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Assessment of quality of water samples collected from different areas of Kolkata district of West Bengal, India

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ABSTRACT

As a result of rapid urbanization and huge increase in population in city like Kolkata in West Bengal, India, limits the adequate supply of pure and safe potable water to the city-dwellers. Overcrowding in a congested city like Kolkata possesses threats for contamination of potable water supply which may deteriorate the physical, chemical as well as the bacteriological quality. The sanitary effluents when contaminate the drinking water supply sources which may cause potential health hazards to a huge number of residents and can even lead to spread of infective pathogenic bacterial strains within the population. Keeping this view the present study aims in the survey of potable water samples collected from different sources in and around the Kolkata district. Direct contact and intake of those water samples are very common phenomenon for the people residing in a congested city like Kolkata. A number of water samples from different areas consisting of varying population densities and also having numerous sources are collected and analyzed using commercially available kits. The study mainly based on observing the physical parameters as well as the chemical and bacteriological quantity and quality of the source sample of drinking water mainly from domestic sources as well as the water collected from open water bodies and the municipality supplies including tap water and deep tube wells. The presence of pathogenic bacterial strains along with the coliform contamination of the sample water tested signified a threat to the suitable drinking water in certain selected areas of this crowded city like Kolkata. If the contaminated water sources are not purified the surviving outrageous intensity of fecal *E. coli, Vibrio cholera, Salmonella* species and other pathogens will pose unfavorable difficulty by upgrading recurrence of water borne infection. The present survey will throw light on the current situation of the quality of potable water in certain areas of Kolkata so that necessary action should be undertaken in those areas to cope up with the situation for the benefit of the people residing there and to provide safe and pure drinking water following WHO guidelines.

Keywords: Potable water; Bacteriological; Kolkata; Pathogen

1. INTRODUCTION

According to the World Health Organization estimation up to 80% of all sicknesses and diseases in humans in the world are caused by inadequate sanitation, polluted water or unavailability of pure and safe water. It was estimated that nearly 1.5 billion people lack safe drinking water and that at least 5 million deaths per year can be attributed to water- borne diseases (WHO 2004). Pathogenic organisms associated with potable and drinking-water supplies in developing countries are based on four bacterial indicators including faecal coliforms, *Escherichia coli, Enterococci* and faecal *Streptococci* and their relationship to the prevalence of diarrhoeal disease in Cebu, Philippines (Moe *et al.*, 1991). The drinking-water supply if it is contaminated with infective microorganisms is not safe for human consumption and polluted water causes various water-borne gastrointestinal diseases like diarrhoea, dysentery, due to the presence of virulent bacterial strains *Vibrio cholerae* and *Salmonella sp*. Most of the enteric diseases of human and animals are transmitted through contaminated food and water (Johnson *et al*., 2003). In order to overcome the threat of deterioration water quality periodic monitoring of aquatic resources is of utmost requirement, which helps to keep check on the level of contaminants and to conduct necessary curative measures for the wellbeing of aquatic body (Bellingham, 2012).

Coliforms are mostly present in large numbers among the intestinal flora of humans and other warm-blooded animals (Pal, 2014). The presence of *E. coli* in water is a strong indication of recent sewage or faecal contamination. Sewage may contain many types of disease causing organisms. *E. coli* comes from human and animal waste. When these waters are used as sources of drinking water and the water is not treated or inadequately treated, *E. coli* may enter in the drinking water (Health Canada, 2008). The presence of faecal coliform in aquatic environments serve as an indicator and specify that the water has been contaminated with the faecal material of humans or animals. Faecal coliform bacteria can enter aquatic bodies through direct point and non-pint sources as well as from human wastes (Doyle and Erickson, 2006).

The faecal matters are thus contaminated with coliform bacterial species. As a consequence, coliforms, detected in higher concentrations than pathogenic bacteria, are used as an index of the potential presence of entero-pathogens in water environments which indicates the possibility of sewage contamination with potable water sources. The use of the coliform group, mainly *E. coli* species as an indicator of microbiological water quality dates from their first isolation from feces at the end of the 19th century (Pal, 2014).The transmission of waterborne diseases is still a matter of major concern in the present decade despite worldwide efforts are being undertaken using modern technologies which are being utilized for the production of safe drinking water (Venter, 2000). This problem is not only confined to the developing but also in developed countries of the world where water treatment may or may not exist or is inadequate.

There may also be contamination during storage, lack of regulations, limited understanding and awareness among the population (American Academy of Microbiology, 1996). In thickly populated congested city like Kolkata there is higher probability of contamination of drinking water sources and thus careful surveillance is of utmost requirement. Keeping this particular view in mind the present study has been designed to assess the potable water quality in terms of physical, chemical and microbiological parameters of few selected congested overcrowded zones of Kolkata. This analysis will throw some light on the present scenario of the water quality management of the city.

2. MATERIALS AND METHODS

2. 1. Sample collection procedure for Bacteriological analysis of drinking water

Sample water is collected from natural water bodies like ponds where human activities are noticed, municipal tap, drinking water bottles or containers from household sources in different areas of Kolkata district of West Bengal. About 500 ml of sample water are collected in sterile screw tight containers. After pouring the sample water in the container small air space is left to make shaking before analysis. When collecting sample water from tap source special precautions are taken in removing any attachment from the tap as well as using a clean cloth outlet of the tap wipe to remove any dirt and then turning on the tap for maximum flow and running the water for two minutes before collecting the sample water in sterile bottles. Collected sample delivered to laboratory within 20 to 30 minutes assessing the microbiological parameters using commercially available kits.

2. 2. Parameters selected for collected water samples

The following basic parameters included in this study:

2. 2. 1. Physical parameters

The physical parameters tested include temperate, conductivity, colour, odour and turbidity. The temperature and the conductivity are tested using suitable instrument Multi-parameter Testr 35 Series of Eutech make. The colour and odour are determined by visual observations of the collected water samples.

2. 2. 2. Chemical parameters

The chemical parameters included in this study are based on the determination of the pH, Salinity, Total Dissolved Solids (TDS) and the detection of harmful chemicals iron and fluoride. The pH, Salinity and TDS are measured using Multi-parameter Testr 35 Series of Eutech make after calibrating the instrument with suitable standard buffers before testing individual parameters following manufacturer's instructions. The iron and fluoride are estimated using AQUA Check Iron Test Kit and Fluoride Test Kit of HiMedia Laboratories respectively according to the instructions supplied with the kits.

2. 2. 3. Bacteriological parameters

For the detection of presence or absence of coliform bacteria in collected sample water commercially available PA Coliform Kit MS1186 of HiMedia Laboratories is used in this study. The procedures followed according to instructions provided along with the kit. Briefly the entire quantity of dehydrated medium PA Broth for a single test is dissolved by swirling in 100 ml of sample.

After dissolution the mixture is incubated in 35°C for 48 hrs. The colour change of the medium after incubation signifies the presence or absence of coliforms. The rapid detection of pathogenic bacterial strains simultaneously in water samples including *Salmonella* species, *E. coli, Citrobacter* species and *Vibrio* species the HiWater Test Kit K015 of HiMedia Laboratories is suitably used following the instructions supplied with the kit. Supplied within the kit two dehydrated media; 'Medium A' for the simultaneous detection of *Salmonella, E. coli, Citrobacter species* in sample water and 'Medium B' for the detection of *Vibrio* species (*V. cholera V. parahaemolyticus*, other *Vibrios*)

3. RESULTS

The sample water collected from various parts of Kolkata are analysed based on the physical, chemical and microbiological parameters.

3. 1. Analyses of the physical parameters

3. 1. 1. Colour

Colour in surface water and ground waters results primarily from the presence of natural organic matter, particularly aquatic humic matter (APHA *et* al., 2012). In this study almost all the sample water collected from municipal tap and household sources are colourless except those collected from tube wells or ponds (Table 1). The appearance of slight turbidity on visual inspection in the ground water samples gave a deviation from the true colourless state of the other samples. The turbidity in water samples is caused due to suspended and colloid matters such as clay, silts, finely divided organic and inorganic matter, plankton and other microscopic organisms (McCoy and Olson, 1986; APHA *et al*., 2012).

3. 1. 2. Odour

Odour is recognized as a quality factor affecting acceptability of drinking water for human use (U.S. EPA, 1973). Since some odourous materials are detectable when present in only a few nanograms per litre it is usually impractical and sometimes impossible to isolate and identify the odour-producing chemicals. The human nose is the practical odour-testing device used in this method (Mallevialle and Suffet, 1987). All the samples analysed were odourless which are collected from tap or household containers. The sample from the tube wells and ponds gave unobjectionable odour (Table 1).

3. 1. 3. Temperature

The temperature of the water samples varied according to time of collection. The water collected from household sources showed minor variations in temperature while the water collected from open water-bodies varies with location although the range of variation is not very high (Table 1).

3. 1. 4. Conductivity

The electrical conductivity is a measure of the ability of an aqueous solution to carry an electrical current. This ability depends on the presence of ions; on their total concentration, mobility and valence. In SI (International System of Units) conductivity is reported as milli-siemens per meter (mS/m) or µS/cm where 1 mS/m = 10 µS/cm (APHA *et al.*, 2012). The conductivity of the potable water samples varied in different areas of Kolkata and it ranged within 210 µS/cm – 945 µS/cm (Table 1). According to European Economic Community Standards for physiochemical parameters in relation to the natural water structure, guide level for conductivity is 400 µS/cm (AWWA, 1990).

Table 1. Physical parameters tested in water samples collected from certain locations of city Kolkata.

Location	Source	Colour	Odour	Temperature (°C)	Conductivity (µS/cm)
Bowbazar	Tap	Colourless	Odourless	22.8	222
Dumdum	Pond	Turbid	Unobjectionable odour	20.4	942
Urquhart Square	Tap	Colourless	Odourless	23.7	306
Taltala	Tap	Colourless	Odourless	22.6	215
Goabagan Lane	House-hold bottles	Colourless	Odourless	23.6	221
Shyambazar	House-hold bottles	Colourless	Odourless	24.4	220
Sakuntala Park	Pond	Turbid	Unobjectionable odour	21.8	664
Kasba	Tap	Colourless	Odourless	22.5	465
Entally	Tap	Colourless	Odourless	22.9	247
Sealdah	House-hold bottles	Colourless	Odourless	22.7	267
Picnic Garden	House-hold bottles	Colourless	Odourless	23.1	234
Beliaghata	Tube-well	Slight reddish tinge	Unobjectionable odour	23.2	756
Kestopore	Pond	Turbid	Unobjectionable odour	25.6	945
Hazra	Tap	Colourless	Odourless	23.7	278

Burrabazar	Tap	Colourless	Odourless	24.6	436
Ultadanga	House-hold bottles	Colourless	Odourless	21.7	225
Manicktala	Tap	Colourless	Odourless	23.1	289
Park Circus	Tap	Colourless	Odourless	22.7	210
Thakurpukur	Tube-well	Pale Yellow-reddish tinge	Unobjectionable odour	20.6	745
Anandapur	Tube-well	Slight reddish tinge	Unobjectionable odour	19.5	834

3. 2. Analyses of the chemical parameters

3. 2. 1. pH

The pH value of tested water samples refers to the intensity of the acidic or alkaline condition of a solution (Murhekar, 2011). Changes in pH values can directly affect metabolic activity of living organisms. The pH values of water also determine the chemistry and availability of nutrients. Organisms have a limited range of pH tolerance. Natural levels of the alkalinity refers to the condition when pH value exceeds 7 tend not to be as important as levels of acidity since it pose a constraint on the organismal function and activities (Cain *et al*., 2014). The pH interferes with the chemical reactions of water and hence considered valued factor for representing water quality (Fakayode, 2005). For sustenance of aquatic biota, pH must be within the range of 6.5 to 8.2 (Wang, 2002). The pH value obtained when the different sample waters from various areas and sources in Kolkata are analysed ranged from 7.85-8.68 (Table 2) showing alkaline nature.

3. 2. 2. Salinity

Salinity is conceived as a measure of the mass of dissolved salts in a given mass of aquatic solution. Freshwater has very little salt, usually less than 0.5 ppt (parts per thousand). Water with salinity of 0.5-17 ppt is known as brackish water. Seawater on an average shows a salinity of 30-40 ppt (APHA *et al*., 2012). The sample water investigated in this study is mainly fresh water and ground water. The salinity levels in the collected water samples in Kolkata ranged from 0.121-0.511 ppt (Table 2).

3. 2. 3. Total Dissolved Solids (TDS)

TDS also plays major role in the maintenance of health of the aquatic ecosystem and excess TDS values are the result of the higher ionic deposition (Singh, 2010). Lower values of the TDS denoted the less ionic concentration, which may the result of ample rainfall and surface (Bhatt *et al*., 1999). Waters with high TDS generally are of inferior palatability and may induce an unfavorable physiological reaction in transient consumers. The desirable limit for TDS in drinking water is 500 mg/l (APHA *et al*., 2012). The TDS determined in this study in selected locations and sources of potable water varied within a range from 154 mg/l to 666 mg/l (Table 2).

3. 2. 4. Iron

Iron usually occurs in all natural waters in both oxidised (Ferric) as well as reduced (Ferrous) forms. Since the ground water is often anoxic any soluble iron is mostly present in the ferrous state. According to U.S. EPA the standard concentrations of iron in drinking water are normally less than 0.3 mg/l (APHA *et al*., 2012) but it varies and can have a higher concentration where cast iron, steel or galvanised iron pipes are used for water distribution (WHO, 2006). Presence of iron in water promotes growth of undesirable iron bacteria that result in deposition of slimy coating in the piping (WHO, 2006; AWWA, 1990; Rannamaee and Veldre, 1998). Elevated iron levels in water can impart objectionable taste and colours (APHA, *et al*., 2012). The estimated iron concentration in this study in certain locations of Kolkata ranged from 0.1mg/l to 0.5 mg/l (Table 2).

3. 2. 5. Fluoride

Fluoride is widely distributed in the lithosphere and hydrosphere. Because of the dissolving power of water and movement of water in hydrological cycle fluoride is found in all waters (AWWA, 1990). According to Wyatt *et al*., (Wyatt *et al*., 1997) there is a link between arsenic (As) and fluoride (F) in drinking water. Two forms of chronic effects are recognised generally as being caused by excess intake of fluoride over long periods of time. These are mottling of tooth enamel or dental fluorosis and skeletal fluorosis (Srikanth *et al*., 2002; Malde *et al*., 1997; Mascarenhas, 2000; Shivshankara *et al*., 2000). The concentration of fluorides on water follows a complex effect on human health. A concentration of fluoride less than 0.5 mg/l is responsible for dental caries above 0.9 mg/l is responsible for the appearance of the disease fluorosis. Thus the WHO guideline value for fluoride concentration is 0.5-0.9 mg/l (WHO, 2006). The concentration of fluoride levels detected in water samples in different zones of Kolkata ranged from 0.1 mg/l - 0.4 mg/l (Table 2).

Table 2. Chemical parameters tested in water samples collected from certain locations of city Kolkata.

Location	Source	pH	Salinity (ppt)	TDS (mg/l)	Iron (mg/l)	Fluoride (mg/l)
Bowbazar	Tap	8.06	0.123	158	0.3	0.2
Dumdum	Pond	7.98	0.511	666	0.5	0.4
Urquhart Square	Tap	8.68	0.178	217	0.3	0.2
Taltala	Tap	8.12	0.121	155	0.1	0.2
Goabagan Lane	House-hold bottles	7.93	0.124	156	0.0	0.2
Shyambazar	House-hold bottles	8.03	0.213	162	0.1	0.2

Sakuntala Park	Pond	7.96	0.312	346	0.4	0.3
Kasba	Tap	8.56	0.354	278	0.2	0.2
Entally	Tap	8.13	0.134	154	0.1	0.1
Sealdah	House-hold bottles	8.21	0.125	165	0.1	0.1
Picnic Garden	House-hold bottles	7.89	0.246	269	0.2	0.4
Beliaghata	Tube-well	7.87	0.355	316	0.4	0.4
Kestopore	Pond	7.95	0.476	478	0.5	0.3
Hazra	Tap	8.04	0.145	167	0.1	0.1
Burrabazar	Tap	7.85	0.312	377	0.2	0.2
Ultadanga	House-hold bottles	7.90	0.443	513	0.3	0.2
Manicktala	Tap	7.95	0.178	187	0.0	0.1
Park Circus	Tap	8.10	0.165	170	0.1	0.1
Thakurpukur	Tube-well	8.67	0.235	257	0.3	0.3
Anandapur	Tube-well	8.22	0.478	519	0.4	0.4

3. 3. Analysis of the bacteriological parameters

The contamination of drinking water sources with microbial pathogens is the leading cause of more than three million deaths every year from water-related disease and 43% of water-related deaths are due to diarrhoea (WHO, 2008). The majority of the infectious diseases are caused by bacteria, fungi, viruses and parasites associated with human excreta which contaminate water supplies (Tambekar and Hirulkar, 2007). The coliform bacteria were regarded as a group belonging to the genera *Escherechia*, *Citrobacter*, *Klebsiella* and *Enterobacter*, but other genera including *Serratia* and *Hafnia*.

The total coliform group includes both faecal and environmental species and they occur in both sewage and natural waters. Some of the bacteria belonging to the total coliform are excreted in human faeces but many coliforms are heterotrophic and multiply in water and soil. The indicator organism of choice for faecal pollution is *E. coli*. Thermotolerant coliforms can be used as alternative test for *E. coli* in many circumstances. Total coliforms are generally measured in 100 ml of sample water utilizing the property of acid production from lactose or enzyme β-galactosidase.

Methods including MPN (Most Probable Number) and P/A tests (Presence/Absence) are generally employed for the coliform detection in drinking water (Ashbolt *et al*., 2001; Grabow, 1996; Sueiro *et al*., 2001; WHO, 2006). The PA Coliform Kit is used in this study to detect harmful coliform bacteria in potable water samples in certain locations of Kolkata.

The results of presence or absence of coliform bacteria in sample water are tabulated in Table 3 (Table 3). Presence of coliform bacteria detected in samples collected from Dumdum, Goabagan, Sakuntalapark, Kestopore and Anandapur (Table 3). The probability of major pathogenic bacterial species which are included in the presence of coliform in the sample tested includes *E. aerogenes*, *E. coli*, *E. faecalis*, *K. pneumonia*, *S. typhimurium* (Greenberg *et al*., 1985).

For rapid and simultaneous detection of *Salmonella* species, *E. coli*, *Citrobacter* species and *Vibrio* species the HiWater Test Kit is used. The Medium A supplied with HiWater Test kit utilizes the modified form of Manja *et al.* (Manja *et al*., 1982) protocol where the differentiation of bacterial species belonging to *Salmonella*, *Citrobacter* was based on H_2S production and the detection of *E. coli* on the basis of colour change of the medium. The chemical composition of the medium A includes Peptone as source of Nitrogen, Ferric Ammonium Citrate and Sodium thiosulphate. The production of H_2S gas is identified when the sample water containing enteric bacterial species belonging to group of *Salmonella* or *Citrobacter* reduces Sodium thiosulphate. The other reagents present in the medium like Dipotassium hydrogen phosphate acts as a buffer and Sodium lauryl sulphate inhibits the growth of associated microflora. Bromocresol purple acts as an indicator for pH change as the original reddish-purple colour of the medium shifts to yellow signifying the presence of *E. coli* bacterial species. The different sample water tested in this study showed the presence of *E. coli*, *Salmonella* species and *Citrobacter* species in certain locations of Kolkata (Table 3). Similarly the Medium B supplied in the same kit is the *Vibrio* broth for the identification of the *V. cholera*, *V. parahaemolyticus* and other *Vibrio* species. Briefly the medium contains Peptone, Sodium citrate, Bile salt, Sucrose, Sodium thiosulphate, Sodium chloride and Indicator mix. Sucrose acts as fermentable carbohydrate and thiosulphate is the sulphur source. The alkaline pH helps in the isolation of the *V. cholera*. Incubating the Medium B mixing with different sample water in this study in Kolkata detected *V. cholerae* as well as *V. parahaemolyticus* in certain water samples collected (Table 3).

Table 2. Bacteriological parameters tested in water samples collected from certain locations of city Kolkata.

Location	Source	PA Coliform Kit (+)-Presence of coliform bacteria (-)- Absence of coliform bacteria	HiWater Test Kit	
			Medium A (+)- Presence of bacteria (-)- Absence of bacteria	Medium B (+)- Presence of bacteria (-)- Absence of bacteria
Bowbazar	Tap	(-)	(+) *E. coli*	(-)
Dumdum	Pond	(+)	(+) *Salmonella, Citrobacter*	(+) *V. parahaemolyticus*
Urquhart Square	Tap	(-)	(+) *E. coli*	(-)

Taltala	Tap	(-)	(-)	(+) *V. cholera*
Goabagan Lane	House-hold bottles	(+)	(+) *E. coli*	(+) *V. cholera*
Shyambazar	House-hold bottles	(-)	(+) *E. coli*	(-)
Sakuntala Park	Pond	(+)	(+) *Salmonella*	(-)
Kasba	Tap	(-)	(+) *E. coli*	(-)
Entally	Tap	(-)	(-)	(-)
Sealdah	House-hold bottles	(-)	(+) *Citrobacter*	(+) *V. parahaemolyticus*
Picnic Garden	House-hold bottles	(-)	(+) *E. coli*	(-)
Beliaghata	Tube-well	(-)	(+) *E. coli*	(-)
Kestopore	Pond	(+)	(+) *Salmonella, Citrobacter*	(-)
Hazra	Tap	(-)	(-)	(-)
Burrabazar	Tap	(-)	(+) *Salmonella*	(-)
Ultadanga	House-hold bottles	(-)	(-)	(-)
Manicktala	Tap	(-)	(-)	(-)
Park Circus	Tap	(-)	(+) *E. coli*	(-)
Thakurpukur	Tube-well	(-)	(-)	(-)
Anandapur	Tube-well	(+)	(+) *E, coli*	(-)

4. DISCUSSION

The present study was planned to monitor the potable water quality consumed or used by the people residing in congested and overcrowded areas of the city Kolkata. The water sample chosen for analyses included the drinking water as well as the water used for day to day human activities like cooking, mouth washing, bathing etc. The sample water collected from house hold containers are used for drinking and those from tube wells and municipal taps as well as open water bodies like ponds are used for drinking in some locations as well as doing other activities. The storage of drinking water is also an important aspect for quality of water assessment. The stored drinking water from house hold sources located in thickly populated slum area are very prone to acquire coliform and other indicator microorganism during storage or the conditions of the containers used for storing. Moreover the pollutant load of drinking water is significantly influenced by the pipes and fittings (Seifert *et al.*, 2000). There are many reasons for bacteriological contamination of water at domestic level or consumer ends. Moreover in congested city like Kolkata drinking water and sewage pipelines usually run at close proximity creating a huge probability of mixing of waters due to leakage of old pipelines.

According to WHO guideline (WHO, 2006) presence of organic colouring matter in water stimulates the growth of many microorganisms. Discolouration of potable water may arise from the dissolution of iron or copper in distribution pipes, which can be enhanced by bacteriological processes. Microbiological action can also produce 'red water' resulting from the oxidation of iron from ferrous to ferric by iron bacteria (WHO, 2006). In this study the colour of the water samples collected from tube-well in areas such as Beliaghata, Thakurpukur and Anandapur showed a slight reddish tinge whereas those collected from ponds in areas like Sakuntalapark, Kestopore and Dumdum were turbid.

Similarly the sample water collected from ponds and tube-wells from areas like Dumdum, Sakuntalapark, Beliaghata, Kestopore Thakurpukur and Anandapur when tested an unobjectionable odour was detected in those samples in contrast to sample collected from either tap or household bottles indifferent localities. This was correlated with the fact that those samples were not colourless in contrast to other samples. Thus the presence of odour in those samples signified the presence of microbial, chemical and physical contaminants of water.

The conductivity of water guide value is 400 μS/cm (AWWA, 1990). The sample tested in this study showed that water collected from ponds and tube-wells have a conductivity range much higher than the acceptable value. The water collected from tap or household bottles were within the permissible limits except the tap water collected from Burrabazar area.

The pH parameter of the tested water sample in Kolkata was in the alkaline range which is suitable for human consumption. Similarly the salinity of the water samples is in the normal range of 0.5 ppt except in Dumdum pond sample where the value exceeds the normal limit.
Total Dissolved Solids (TDS) comprise inorganic salts including Ca, Mg, K, Na, HCO_3, Cl and SO_4 as well as small amounts of organic matter that are dissolved in aqueous medium. Water gets contaminated with TDS from natural sources, sewage, urban runoff and industrial wastewater. According to WHO guidelines the concentration of TDS in potable water greater than 1200 mg/l is objectionable whereas extremely low concentration renders flat, insipid taste to drinking water (WHO, 2006). The sample water tested in Kolkata the TDS concentration is within the acceptable limit of 500 mg/l (APHA, *et al*., 2012) in majority of the sample tested except the sample from Dumdum pond and Anandapur tube-well where beyond acceptable limit concentration have been detected in this study.

Iron is the most abundant element, by weight, in the earth's crust. Iron is the second most abundant metal in earth's crust. It is an essential element in human nutrition. The minimum daily requirement of iron ranged from about 10 to 50 mg/day (WHO 1988). Iron concentration greater than 1.0 mg/l markedly impair the potability of the water and there is usually no noticeable taste at iron concentration below 0.3 mg/l (WHO 2003). Natural water contains variable amounts of iron and in ground water it is normally present in the ferrous or bivalent from (Fe^{++}) (Kumar and Puri 2012). The iron concentration estimated in the sample collected from different areas of Kolkata are more or less within range of 0.3 mg/l exceptions noticed in areas including Dumdum, Sakuntalapark, Beliaghata, Kestopore and Anandapur where relatively higher concentrations were noticed.

The maximum permissible limit of fluoride in drinking water is 1.5 ppm or mg/l and highest desirable limit is 1.0 ppm (WHO, 1984; Kumar and Puri 2012). Fluoride concentrations beyond permissible limits to the extent 1.5 ppm in drinking water cause dental fluorosis and much higher concentration skeletal fluorosis. In contrast low concentration (approximately 0.5 ppm) provides protection against dental caries. According to previous report India is among the 23 nations around the globe where fluoride related health problems occur due to the consumption of drinking water having high concentration of fluoride from 1.0 to 400 mg/l. Moreover it was also reported that near about 20 million people are affected by fluorosis and about 40 million people are exposed to risk of endemic fluorosis (Chinoy, 1991; Kumar and Puri 2012). In the present study conducted in Kolkata in the state of West Bengal, India, the concentration of fluoride in the water sample tested is within the permissible limit.

Fecal coliform bacteria are a collection of relatively harmless microorganisms that live in large number in the intestines of the warm and cold blooded animals. They aid in the digestion of food. Specific subgroups of this collection are the fecal coliform bacteria, the most common member being *Escherichia coli* (*E. coli*). The presence of indicator organisms (*E. coli* or thermotolerant coliform bacteria) in water indicates recent contamination of the water source with fecal matter and hence possible presence of intestinal pathogens. According to World Health Organization (WHO) guidelines (WHO, 1996), *E. coli* or thermotolerant coliform bacteria should not be detectable in any water intended for drinkingAt the time this occurred, the source water may have been contaminated by pathogens or disease-producing bacteria or viruses which can also exist in fecal material. Some water-borne pathogenic diseases include typhoid fever, viral, and bacterial gastroenteritis and hepatitis A.

The presence of fecal contamination is an indicator that a potential health risk exists for individuals exposed to this water (WHO, 1996). The presence or absence of faecal indicator bacteria is another commonly used operational monitoring parameter. There are contaminating pathogens that are resistant to disinfectants (Chlorination) than the commonly used indicator organism *E. coli* or thermotolerant coliforms including the presence of more resistant faecal indicator bacteria (Intestinal enterococci), *Clostridium perfringes* spores or coliphages (WHO, 2012). Thus the presence or absence of *E. coli* cannot be a suitable index for the determination of other bacteria in water sample. In the present study the presence/absence of coliforms are determined in sample water collected in certain areas of Kolkata district.

The presence of coliforms were detected in samples collected from Dumdum, Goabagan, Sakuntalapark, Kestopore and Anandapur suggesting proper time to time monitoring as well as purification of the water sources are of urgent need. The presence of coliforms in water collected from ponds (Dumdum, Kestopore, Sakuntalapark) signified the contamination of faecal matters in those water bodies. The sample obtained from Goabagan which was collected from house hold bottles signified either there is contamination in the supply tank from where the water is kept and also the container where it is stored.

The sample collected from Anandapur tube-well might be contaminated from underground source. Analyses of the water samples for the presence/absence bacteria namely *E. coli*, *Salmonella*, *Citrobacter* and *Vibrio* species gave positive results in certain samples investigated. *E. coli* was detected in majority of the samples irrespective of whether collected from open water bodies or underground source or household source or municipal tap. In contrast *Salmonella*, *Citrobacter* species as well as *Vibrio* species occurrances were detected in few of the samples (Table 3). This signified that the sample water collected from selected overcrowded parts of Kolkata has bacterial contaminations.

5. CONCLUSIONS

It is evident from this present survey that most of the sources of domestic water as well as open and ground water sources in certain congested areas of Kolkata are contaminated with bacterial pathogens capable of causing enteric diseases and do not meet the WHO guidelines for drinking water quality. The physical and chemical parameters are more-or-less within the acceptable limits of WHO guidelines with few exceptions in certain areas. All these factors might pose for possible human health hazards particularly to the residents of those zones and they are at risk of acquiring water-borne diseases as well as contaminated-water related diseases. The results of this study also suggest that tap water may be safer, but additional sampling is needed in comparison to open water sources like ponds for drinking purpose. Moreover the bacteriological contaminations are also possible from leakage of pipelines and also the place of storage and collection of potable water. Basic sewage disposable pipelines improvement may be worthwhile at the moment for preventing the faecal bacterial contaminations in drinking water. Basic treatment of the water at the community or household level by chemical disinfection using chlorine, filtration using simple household filters, and boiling should also be promoted. Thus few simple interventions may mitigate the health hazards associated with potable water and ensures access to safe drinking water which in turn would result in 200 million/year fewer diarrheal episodes and 2.1 million/year fewer deaths caused by diarrhoea (Esrey *et al*., 1991).

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