INNSPUB

International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print), 2222-5234 (Online)
http://www.innspub.net
Vol. 19, No. 5, p. 85-92, 2021

RESEARCH PAPER OPEN ACCESS

Bacteriological quality of drinking water collected from different sources, seasons and areas of Barpeta district of Assam, India

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Key words: Drinking water, Total plate count, Total coliform, Faecal coliform, *Escherichia coli*, *Salmonella,* Barpeta.

http://dx.doi.org/10.12692/ijb/19.5.85-92 Article published on November 30, 2021

Abstract

The drinking water quality with respect to bacteriological examination by quantitative determination of total coliform, faecal coliform count (M.P.N.), total plate count bacteria, *E. coli* and *Salmonella* bacteria were done for 180 numbers of samples collected from tube well, well, river, pond and P.H.E. supply water in summer, monsoon, and winter seasons from 26 different areas of Barpeta district has been analyzed. Out of 180 water samples analyzed, 93 samples were from tube well, which occupies 51.67% of the total percentage of the source of water, 63 from well (occupies 35.00%), 6 from rivers (occupies 3.33%), 9 each from ponds and P.H.E. supply water (each occupies 5.00%) of all the sources. Out of 180 samples tested, the total number of positive cases for Total Plate Count bacteria at 22°C and 37°C were 167 (92.78%) and 163 (90.56%), respectively. *Salmonella* bacteria were found positive for 57 (31.67%) samples, *E. coli* positive for 112 (62.22%) samples; 95 (52.78%) and 70 (38.89%) samples were found contaminated with Total coliform and Faecal coliform bacteria, respectively. The percentage of occurrence of bacterial populations was found maximum in the pond and river water followed by well water and the minimum was in P.H.E. supply water followed by tube well water. The minimum number of *Salmonella* bacteria was isolated from tube well water and the maximum was from pond water. The results also indicated that the bacterial population was found maximum in the monsoon season, followed by summer and winter. The present study indicates the presence of *E. coli*, Coliforms and *Salmonella* bacteria in different sources of drinking water itself is an indication of poor handling and unhygienic conditions. Proper doses of disinfectants should be used at regular intervals in different drinking water sources.

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Introduction

Water is the most abundant chemical in the human body and plays a central role in the regulation of nutrient transport, toxic waste removal, thermal regulation, digestion, organ functioning and metabolic activities. The quality of water is getting vastly deteriorated due to unscientific waste disposal, improper water management and carelessness towards the environment. This has led to the scarcity of potable water affecting human health (Agarkar and Thombre, 2005). The quality of drinking water has always been a major health concern, especially in developing countries, where 80% of the disease cases are attributed to inadequate sanitation and the use of polluted water (Yasin *et al*., 2015). Poor sanitation and food are the main sources for contamination with pathogens of the gastrointestinal tract; drinking water is the major source of microbial pathogens in developing regions (Ashbolt, 2004).

Bacterial pollution of groundwater has become a great problem these days. Due to the use of contaminated drinking water, the population suffers from a variety of waterborne diseases such as diarrhoea, cholera, jaundice, typhoid, dysentery and viral infection (Nakade, 2013; Anwar *et al*., 2010 and Bahador *et al*., 2005). The pathogens that are transmitted through fecally polluted water are bacteria, mainly Enteropathogenic and Enterotoxigenic *Escherichia coli*, *Salmonella* spp, *Shigella* spp, *Proteus* spp, *Vibrio* spp. Viruses that spread through water are *Adenovirus, Enterovirus, Hepatitis* A, C, D, E, *Noroviruses* and *Rotavirus*. The pathogens that are transmitted by the faecal-oral route, drinking water are the only vehicle of transmission. Contamination of foods, hands, utensils and clothing can also play a role, particularly when domestic hygiene is poor. Waterborne diseases account for one-third of the intestinal infections worldwide (Hunter, 1997). The diseases most frequently associated with water are enteric infections such as diarrhoea, Gastroenteritis, Giardiasis. Several waterborne pathogens such as *Vibro cholerae*, *Hepatitis* E virus, Enteropathogenic, *E. coli* and *Salmonella* have high mortality and may lead to outbreaks (Anon, 1999). *Escherichia coli* are responsible for a number of widespread epidemics of diarrhoea and gastroenteritis in infants and children [Patil and Tambekar, 2003]. The various water sources may contain not only natural and soil bacteria but also large numbers of organisms derived from sewage. Wastewater discharges in freshwater are a major source of faecal organisms including pathogens (WHO, 2008; Grabow, 1996). Drinking water polluted by any pathogenic bacteria is unsafe for human consumption and household use (Muhammad *et al*., 2012).

The U.S. Environmental Protection Agency (E.P.A.) requires all drinking water systems to monitor for total coliforms in distribution systems. Coliform bacteria are the standard used for bacterial quality in drinking water. Coliform bacteria are not a single bacteria species; rather, it is a grouping of several different bacterial species. The presence of coliform bacteria in water sources indicates that sewage or some type of surface water is entering and contaminating the water supply. The presence of coliform bacteria in drinking water indicates that the water is not properly treated to eliminate pathogens or that it got contaminated somewhere in the distribution system.

Microbiological examination of drinking water is an attempt to determine the relation of the possible transmission of waterborne disease. It is usually not practical to examine water supplies for the various pathogens that may be present. Therefore, the routine monitoring of water is based on the testing of indicator organisms. Selected indicator organisms are routinely monitored to indicate the probability of a pathogenic population in water. These indicator organisms are known as coliform bacteria, which constitute the normal flora of the human intestine and are discharged into the human faeces. Estimation of coliforms helps in determining the faecal contamination of water and probably the presence of intestinal pathogens. Total coliform bacteria describe a group of enteric bacteria that includes *E.coli, Klebsiella* species, *Enterobacter* species and

Citrobacter species (Chao *et al*., 2004). Although they are generally not harmful themselves, they indicate the possible presence of other pathogenic bacteria, viruses and protozoans (Kara *et al*., 2004). Coliforms are the primary indicator of water pollution. The presence of these microbes is associated with the presence of disease-causing microorganisms (Muhammad *et al*., 2013). *Escherichia coli* is a taxonomically well-defined member of the family *Enterobacteriaceae* and is characterized by possessing enzymes B-galactosidase, growing at 44˚C on complex media like Endo or E.M.B. agar, ferments lactose with the production of acid and gas at 44^{O}C within 24-48 hours. *E. coli* is widely used as an index of faecal pollution of water because it is easily detected, it is present in abundance as compared to other organisms, it survives for a longer period and its source is the exclusively human and animal intestine. It has been reported by Muhammad *et al.* (2012) that *Escherichia coli* can survive six times more than other microbes in water. The origin of *E. coli* is almost exclusively of faecal origin, thus, if it is found in water or food, it indicates fecal contamination and an imminent health danger, as other faecal pathogens such as viruses or parasites may also be present. The majority of tests for bacteria depend on using three indicator bacterial types. They are the total coliform group, the faecal coliform group and *E. coli*. Fecal coliforms are the group of the total coliforms that are considered to be present specifically in the gut and feces of warm-blooded animals. Because the origins of fecal coliforms are more specific than the origins of the more general total coliform group of bacteria, faecal coliforms are considered a more accurate indication of animal or human waste than the total coliforms. Total plate count bacteria are bacteria that exist in two forms such as natural flora and faecal flora. A rising plate count indicates the earliest sign of the danger of pollution. Therefore its detection is an indication of faecal pollution and its presence in drinking water indirectly indicates the presence of other members of the family *Enterobacteriaceae* such as the species of *Salmonella, Shigella, Vibrio, Proteus, Pseudomonas, Enterobacter*, *Streptococci,* and *Clostridium*. The increase of pollution in natural waters has increased the detection frequency and persistence of pathogenic microorganisms, mainly *Salmonella sp.,* in areas affected by sewage discharges (Borrego *et al*., 1987). Since unsafe water is responsible for any illness, deaths and economic failure, water quality monitoring is essential (Bedada *et al*., 2018). Though several workers have studied the Bacteriological quality of drinking water in India and aboard but there is no recent information on the bacteriological analysis of drinking water from different sources in the Barpeta district of Assam. Hence, keeping in view the importance, the present investigation was undertaken to isolate and identify different types of coliform bacteria, especially *E. coli* and faecal coliform and other genera like *Salmonella* species from drinking water sources collected from different areas and seasons of the district.

Materials and methods

Study area and sampling

The experimental work was conducted in the Microbiological Laboratory, Post Graduate Department of Botany, Madhab Choudhury College, Barpeta, Assam, India, during 2016-2017. The bacteriological quality of drinking water was analysed in three seasons, *viz.,* summer, monsoon and winter. The samples were collected randomly three times in each season from different sources such as tube-well, well, river, pond and P.H.E. supply water of 26 different areas of Rural Development Blocks such as Barpeta, Chenga, Guma Phulbari, Sarukhetri, Paka Betbari, Gobardhana, Rupshi, Chakchaka, Bhabanipur and Bajali of Barpeta district of Assam. The sampling strategy was based on capturing all types of water sources used by the community. The method of sample collection at each source was according to the WHO Guidelines for drinking water quality assessment. Water samples were collected in 500 ml sterilized screw cap bottles. In the case of pond and river water, water samples were collected from 20 to 30 cm depth (to avoid floating materials) according to Mgbemena *et al*., (2012) and each sample was sealed immediately after collection and then placed in icebox and was taken to the laboratory for bacteriological analysis.

The different methods used were as follows

Drinking water samples were analysed using standardized bacteriological methods for water quality analysis to determine the degree of contamination. All samples were analysed for total plate count bacteria, *Salmonella* bacteria, *Escherichia coli*, total and faecal coliform bacteria.

The standard Plate Count method was used for the isolation and estimation of total plate count bacteria. In this method, 1ml of a water sample was poured onto Petri dishes containing non-selective agar medium (Nutrient Agar) and then the Petri dishes were incubated in an incubator at 37±1°C for 24 hours for estimation of faecal flora and at 22±1°C for 72 hours for estimation of the total flora of water. Bacterial colonies were counted with the help of a colony counter and the colonies were estimated as cfu/ml by taking an average of three petri dishes.

The water samples were analysed following the standard procedure as recommended by WHO (1963) for bacteriological examination. After counting the coliform bacteria in Mac Conkey's Agar as per the method described by Cruickshank *et al.*, (1975), representative colonies were picked up and transferred on E.M.B. agar medium and incubated at an inverted position at 37°C for 48 hours. All green metallic sheen colonies (presumptive *Escherichia coli*) and colourless colonies (presumptive *Salmonella*) were subjected to further characterization.

The colourless colonies (transparent) were transferred into Triple Sugar Iron Agar (TSIA) slants for the identification of *Salmonella* bacteria and production of H_2S gas by blackening of the medium indicates the presence of *Salmonella* bacteria (Aneja, 2003). Characterization and preliminary identification of coliform bacteria were made on the basis of morphology, motility, colony characteristics, biochemical reactions (Table-1), Gram's stain and carbohydrate fermentation tests conducted as per the standard procedures described by Cruickshank *et al.*, (1975).

Multiple-Tube Fermentation Technique or M.P.N. method was used to analyse the total coliform and faecal coliform bacteria. In this method, a "presumptive coliform test" is performed first. Here, known volume (10ml, 1ml and 0.1ml) of water are added to lactose fermentation tubes at 37°C for 24 hours and production of acid (colour change) and gas (appearance of a bubble large enough to fill the concavity at the top of the Durham tube) from the fermentation of lactose is a positive test of coliform bacteria. M.P.N. of coliforms was estimated in terms of index /100 ml by using the standard statistical table (APHA, 1995). All the tubes positive for total coliforms were sub-cultured into 10 ml of single strength Mac Conkey broth medium with inverted Durhum tubes and 5ml of Peptone water to determine the presence of faecal coliforms. These tubes were incubated at 44°C for 24 hours. The tubes showing acid and gas and indole productions were taken as positive for faecal coliforms. From the number of positive tubes, M.P.N. of faecal coliforms was calculated by referring to the statistical table for total coliforms.

Results and discussion

In the present study, a total of 180 drinking water samples were collected from different areas, sources and seasons to examine the bacteriological quality and the results are furnished in Table 3 and Fig. 1 & 2. Out of 180 samples, 60 numbers water samples were tested for bacteriological quality for each summer, monsoon and winter season. The results showed that out of 180 different water samples analyzed, 93 samples were from tube well, which occupies 51.67% of the total percentage of the source of water, 63 from well (occupies 35.00%), 6 from rivers (occupies 3.33%), 9 each from ponds and P.H.E. supply water (each occupies 5.00%) of all the sources. Out of 180 samples tested, the total number of positive cases for Total Plate Count bacteria at 22°C and 37°C were 167 (92.78%) and 163 (90.56%), respectively. *Salmonella* bacteria were found positive for 57 (31.67%) samples, *E. coli* positive for 112 (62.22%) samples; 95 (52.78%) and 70 (38.89%) samples were found contaminated with Total coliform and Faecal coliform bacteria,

respectively. It was found from the results (Table 3; Fig. 1 & 2) that the percentage of occurrence of bacterial populations was found maximum in the pond and river water followed by well water and the minimum number was found in P.H.E. supply water followed by tube well water. The minimum number of *Salmonella* bacteria was isolated from tube well water and the maximum was from pond water.

It was also found that *Salmonella* bacteria, Total coliform and Faecal coliform could not be detected in P.H.E. supply water in all three seasons.

Table 1. Biochemical analysis of Bacteria.

Sl. No.	Biochemical Testing	Inferences	Types of Bacteria
1	Indole Test:- Kovacs' reagent: (Paradimethyl amino bezaldehyde+Isoamyl alcohol+Sulphuric acid)	Appearance of pink coloured ring	Presence of *E. coli*
2	Methyl red test:	Appearance of pink coloured ring in methyl red	Presence of *E. coli*
3	Fermentation and gas production test: (Glucose, lactose, sucrose, mannose)	Change of colour from blue to yellow	Presence of fermenting and gas producing bacteria
4	H_2S production test:	Blackening of medium by producing H_2S gas	Presence of *Salmonella* bacteria

Table 2. Guideline value/ permissible limits for Microbiological quality parameters in drinking water (For untreated water entering distribution system)

Parameters	Unit	WHO Guideline value	BIS tolerance limit desirable value	E.P.A. standards
Coliform organisms	MPN/100 ml	0	0	0
Fecal coliform	MPN/100 ml	0	0	0
E. coli	MPN/100 ml	0	0	0
Total plate count bacteria at 22°C for 72 hrs.	1 ml	--------	100 cfu	-------
Total plate count bacteria at 37°C for 24hrs.	1 ml	--------	20 cfu	--------
Salmonella bacteria	1 ml at 37°C	0	0	0

The results obtained from Table 4; Fig. 3 & 4 indicated that the bacterial population was found maximum in the monsoon season followed by summer and winter. *E. coli*, total coliform and faecal coliform bacteria were isolated in three seasons from most of the sampling areas of the district, while these bacteria were not detected in P.H.E. supply water in all the seasons. Percentage of occurrence of total coliform and faecal coliform were found very high in well, river and pond water in the three seasons, while total coliform and faecal coliform were found less in tube well water. *Salmonella* bacteria were not detected in P.H.E. supply water in all three seasons, but 100% was isolated from the pond and river water in monsoon and 100% of river water was contaminated with *Salmonella* bacteria in the summer season. It was observed that the highest number (100%) of total plate count bacteria (22°C and 37°C) were isolated from all sources of water in the three seasons, while the lowest numbers were found in tube well water.

It was also observed from the investigation that water samples collected from the areas and sources like

Dangarkuchi (well), Barbila (well), Azad Nagar (River), Sundaridia (well), Bhella (well), Paka-Betbari (well), Palhazi (well), Mandia (well), Kalgachia (pond), Moinbori (river), Kaljhar (pond), Bohari (well), Belbari (well), Nashatra (well), Bangalipara (well), Sorbhog (well), Raha (well), Kharisala (pond), Gunialguri (pond), Pam Dongra (river), Marigaon (river), Uzir Char (river), Baghbor (pond & river), Dighirpam (tube well, well & river), Batgaon (well), Pazarbhanga (river) and Bagodi (pond) were found highly contaminated with *Salmonella* bacteria, *E. coli*, total coliform and faecal coliform bacteria.

Table 3. Percentage occurrence of bacterial populations isolated from different sources of drinking water during the three different seasons. (**Fig**ures in parentheses indicates the total number of contaminated samples).

Sl. No	Sources of water	Number of sampling	Total percentage of source of water	Total plate count bacteria at 22°C	Total plate count bacteria at 37°C	*Salmonella* bacteria	*E. coli*	Total coliform	Faecal coliform
1	Tube well	93	51.67	86.02% (80)	82.80% (77)	12.90% (12)	33.34% (31)	18.28% (17)	2.15% (2)
2	Well	63	35.00	100.00% (63)	100.00% (63)	53.97% (34)	100.00% (63)	100.00% (63)	84.12% (53)
3	River	6	3.33	100.00% (6)	100.00% (6)	50.00% (3)	100.00% (6)	100.00% (6)	100.00% (6)
4	Pond	9	5.00	100.00% (9)	100.00% (9)	88.89% (8)	100.00% (9)	100.00% (9)	100.00% (9)
5	PHE supply	9	5.00	100.00% (9)	88.89.% (8)	Nil	33.33%(3)	Nil	Nil
	Total	180	100	92.78% (167)	90.56% (163)	31.67% (57)	62.22% (112)	52.78% (95)	38.89% (70)

The experimental results revealed that a total of 180 drinking water samples were tested from different sources, seasons and areas of which 93 samples were from tube well, which occupies 51.67% of the total percentage of the source of water, 63 from well (occupies 35.00%), 6 from rivers (occupies 3.33%), 9 each from ponds and P.H.E. supply water (each occupies 5.00%) of all the sources. It was also observed that during monsoon season, all the samples collected and analyzed from different sources were found highly contaminated by Total Count bacteria, *E. coli*, *Salmonella* bacteria, total coliform and faecal coliform bacteria, followed by summer and winter season which failed to meet the WHO, BIS and E.P.A. drinking water standards of zero coliforms per 100 ml making the water unsuitable for drinking purposes.

Table 4. Percentage occurrence of bacterial populations isolated from different sources of drinking water in three seasons.

Seasons	Sources of water	Number of sampling	Total plate count bacteria at 22°C	Total plate count bacteria at 37°C	*Salmonella* bacteria	*E. coli*	Total coliform	Faecal coliform
Summer	Tube well	31	96.78%	80.65%	16.12%	51.61%	25.81%	3.23%
	Well	21	100%	100%	57.14%	100.00%	100.00%	85.71%
	River	2	100%	100%	50.00%	100.00%	100.00%	100.00%
	Pond	3	100%	100%	100.00%	100.00%	100.00%	100.00%
	P.H.E. supply	3	100%	33.34%	Nil	Nil	Nil	Nil
Monsoon	Tube well	31	78.26%	82.60%	Nil	52.17%	52.17%	26.08%
	Well	21	100.00%	100.00%	50.00%	100.00%	100.00%	87.50%
	River	2	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
	Pond	3	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
	P.H.E. supply	3	100.00%	100.00%	Nil	Nil	Nil	Nil
Winter	Tube well	31	64.51%	67.75%	6.45%	9.67%	6.45%	3.23%
	Well	21	100%	100%	38.09%	100.00%	100.00%	76.19%
	River	2	100%	100%	50.00%	100.00%	100.00%	100.00%
	Pond	3	100%	100%	66.67%	100.00%	100.00%	100.00%
	P.H.E. supply	3	100%	100%	Nil	Nil	Nil	Nil

Total number of samples analyzed=180.

The levels of microbial population and indicator bacteria increased during monsoon at the maximum sampling areas may be due to discharges and runoff of solid and liquid waste products containing pollutants and the large volume of waste discharges in the form of effluents; temperature, humidity and rainfall. Similar observations were also made by several authors (Bahador *et al.*, 2005; Bedada *et al.*, 2018; Sobsey, 1999; Doran and Linn, 1979; Akbar *et al.*, 2013; Nafees *et al.*, 2014 and Yadav *et al.*, 2019). Bahador *et al.* (2005) studied the seasonal variation of microbial population in surface water in Pune city and they have reported that microbial populations (total viable count, *Salmonella* and *Shigella*, faecal coliform) were maximum in monsoon season. Bedada *et al.* (2018) reported that out of 218 samples assed majority of the samples (64.7%) contained Heterotrophic Plate Count bacteria above permissible limits of WHO (2003) and total coliforms (51.8%), thermotolerant coliforms (38.5%) were above WHO guideline value of <1/100ml of the total water samples in Ethiopia.

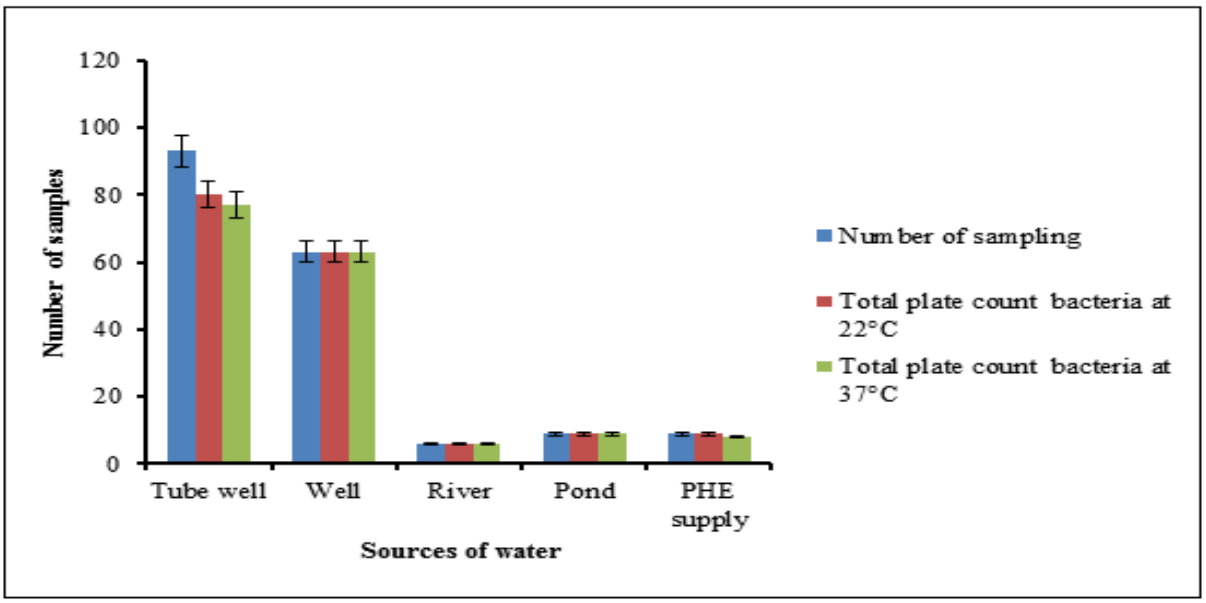

Fig. 1. Number of Total Plate count bacteria at 22°C and at 37°C in different drinking water sources.

It has been reported that the average of total viable count and viable count of microorganisms in the monsoon season is more than summer and winter due to rainfall (Sobsey, 1999). Doran and Linn (1979) reported that heavy rainfall leads to stormwater runoff into surface water sources, which has high counts of indicator bacteria as well as potential pathogens. Akbar *et al.* (2013) assessed the quality of drinking water and risk of waterborne diseases in the rural mountainous area of Azad Kashmir Pakistan and they have reported that 31.5% (80 out of 254 samples) were fit for drinking, whereas 68.5% (174 out of 254) samples were contaminated with *E. coli*. Nafees *et al.* (2014) analysed the Bacteriological quality of drinking water from different sources in CKNP region of Gilgit-Baltistan, Pakistan and they found that the level of contamination ranged from 0-160 CFU for *E. coli*, 0-85 CFU for Enterococci and total bacterial count ranged from 2-180 CFU, whereas they could not detect any Salmonella species in one liter of drinking water. Yadav *et al.,* (2019) have reported that the presence of total and thermotolerant coliforms were highest in the monsoon, followed by summer and post-monsoon/winter seasons. According to W.H.O (2003), bacterial growth increases when temperature increases and it will lower down when the temperature drops. The results revealed that the total bacterial population was found maximum in pond water followed by river water and well water and the minimum was found in tube well and P.H.E. supply water in the three seasons. My results indicated that pond water, well water and river water are maximally contaminated by the different microbial populations

and indicator bacteria which may be due to open surface water sources in which domestic sewage runs through improper drainage, faeces of animals including man, daily cloth and utensil washings with soaps and detergents, bathing and washing of animals, unhygienic conditions, constructional defects, poor sanitation, low level of hygiene education, poor supervision and maintenance and irregular disinfection.

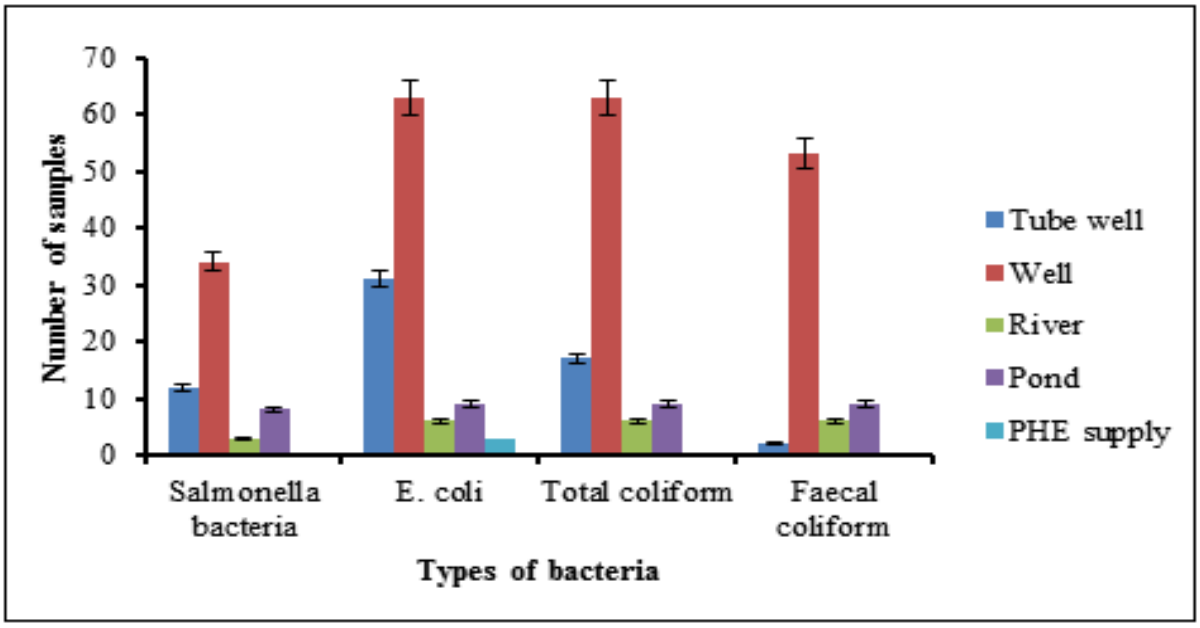

Fig. 2. Number of different types of bacteria isolated from different drinking water sources.

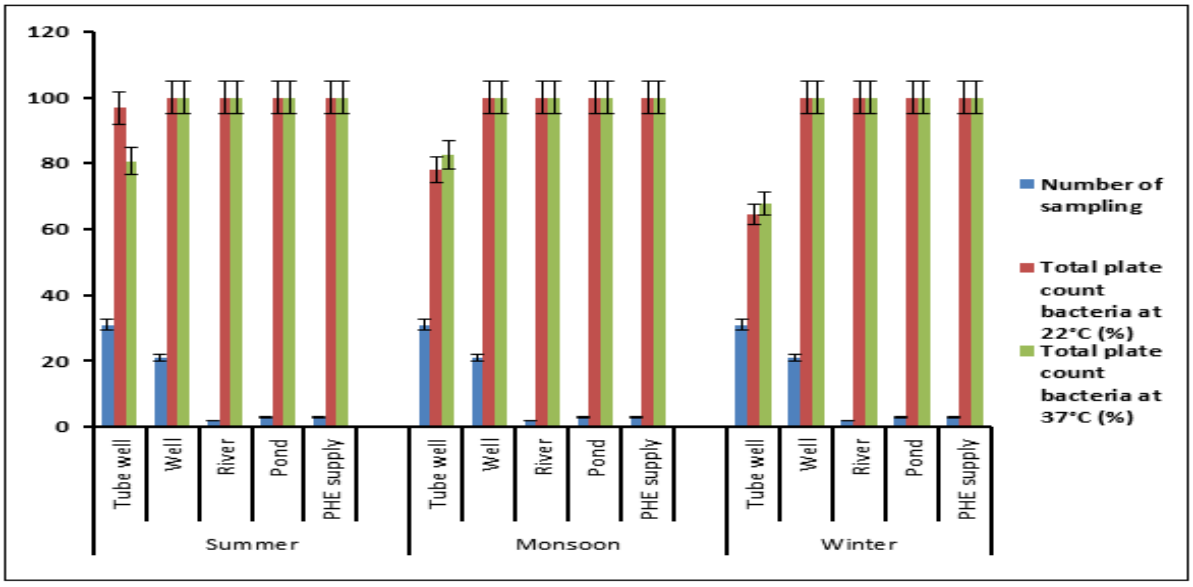

Fig. 3. Percentage occurrence of Total Plate Count bacteria at 22°C and at 37°C in different sources of water in three seasons.

The present findings are similar to the findings made by several researchers (Prajapati and Mathur, 2005; Bahador *et al.,* 2005; Borah *et al.*, 2010; Abera *et al.*, 2011; Jain *et al.*, 2012; Yasin *et al.*, 2015 and Parvez *et al.,* 2016). Prajapati and Mathur (2005) reported that well water was highly contaminated with faecal coliforms as compared to hand pumps throughout the year. Bahador *et al.* (2005) reported that the Pavana river became bacteriologically polluted due to the washerwomen, some industrial units, agricultural

activities, and rituals concerned. Borah *et al.* (2010) found a high level of microbial contamination of water supply in tea estates, tube well, well and pond due to water distribution network as well as much body contact with the water, which suggests the reason for the high prevalence of waterborne diseases. Abera *et al.* (2011) studied the bacteriological analysis of drinking water sources in Ethiopia and they found that both protected and unprotected wells were contaminated by fecal coliform, which was particularly *E. coli*. Jain *et al.* (2012) isolated coliform bacteria count ranging from 1 to >1600/100ml drinking water from different sources, of which 80% samples were contaminated with coliform bacteria out of 100 samples. Yasin *et al.* (2015) studied the Physico-chemical and bacteriological quality of drinking water of different sources, Jimma zone, Southwest Ethiopia and they reported that most of the water samples analyzed for bacteriological quality did not meet the standards of WHO. Parvez *et al.* (2016) analyzed a total of 106 water samples from different sources such as tube well, deep well, surface and municipally supplied water and they have reported that 80% of samples were contaminated with coliform and 34% were with faecal coliforms bacteria, reporting the highest coliform count was >1100 cfu/100ml in the surface from the pond.

From the results it was found that *Salmonella* bacteria were not detected in P.H.E. supply water in all three seasons, but 100% was isolated from the pond and river water in monsoon and 100% of river water were contaminated with *Salmonella* bacteria in the summer season. Similar observations were also made by Bahador *et al.* (2005), who detected *Salmonella* bacteria in the Panama River in monsoon season and the presence of *Salmonella* bacteria in river water may be domestic sewage discharges and industrial effluents and Nakade (2013), who found the presence of *Salmonella* bacteria in tap water in the months of July and August.

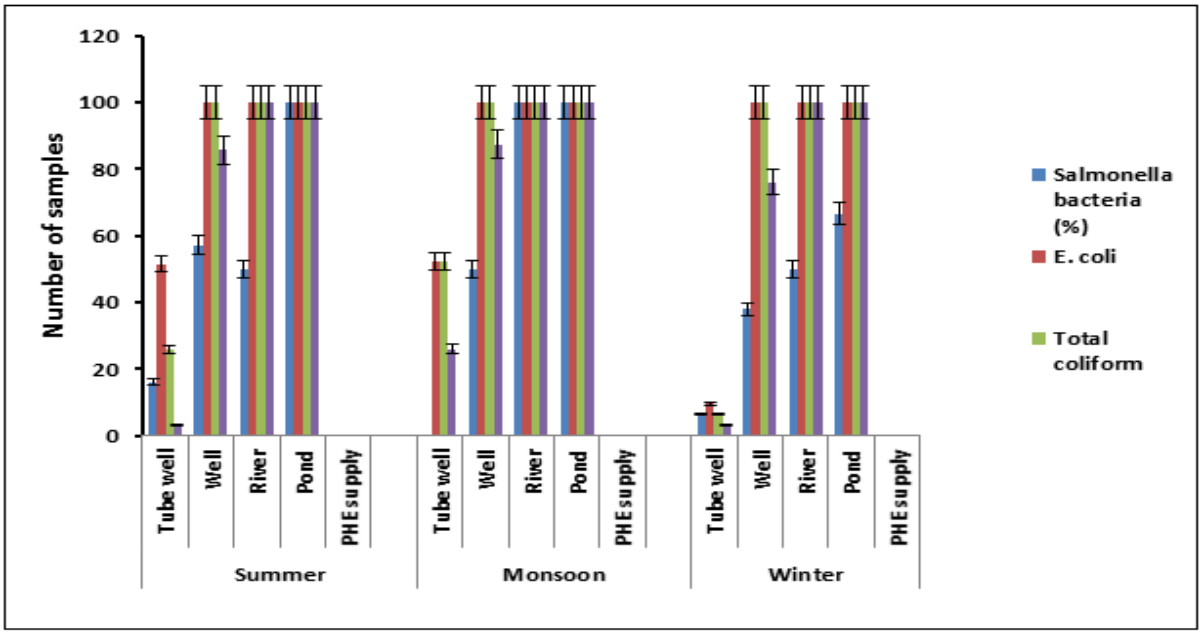

Fig. 4. Percentage occurrence of *Salmonella* bacteria, *E. coli*, Total coliform and Faecal coliform in different sources of water in three seasons.

In the present study, the bacterial population was found minimum in tube well and P.H.E. supply water in the three seasons may be due to that tube well water is underground where microbial contamination may be free, if contaminated it may be from outer contamination by handling or during storage and in case of P.H.E. supply water found least polluted because of frequent chlorination and maintenance of hygienic conditions. It has been found that the overall variation in the total microbial population in different

drinking water sources in the three seasons may be the changing of climatic conditions especially increasing in temperature. Temperature is an important controlling factor that influences bacterial growth (Yadav *et al*., 2019).

Conclusion

In the present study, maximum numbers of water samples collected from different sources, areas and seasons of the district were contaminated with various types of bacteria indicates the polluted condition of the water resources which is a matter of public health concern.

The different microbiological parameters analyzed in the present study where maximum water samples fail to meet the permissible limits of WHO and BIS and such drinking water is not fit for human consumption. The presence of *E. coli*, coliforms and *Salmonella* bacteria in different sources of water indicates poor handling and unhygienic conditions. The water treatment process should properly be followed by the people to control the pathogens as per the guidelines of the Public Health and Engineering Department, Govt. of Assam and WHO. Drinking water from different sources should be filtered and then boiled. Boiling is the best method of water treatment which kills all pathogenic microorganisms present in drinking water. The general cleanliness and hygiene of water main storage reservoirs should be maintained. Proper doses of disinfectants should be used at regular intervals in different drinking water sources.

The P.H.E. department may be aware of the people regarding safe drinking water, methods of treatment of water, the transmission of different waterborne diseases and health and hygienic conditions. Thus, the current work is thought to be a new breakthrough in connection with public and community health.

Acknowledgement

The author is thankful to the University Grants Commission for providing financial assistance to carry out the research work. The author is also grateful to the Head of the Post Graduate Department of Botany, Madhab Choudhury College, Barpeta, Assam, for providing laboratory facilities.

Declaration of interest

The author of this paper had no personal or financial conflicts of interest.

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