-	-	-	-	-	-	-	-
8.	**AD**	-	-	-	-	-	-	-	-	-	-	-	-
9.	**MD**	-	-	-	-	-	-	-	-	-	-	-	-
10.	**PD**	-	-	-	-	-	-	-	-	-	-	-	-

(+) = Presence, (-) = Absence

Table 9: Cultural characteristics of *E. coli* growth on selective agar medium in the first year

S.no	Sites	Bacterial characterization												
		Morpho-logy	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1.	**SD**	**Color**	White	Metallic	White	White	White	White	White	White	Metallic	White	-	White
		Shape	Round	Circular	Round	Round	Round	Circular	Round	Circular	Round	Circular	-	Circular
		Surface	Smooth	Rough	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Rough	Smooth	-	Smooth
2.	**HM**	**Color**	-	White	-	-	White	White	White	White	-	White	-	-
		Shape	-	Round	-	-	Circular	Round	Circular	Round	-	Round	-	-
		Surface	-	Smooth	-	-	Smooth	Smooth	Rough	Smooth	-	Smooth	-	-
3.	**RD**	**Color**	Metallic	-	White	White	White	White	Metallic	Metallic	Metallic	White	White	White
		Shape	Round	-	Round	Round	Round	Circular	Round	Circular	Round	Round	Round	Round
		Surface	Smooth	-	Smooth	Smooth	Smooth	Rough	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth
4.	**LD**	**Color**	-	White	White	Metallic	White	White	White	White	White	White	White	White
		Shape	-	Circular	Round	Round	Round	Circular	Round	Circular	Round	Circular	Round	Circular
		Surface	-	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth
5.	**CD**	**Color**	White	-	-	White	White	White	White	White	White	White	-	White
		Shape	Round	-	-	Round	Round	Round	Round	Round	Round	Round	-	Round
		Surface	Smooth	-	-	Smooth	Smooth	Smooth	Rough	Smooth	Smooth	Smooth	-	Smooth
6.	**BN**	**Color**	White	White	White	White	White	White	White	White	White	-	White	White
		Shape	Round	Round	Round	Round	Round	Round	Round	Round	Round	-	Round	Round
		Surface	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Rough	Smooth	Smooth	-	Rough	Smooth
7.	**KN**	**Color**	White	Metallic	White	White	White	White	White	White	-	White	White	White
		Shape	Round	Circular	Round	Round	Round	Circular	Round	Round	-	Round	Round	Circular
		Surface	Smooth	Rough	Smooth	Smooth	Smooth	Rough	Smooth	Smooth	-	Smooth	Smooth	Smooth
8.	**AD**	**Color**	-	Metallic	White	White	White	White	Metallic	White	White	White	-	White
		Shape	-	Round	Round	Round	Round	Round	Round	Round	Round	Circular	-	Circular
		Surface	-	Rough	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Rough	-	Smooth
9.	**MD**	**Color**	White	-	White	White	White	White	White	White	-	White	White	Metallic
		Shape	Round	-	Circular	Circular	Round	Circular	Round	Circular	-	Circular	Round	Circular
		Surface	Smooth	-	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	-	Smooth	Smooth	Smooth
10.	**PD**	**Color**	White	metallic	-	White	White	White	White	White	White	White	White	White
		Shape	Round	Round	-	Round	Round	Round	Round	Round	Circular	Round	Round	Circular
		Surface	Smooth	Smooth	-	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth

Table 10: Cultural characteristics of *Shigella* growth on selective agar medium in the first year

S. .no	Sites	Bacterial characterization											
		Morpho-logy	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1.	**SD**	**Color**	Yellow	-	-	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	-
		Shape	Irregular	-	-	Round	Irregular	Irregular	Irregular	Irregular	Irregular	Irregular	Irregular	-
		Surface	Smooth	-	-	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	-
2.	**HM**	**Color**	Yellow	-	Yellow	Yellow	-	Yellow	Yellow	Yellow	-	Yellow	-	-
		Shape	Irregular	-	Irregular	Irregular	-	Irregular	Irregular	Irregular	-	Irregular	-	-
		Surface	Smooth	-	Smooth	Smooth	-	Smooth	Smooth	Smooth	-	Smooth	-	-
3.	**RD**	**Color**	-	Yellow	Yellow	Yellow	Yellow	Yellow	-	Yellow	Yellow	Yellow	-	Yellow
		Shape	-	Irregular	Irregular	Irregular	Irregular	Irregular	-	Irregular	Round	Irregular	-	Round
		Surface	-	Smooth	Smooth	Smooth	Smooth	Smooth	-	Smooth	Smooth	Smooth	-	Smooth
4.	**LD**	**Color**	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	-	Yellow
		Shape	Round	Round	Irregular	Irregular	Irregular	Irregular	Irregular	Irregular	Irregular	Irregular	-	Round
		Surface	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	-	Smooth
5.	**CD**	**Color**	-	-	-	Yellow	-	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	-
		Shape	-	-	-	Irregular	-	Irregular	Irregular	Irregular	Irregular	Irregular	Irregular	-
		Surface	-	-	-	Smooth	-	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	-
6.	**BN**	**Color**	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow
		Shape	Round	Irregular	Irregular	Irregular	Irregular	Irregular	Irregular	Irregular	Irregular	Irregular	Round	Round
		Surface	Smooth	Irregular	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	irregular	Smooth	Smooth	Smooth
7.	**KN**	**Color**	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow
		Shape	Round	Irregular	Irregular	Irregular	Irregular	Irregular	Irregular	Irregular	Irregular	Irregular	Irregular	Irregular
		Surface	Smooth	Irregular	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth
8.	**AD**	**Color**	Yellow	-	Yellow	Yellow	Yellow	Yellow	Yellow	-	Yellow	Yellow	-	-
		Shape	Irregular	-	Irregular	Irregular	Irregular	Irregular	Irregular	-	Round	Irregular	-	-
		Surface	Smooth	-	Smooth	Smooth	Smooth	Smooth	Smooth	-	Smooth	Smooth	-	-
9.	**MD**	**Color**	-	-	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow
		Shape	-	-	Irregular	Irregular	Irregular	Irregular	Irregular	Irregular	Irregular	Irregular	Round	Irregular
		Surface	-	-	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth
10.	**PD**	**Color**	Yellow	-	Yellow	Yellow	-	Yellow	Yellow	Yellow	-	Yellow	-	Yellow
		Shape	Irregular	-	Irregular	Irregular	-	Irregular	Irregular	Irregular	-	Irregular	-	Irregular
		Surface	Smooth	-	Smooth	Smooth	-	Smooth	Smooth	Smooth	-	Smooth	-	Smooth

Table 11: Cultural characteristics of *Salmonella* growth on selective agar medium in the first year

S.no	Sites	Bacterial characterization												
		Morpho-logy	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1.	**SD**	**Color**	Pink	-	Pink	-	Pink	Pink	Pink	Pink	Pink	-	Pink	-
		Shape	Round	-	Round	-	Round	Round	Round	Round	Round	-	Round	-
		Surface	Smooth	-	Smooth	-	Smooth	Smooth	Smooth	Smooth	Smooth	-	Smooth	-
2.	**HM**	**Color**	-	Pink	-	Pink	-	-	Pink	-	Pink	Pink	-	Pink
		Shape	-	Round	-	Round	-	-	Round	-	Round	Round	-	Round
		Surface	-	Smooth	-	Smooth	-	-	Smooth	-	Smooth	Smooth	-	Smooth
3.	**RD**	**Color**	Pink	Pink	Pink	-	Pink	Pink	Pink	Pink	Pink	Pink	Pink	-
		Shape	Round	Round	Round	-	Round	Round	Round	Round	Round	Round	Round	-
		Surface	Smooth	Smooth	Smooth	-	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	-
4.	**LD**	**Color**	Pink	-	Pink	Pink	Pink	Pink	Pink	-	-	Pink	-	-
		Shape	Round	-	Round	Round	Round	Round	Round	-	-	Round	-	-
		Surface	Smooth	-	Smooth	Smooth	Smooth	Smooth	Smooth	-	-	Smooth	-	-
5.	**CD**	**Color**	Pink	Pink	-	-	Pink	-	-	Pink	Pink	-	-	-
		Shape	Round	Round	-	-	Round	-	-	Round	Round	-	-	-
		Surface	Smooth	Smooth	-	-	Smooth	-	-	Smooth	Smooth	-	-	-
6.	**BN**	**Color**	Pink	Pink	Pink	Pink	Pink	Pink	Pink	Pink	Pink	Pink	Pink	Pink
		Shape	Round	Round	Round	Round	Round	Round	Round	Round	Round	Round	Round	Round
		Surface	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	irregular	Smooth	Smooth	Smooth
7.	**KN**	**Color**	Pink	Pink	Pink	Pink	Pink	Pink	Pink	Pink	Pink	Pink	-	Pink
		Shape	Round	Round	Round	Round	Round	Round	Round	Round	Round	Round	-	Round
		Surface	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	-	Smooth
8.	**AD**	**Color**	-	Pink	Pink	Pink	-	Pink	Purple	Pink	Pink	Pink	-	Pink
		Shape	-	Round	Round	Round	-	Round	Round	Round	Round	Round	-	Round
		Surface	-	Smooth	Smooth	Smooth	-	Smooth	Smooth	Smooth	Smooth	Smooth	-	Smooth
9.	**MD**	**Color**	Pink	Pink	-	Pink	Pink	Pink	Pink	Pink	-	Pink	Pink	Pink
		Shape	Round	Round	-	Round	Round	Round	Round	Round	-	Round	Round	Round
		Surface	Smooth	Smooth	-	Smooth	Smooth	Smooth	Smooth	Smooth	-	Smooth	Smooth	Smooth
10.	**PD**	**Color**	-	Pink	Pink	Pink	-	Pink	Pink	Pink	Pink	-	Pink	-
		Shape	-	Round	Round	Round	-	Round	Round	Round	Round	-	Round	-
		Surface	-	Smooth	Smooth	Smooth	-	Smooth	Smooth	Smooth	Smooth	-	Smooth	-

Table 12: Cultural characteristics of *Campylobacter* growth on selective agar medium in the first year

S.no	Sites	Bacterial characterization												
		Morpho-logy	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1.	**SD**	**Colour**	White	-	Grey	-	Grey	White	Grey	White	Cream	-	-	-
		Shape	Round	-	Round	-	Round	Circular	Circular	Circular	Circular	-	-	-
		Surface	Smooth	-	Smooth	-	Smooth	Smooth	Smooth	Smooth	Smooth	-	-	-
2.	**HM**	**Colour**	-	Cream	-	White	Grey	White	Grey	-	-	White	Grey	-
		Shape	-	Circular	-	Circular	Circular	Circular	Circular	-	-	Circular	Round	-
		Surface	-	Smooth	-	Smooth	Smooth	Smooth	Smooth	-	-	Smooth	Smooth	-
3.	**RD**	**Colour**	White	White	Cream	Grey	White	White	White	White	White	White	White	White
		Shape	Circular	Circular	Circular	Circular	Circular	Circular	Circular	Circular	Circular	Circular	Circular	Circular
		Surface	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth
4.	**LD**	**Colour**	White	-	-	White	-	White	White	Grey	White	-	White	-
		Shape	Round	-	-	Circular	-	Circular	Circular	Circular	Circular	-	Circular	-
		Surface	Smooth	-	-	Smooth	-	Smooth	Smooth	Smooth	Smooth	-	Smooth	-
5.	**CD**	**Colour**	-	Cream	-	White	White	White	White	-	White	-	White	White
		Shape	-	Circular	-	Circular	Circular	Circular	Circular	-	Circular	-	Circular	Circular
		Surface	-	Smooth	-	Smooth	Smooth	Smooth	Smooth	-	Smooth	-	Smooth	Smooth
6.	**BN**	**Colour**	White	White	White	White	White	White	White	White	White	White	White	White
		Shape	Circular	Circular	Circular	Circular	Circular	Circular	Circular	Circular	Round	Circular	Round	Circular
		Surface	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth
7.	**KN**	**Colour**	White	White	White	White	White	White	White	-	White	White	White	Cream
		Shape	Circular	Circular	Circular	Circular	Circular	Circular	Circular	-	Circular	Circular	Round	Circular
		Surface	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	-	Smooth	Smooth	Smooth	Smooth
8.	**AD**	**Colour**	White	-	-	White	-	White	White	White	Cream	White	-	-
		Shape	Circular	-	-	Circular	-	Circular	Circular	Circular	Circular	Circular	-	-
		Surface	Smooth	-	-	Smooth	-	Smooth	Smooth	Smooth	Smooth	Smooth	-	-
9.	**MD**	**Colour**	-	White	-	White	White	White	White	White	-	White	-	White
		Shape	-	Circular	-	Circular	Circular	Circular	Round	Circular	-	Circular	-	Circular
		Surface	-	Smooth	-	Smooth	Smooth	Smooth	Smooth	Smooth	-	Smooth	-	Smooth
10.	**PD**	**Colour**	White	-	White	White	White	White	White	White	-	White	-	White
		Shape	Circular	-	Circular	Circular	Circular	Circular	Circular	Circular	-	Circular	-	Circular
		Surface	Smooth	-	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	-	Smooth	-	Smooth

Table 13: Cultural characteristics of *Clostridium* growth on selective agar medium in the first year

S.no	Sites	Bacterial characterization												
		Morphology	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1.	**SD**	**Color**	White	-	White	Yellow	White	White	White	White	Yellow	White	-	White
		Shape	Round	-	Round	Round	Round	Round	Round	Round	Round	Round	-	Circular
		Surface	Smooth	-	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	-	Smooth
2.	**HM**	**Color**	-	White	-	White	White	White	White	Yellow	-	White	-	-
		Shape	-	Round	-	Round	Round	Round	Round	Round	-	Round	-	-
		Surface	-	Smooth	-	Smooth	Smooth	Smooth	Smooth	Smooth	-	Smooth	-	-
3.	**RD**	**Color**	White	-	White	-	White	White	White	White	White	-	White	Yellow
		Shape	Round	-	Round	-	Round	Round	Round	Round	Round	-	Round	Round
		Surface	Smooth	-	Smooth	-	Smooth	Smooth	Smooth	Smooth	Smooth	-	Smooth	Smooth
4.	**LD**	**Color**	White	White	White	Yellow	White	White	White	Yellow	White	White	White	White
		Shape	Round	Round	Round	Round	Round	Round	Round	Round	Round	Round	Round	Round
		Surface	Smooth	Irregular	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth
5.	**CD**	**Color**	-	White	-	Yellow	White	White	-	White	-	White	-	White
		Shape	-	Round	-	Round	Round	Round	-	Round	-	Round	-	Round
		Surface	-	Smooth	-	Smooth	Smooth	Smooth	-	Smooth	-	Smooth	-	Smooth
6.	**BN**	**Color**	White	-	White	Yellow	White	White	White	White	White	White	Yellow	White
		Shape	Round	-	Round	Round	Round	Round	Round	Round	Round	Round	Round	Round
		Surface	Smooth	-	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth
7.	**KN**	**Colour**	White	White	Yellow	White	White	White	White	White	White	White	-	White
		Shape	Round	Round	Round	Round	Round	Round	Round	Round	Round	Round	-	Round
		Surface	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	-	Smooth
8.	**AD**	**Colour**	White	-	-	White	White	White	White	White	-	White	White	-
		Shape	Round	-	-	Round	Round	Round	Round	Round	-	Round	Round	-
		Surface	Smooth	-	-	Smooth	Smooth	Smooth	Smooth	Smooth	-	Smooth	Smooth	-
9.	**MD**	**Colour**	White	White	White	White	White	White	White	White	-	-	-	White
		Shape	Round	Round	Round	Round	Round	Round	Round	Round	-	-	-	Round
		Surface	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	-	-	-	Smooth
10.	**PD**	**Colour**	-	White	-	White	White	White	-	White	White	White	White	White
		Shape	-	Round	-	Round	Round	Round	-	Round	Round	Round	Round	Round
		Surface	-	Smooth	-	Smooth	Smooth	Smooth	-	Smooth	Smooth	Smooth	Smooth	Smooth

CONCLUSION

The physico-chemical assessment of community water sources in the Himalayan region of Pithoragarh, Uttarakhand, has provided crucial insights into the overall quality and safety of drinking water in this remote and ecologically sensitive area. The study revealed seasonal variations in different parameters reflecting both natural environmental changes and human influences. The fluctuations indicate vulnerability to contamination and quality degradation. These findings highlight the urgent need for continuous monitoring of water quality and the implementation of protective measures to safeguard community health. Local authorities should prioritize the development of low-cost water purification solutions and ensure regular testing of water sources, especially during periods of increased contamination risk. Community engagement and education on safe water handling, sanitation, and hygiene practices are essential to mitigate the spread of waterborne diseases. Furthermore, improved infrastructure for waste management and sustainable water resource planning is critical in maintaining water safety over time. This study serves as a valuable resource for researchers and public health officials aiming to enhance water security in rural Himalayan regions and protect vulnerable populations from preventable health risks.

ACKNOWLEDGMENT
The authors are thankful to the Department of Zoology, L.S.M. Campus, Pithoragarh, Uttarakhand, for providing the facilities to conduct the research successfully.

REFERENCES
APHA, (2012). Standard methods for the examination of water and wastewater, 22nd edn. American Public Health Association, Washington, DC.
Bassin, J. P., Castro, F. D., Valério, R. R., Santiago, E. P., Lemos, F. R., & Bassin, I. D. (2021). The impact of wastewater treatment plants on global climate change. In *Water conservation in the era of global climate change*, 367-410. *DOI https://doi.org/10.1016/B978-0-12-820200-5.00001-4.*
Batra, P. Barkodia, M. Ahlawat, U. Sansanwal, R. Sharma, T. Wati, L. Endophytes, (2018). An environmentally friendly Bacteria for plant growth promotion. *International Journal of Current Microbiology and Applied Sciences,* **7**(2), 1899-1911.
Bhardwaj, R., Gupta, A., & Garg, J. K. (2018). Analysis of physico-chemical characteristics of the river Yamuna, Delhi stretch with an assessment of site-specific water quality index. *Pollution Research*, **37**(2), 446-459.
Bi, S. L., Shi, L., Yan, H., & Meng, H. C. (2013). Comparison of various culture methods (Skirrow medium, a blood-free medium, and a filtration system enriched in Bolton and Preston broths) for isolation of Campylobacter spp. from raw meat samples. *Annals of Microbiology*, **63**, 179-185.
Bolton, F., & Robertson, L. (1982). A selective medium for isolating Campylobacter. *Journal of Clinical Pathology*, **35**(4), 462-467. *DOI https://doi.org/10.1136/jcp.35.4.462*.
Cheyne, B. M., Van, D. M. I., Anderson, W. B., & Huck, P. M. (2009). An evaluation of methods for isolating Yersinia enterocolitica from surface waters in the Grand River watershed. *Journal of water and health*, 7(3), 392-403.
Chigbu, P., & Sobolev, D. (2007). Bacteriological analysis of water. In Handbook of water analysis. 111-148.
Chouhan, S. (2015). Recovery of Salmonella and Shigella isolates from drinking water. *European Journal of Experimental Biology*, **5**(7), 49-61.
Dinakaran, V. T., Chandrasekaran, M., Sivanandham, V., Murugaiah, S. G., Santhaseelan, H., Krishnan, M., & Rathinam, A. J. (2023). Seasonal effluxes of microbial pollution and physicochemical assemblages along south south-east coast of India during the southwest and northeast monsoons. *Regional Studies in Marine Science*, **59**, 102804.
Fazal-ur-Rehman, M., (2019). Polluted waterborne diseases: Symptoms, causes, treatment, and prevention. *Journal of Medicinal and Chemical Sciences*., **2**(1), 21-6.
Gaurav, A., Singh, S. P., Gill, J. P. S., Kumar, R., & Kumar, D. (2013). Isolation and identification of Shigella spp. from human fecal samples collected from Pantnagar, India. *Veterinary World,* **6**(7), 376-379.
Gorde S. P., and Jadhav M. V., (2013). Assessment of water quality parameters: A review. *International Journal of Engineering Research and Applications* **3**(6): 2029-2035.
Gunawardhana, L. N., and Kazama, S. (2011). Climate change impacts on groundwater temperature change in the Sendai plain, Japan. *Hydrological Processes* **25**(17): 2665-2678.
Hammer, Ø., & Harper, D. A., (2001). Past: paleontological statistics software package for education and data analysis. *Palaeontologia electronica*, 4(1), 1-9.
Heiberger, R. M., & Neuwirth, E., (2009). R through Excel: A spreadsheet interface for statistics, data analysis, and graphics, 323-330. New York: Springer.
Jan, S., Khan, I., Dar, G. H., Kamili, A. N., & Tak, I. U. R. (2016). Ecological and microbiological characteristics of the Jhelum River in Kashmir Himalaya. *Journal of Bacteriology & Parasitology,* **7**(3), 1000277. *DOI: https://doi.org/10.4172/2155-9597.1000277.*
Jasechko, S., Birks, S. J., Gleeson, T., Wada, Y., Fawcett, P. J., Sharp, Z. D., & Welker, J. M. (2014). The pronounced seasonality of global groundwater recharge. *Water Resources Research*, **50**(11),

8845-8867.

Jasmin I and Mallikarjuna P. (2014). Physicochemical quality evaluation of groundwater and development of drinking water quality index for Araniar River Basin, Tamil Nadu, India. *Environmental Monitoring and Assessment*, **186**: 935-948.

Jha, D. K., Prashanthi Devi, M., Vinithkumar, N. V., Das, A. K., Dheenan, P. S., Venkateshwaran, P., & Kirubagaran, R. (2013). Comparative investigation of water quality parameters of aerial & range bay, Andaman Islands using in-situ measurements and spatial modeling techniques. *Water Quality, Exposure and Health,* **5**, 57-67.

Johnston, R., Heijnen, H., & Wurzel, P. (2001). Safe water technology. *United Nations Synthesis Report on Arsenic in Drinking Water*, 1-98.

Kannahi, M., & Sivasankari, S. (2014). Isolation and identification of bioluminescent bacteria from marine water at Nagapattinam sea shore area. *International Journal of Pharmaceutical Sciences Review and Research,* **26**(2), 346-351.

Kim, J., Guk, J. H., Mun, S. H., An, J. U., Song, H., Kim, J., & Cho, S. (2019). Metagenomic analysis of isolation methods of a targeted microbe, Campylobacter jejuni, from chicken feces with high microbial contamination. *Microbiome*, **7**, 1-16.

Leininger, D. J., Roberson, J. R., & Elvinger, F. (2001). Use of eosin methylene blue agar to differentiate Escherichia coli from other gram-negative mastitis pathogens. *Journal of Veterinary Diagnostic Investigation*, **13**(3), 273-275.

Lin, Y. T., & Labbe, R. (2003). Enterotoxigenicity and genetic relatedness of Clostridium perfringens isolates from retail foods in the United States. *Applied and Environmental Microbiology*, **69**(3), 1642-1646. *DOI https://doi.org/10.1128/AEM.69.3.1642-1646.2003***.**

McConn, B. R., Kraft, A. L., Durso, L. M., Ibekwe, A. M., Frye, J. G., Wells, J. E., & Sharma, M. (2024). An analysis of culture-based methods used for the detection and isolation of Salmonella spp., Escherichia coli, and Enterococcus spp. from surface water: A systematic review. *Science of The Total Environment*, 927, 172190. *DOI https://doi.org/10.1016/j.scitotenv.2024.172190*.

Menberg K, Blum P, Kurylyk BL and Bayer P. (2014) Observed groundwater temperature response to recent climate change. *Hydrology and Earth System Sciences*, **18**(11): 4453-4466.

Murchie, L., Xia, B., Madden, R. H., Whyte, P., & Kelly, L. (2008). Qualitative exposure assessment for Salmonella spp. in shell eggs produced on the island of Ireland. *International journal of food microbiology*, **125**(3), 308-319. *DOI https://doi.org/10.1016/j.ijfoodmicro.2008.04.026*.

Obi C. L., Potgieter N, Bessong P. O., and Matsaung G. (2002). Assessment of the microbial quality of river water sources in rural Venda communities in South Africa. *Water South Africa* **28**(3): 287-292.

Oliveira, C. M. D. (2017). Sustainable access to safe drinking water: fundamental human right in the international and national scene. *Revista Ambiente & Água*, **12**(6), 985-1000.

Patil V. T., and Patil P. R. (2010) Physicochemical analysis of selected groundwater samples of Amalner Town in Jalgaon District, Maharashtra, *Indian Journal of Chemistry*, **7**: 111.

Paul, S. K., Khan, M. S. R., Rashid, M. A., Hassan, J., & Mahmud, S. M. S. (2010). Isolation and characterization of Escherichia coli from buffalo calves in some selected areas of Bangladesh. *Bangladesh Journal of Veterinary Medicine*, **8**(1), 23-26. *DOI https://doi.org/10.3329/bjvm.v8i1.7398*

Qureshi S. S., Channa A, Memon S. A, Khan Q, Jamali G. A, Panhwar A and Saleh T. A. (2021). Assessment of physicochemical characteristics in groundwater quality parameters. *Environmental Technology and Innovation,* **24**: 101877.

Robinson, M., Gallagher, D., & Reay, W. (1998). Field observations of tidal and seasonal variations in groundwater discharge to tidal estuarine surface water. *Groundwater Monitoring & Remediation*, **18**(1), 83-92.

Schiemann, D.A., (1979). Synthesis of a selective agar medium for Yersinia enterocolitica. *Canadian Journal of Microbiology*. **25**, 1298–1304. *DOI https://doi.org/10.1139/m79-205*.

Sharma A, Dubey N and Sharan B. (2005) Characterization of aeromonads isolated from the river Narmada, India. *International Journal of Hygiene and Environmental Health*., **208**(5) 425-433.
Shenai-Tirodkar, P. S., Gauns, M. U., & Ansari, Z. A. (2016). Evaluation of surface water and sediment quality in Chicalim Bay, Nerul Creek, and Chapora Bay from Goa coast, India-A statistical approach. *Environmental monitoring and assessment*, 188, 1-13.
Singh, M. R., & Sao, S. (2015). Isolation and Identification of Bacteria from Hasdeo River Water in Champa Region and Level of Microbial Pollution. *International Journal of Research*, 97-101.
Singh, R. K., Pandey, A., Pandey, R., and Tiwari, S. P. (2010). Microbial evaluation of water bodies from Jaunpur, UP, India. *Pollution Research.,* **29**(2): 365-370.
Tyagi, S., Singh, P., Dobhal, R., Uniyal, D. P., Sharma, B., & Singh, R. (2015). Spatial and temporal variations in quality of drinking water sources of Dehradun district in India. *International Journal of Environmental Technology and Management*, **18**(5-6), 375-399.
WHO. The World Health Report. Switzerland: World Health Organization; 2002.
Wohlsen, T., Bayliss, J., Gray, B., Bates, J., & Katouli, M. (2006). Evaluation of an alternative method for the enumeration and confirmation of Clostridium perfringens from treated and untreated sewage. *Letters in applied microbiology*, **42**(5), 438-444. *DOI https://doi.org/10.1111/j.1472-765X.2006.01912.x.*
World Health Organization (2004) Guidelines for drinking-water quality, Vol. 1, World Health Organization.
Zamxaka M, Pironchev A. G., Muyima N. Y. O. Microbiological and physico-chemical assessment of the quality of domestic water sources in selected rural communities of the Eastern Cape Province, South Africa. *Water South Africa.* 2004; **30**:33-340.
Zhang, M., Wu, Z., Sun, Q., Ding, Y., Ding, Z., & Sun, L. (2019). The spatial and seasonal variations of bacterial community structure and influencing factors in river sediments. *Journal of environmental management*, 248, 109293. *DOI https://doi.org/10.1016/j.jenvman.2019.109293*.