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Studies on the potable water quality in certain districts of West Bengal and its effect on human health

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ABSTRACT

The public health protection in any part of the world depends largely on adequate supply of pure and safe drinking water. The increasing human population has posed a great problem in this endeavour. The presence of harmful toxic inorganic and organic chemicals as well as detection of pathogens including the coliform group in concentration greater than the permissible limits has led to public health hazards. The aim of this work is to compare the water quality in certain thickly populated districts of West Bengal India to assess the current scenario of potable water sources. The physical, biochemical and bacteriological parameters are tested in water samples collected from different open water bodies and domestic sources in different districts of West Bengal and the data are compared. The sources of this pollutants in the water are also ascertained and suitable remedial measures are suggested in those areas where the WHO permissible limits exceeded for human consumption and uses. For the bacteriological analyses the presence/absence of coliforms are carried out to authenticate the contamination of harmful pathogenic strains which indicated the sewage contamination of the drinking water and is not safe for human health. This study also reflected the fact that mostly the overcrowded congested districts are more prone to polluted water where suitable purification systems are inadequate. Moreover open water bodies are mostly polluted due to anthropogenic effects where disposal of human wastes as well as domestic wastes are dumped. The presence of highly pathogenic strains including *V. cholerae, Salmonella sp.* have been detected in open water body sources such as ponds in different areas tested in this study. The presence of pathogenic strains and alterations of both physical and chemical parameters of potable water is a serious problem and remedial measures for establishment of suitable purification system is of utmost need in the well-being of the people residing

in those areas. This study will throw some light on the present situation of the water quality on a comparative basis in certain districts of West Bengal including the highly congested Kolkata district so that improvement of safe and pure water supply can be made following WHO guidelines in areas where water pollution are recorded.

Keywords: Districts of West Bengal; Potable water; Coliforms; Pathogenic strains

1. INTRODUCTION

Pure and safe supply of drinking water is the need for human survival. Water quality is affected mainly due to contamination which alters the physical, biochemical as well as the microbiological aspects of the potable water. According to available data approximately 4% of urban population of the world are suffering from lack of suitable drinking water. Moreover near about 1.8 million people of the world are having access to drinking water contaminated with faecal matters [1,2]. This is an alarming situation and is the source of high morbidity and mortality caused due to enteropathogenic organisms contaminating the drinking water [3]. Studies have shown that human and animal activities are responsible for the quality of water sources [4,5]. The principal factor that governs the microbial contamination of drinking water is the inadequate and unsuitable technology for the sewage disposal due to poor sanitation in developing parts of the world having a high population density [6]. Rural parts along with developing human population are well known for the lack of hygiene which only serves to compound the problem of poor water quality [7]. These areas are highly potent for the development of an increasing risk of pathogenic bacterial diarrheal diseases which threatens the well-being of the people residing in those zones. Moreover anthropogenic activities that contribute to contamination includes bathing and washing of clothes in open water body sources including the river or ponds or wells that alters the physical, biochemical parameters of the water and makes it unsuitable for human uses and consumption [8]. The most vital aspect of water quality management is the detection of pathogenic microbial contaminations that are the leading cause of gastro intestinal diseases in humans. For the detection of bacterial contamination of drinking water the indicator bacterial species mostly used worldwide is the *Escherichia coli* (*E. coli*) whose presence determines the faecal contamination of the drinking water source [9]. The microbial aspects of the drinking water is determined according to the permissible limits prescribed in WHO guidelines [10]. The presence of enteric diarrhoegenic pathogenic organisms contaminating the potable water is a leading cause of concern in the developing countries [11,12]. It was also noted that the absence of indicator organisms in water sources does not guarantee safety of drinking water [13]. The indicator bacterial species *E. coli* signifying the faecal contamination in water itself display diversity of pathogenic strains capable of causing enteric infections if consumed [14,15] The present study aims to evaluate the presence of certain physical, biochemical as well as microbial contaminants in the potable water both open water bodies and municipal supplies or domestic storage areas in certain thickly populated urban and rural areas of West Bengal, India, to assess the impact of human activities on the quality of water and to ascertain the associated health risks on consumption of the polluted water.

2. MATERIALS AND METHODS

2.1. Sample collection for analysis of drinking water quality from different sources

Sample water for testing the physical, biochemical and bacteriological parameters is collected from open water bodies like ponds where human activities are noticed including the drinking purpose, municipal tap, drinking water bottles or containers from domestic sources from certain districts areas of West Bengal as well as Kolkata district. In brief about 500 ml of sample water are collected in sterile screw tight containers leaving small air space to make shaking before analysis. Special precautions are taken when collecting sample water from municipal tap sources including avoiding any type of contamination like attachment of the container neck to the tap and also wiping the tap before collection to remove dirt if any. Then turning on the tap for maximum flow and running the water for two minutes before collecting the sample water in sterile bottles. Certain parameters of the collected sample water are tested in situ and the remaining sample delivered to laboratory with special precautions for assessing the microbiological parameters using commercially available kits.

2.2. Parameters tested

The physical parameters which affect the drinking water quality selected in this study include temperate, conductivity, colour, odour and turbidity. The temperature and the conductivity of the water samples are measured using Multi-parameter Testr 35 Series of Eutech make before calibrating the instrument with suitable buffers following manufacturers' instructions. The colour and odour are determined by visual observations of the collected water samples.

The selected chemical parameters tested are based on the determination of the pH, Salinity, Total Dissolved Solids (TDS) and the detection of certain harmful elements including 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 detection of 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.

The microbial aspects mainly carried out is the detection of indicator species specifying the presence of contaminants and certain pathogenic bacterial strains capable of causing diseases in humans. The detection of presence or absence of coliform bacteria which is considered as an indicator species in collected sample water is conducted using commercially available PA Coliform Kit MS1186 of HiMedia Laboratories. 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. For 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

3.1. Analyses of the selected physical parameters affecting water quality

The drinking water samples collected from various parts of West Bengal district areas are analysed and the physical parameters affecting the quality are selected.

Colour of the water sample whether surface water or ground waters results primarily from the presence of organic matter, particularly aquatic humic matter occurring naturally [16]. 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 water collected from pond in Namkhana and Diamond Harbour of South 24-Parganas district showed turbidity and reddish tinge respectively.

The appearance of slight turbidity on visual inspection in the ground water samples collected from Madarihat gave a deviation from the true colourless state of the other samples (Table 1). It has been reported from previous studies that the turbidity in water samples signified that the water samples are contaminated with suspended and colloid matters such as clay, silts, finely divided organic and inorganic matter, plankton and other microscopic organisms [17,16] which is not suitable for human consumption and use.

Another physical parameter which plays a significant role in the palatibilty of potable water includes the odour which is regarded as a quality factor affecting the quality of drinking water for human use [18]. Studies conducted on this factor as a water quality altering agent reported that the presence of odourous materials are detectable when present in only a few nanograms per litre and it is usually undetectable and sometimes odour-producing agent is not even possible to isolate and identify. The human nose can be used as the practical odour-testing device [19] and this method has been utilized in this study. The samples collected from municipal supplies in districts like Kolkata, when analysed were odourless which are collected from tap or household containers. The sample from the tube wells and ponds gave unobjectionable odour (Table 1) in majority of the districts signifying that those sample water are contaminated with odoriferous chemicals.

The temperature of the water samples determines the physical condition of the water and is very much related with the seasons. Usually water temperature in open water bodies are closely associated with season and the time of collection varied according. 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).

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 [16]. The conductivity of the potable water samples varied in different district areas of West Bengal varied a lot in different locations. Moderately high conductivity value was reported from samples collected in few areas belonging to Hooghly district. In South 24-Parganas district the sample collected from certain areas showed a wide range of conductivity (Table 1). In the Kolkata district the conductivity ranged within 210-945 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 [20].

Table 1. Comparison of the selected physical parameters of water sample collected from different sources in different areas of certain districts of West Bengal.

Location	Source	District	Colour	Odour	Temp. (°C)	Conductivity (µS/cm)
Namkhana	Pond	South 24-Parganas	Turbid	Unobjectionable odour	22.6	267
Madarihat	Tap	South 24-Parganas	Slightly Turbid	Odourless	21.8	224
Diamond Harbour	Tap	South 24-Parganas	Colourless	Odourless	22.7	1104
Diamond Harbour	Pond	South 24-Parganas	Reddish tinge	Odourless	23.4	2.16 mS/cm
Subhobuddhipur	Pond	South 24-Parganas	Slightly Turbid	Odourless	22.6	480
Baruipur	Tube well	South 24-Parganas	Slightly Turbid	Odourless	22.4	865
Sonarpur	Tap	South 24-Parganas	Colourless	Odourless	22.6	682
Dankuni	Tube well	Hooghly	Slightly Turbid	Odourless	23.5	540
Serampore	Tap	Hooghly	Colourless	Odourless	22.7	446
Chinsura	Pond	Hooghly	Turbid with greenish tinge	Unobjectionable odour	23.8	678
Chandan Nagar	Domestic Reservoir	Hooghly	Colourless	Odourless	22.6	475
Amta	Tube well	Howrah	Turbid	Odourless	22.7	694
Amta	Pond	Howrah	Turbid	Unobjectionable odour	22.4	571
Bally	Pond	Howrah	Turbid	Odourless	22.6	560
Memary	Well	Burdwan	Slightly Turbid	Odourless	23.7	775
Shaktigarh	Domestic container	Burdwan	Colourless	Odourless	23.3	567
Rabindra Nagar	Tap	North 24-Parganas	Colourless	Odourless	22.6	767
Belghoria	Pond	North 24-Parganas	Slightly Turbid	Unobjectionable odour	24.0	210
Dumdum	Pond	Kolkata	Turbid	Unobjectionable odour	20.4	942

Taltala	Tap	Kolkata	Colourless	Odourless	22.6	215
Goabagan Lane	House-hold bottles	Kolkata	Colourless	Odourless	23.6	221
Beliaghata	Tube-well	Kolkata	Slight reddish tinge	Unobjectionable odour	23.2	756
Anandapur	Tube-well	Kolkata	Slight reddish tinge	Unobjectionable odour	19.5	834

3.2. The selected chemical parameters affecting water quality

The chemical parameters selected in this study to monitor the quality of the sample water collected includes pH, Salinity, Total dissolved solids (TDS), detection of the amount of elements like iron or fluoride.

The pH value is an important aspect of water quality assessment since it determines the chemical state as well as the availability of nutrients. The pH tolerance of organisms varies within a short range and a value greater than 7 or less than that signifies whether the sample is alkaline or acidic respectively. It has been reported that a pH value of drinking water exceeding 7 is not suitable for human consumption leading to metabolic disorders [21-22]. The pH value of tested water samples refers to the intensity of the acidic or alkaline condition of a solution [23]. The optimum pH value for sustenance of aquatic biota ranges between of 6.5 to 8.2 [24]. The pH value obtained when the different sample waters from various areas and sources in certain districts of West Bengal are analysed ranged from 7.30-8.83 (Table 2) showing alkaline nature. Maximum pH value recorded from Diamond Harbour in South 24-Parganas district (Table 2).

Salinity of water samples signifies the measure of the amount of dissolved salts in a given volume of aquatic solution. The salinity of Freshwater having very little salt, usually has a value less than 0.5 ppt (parts per thousand). On the other hand Brakish water shows a wide range of salinity within 0.5-17 ppt. Marine aquatic samples on an average shows a salinity of 30-40 ppt [16]. The sample water investigated in this study is mainly fresh water and ground water. The salinity levels in the collected water samples in selected districts of West Bengal showed a wide range from 0.121 ppt to 1.2 ppt (Table 2).

TDS determines the concentration of ions in a water solution and a higher value signifies high ionic deposition which regulates the health of the aquatic ecosystem including the flora and fauna [25]. The water samples with lower values of the TDS denoted the less ionic concentration, signifying ample rainfall and surface run offs [26]. The palatability of drinking water samples are not acceptable with high TDS and generally imparts inferior and unfavorable physiological reaction and thus not suitable for human consumption. The desirable limit for TDS in drinking water fit for consumption is 500 mg/l [16]. The TDS determined in this study in selected locations and sources of potable water varied within a range from 154 mg/l to 1480 mg/l. The highest TDS recorded in a sample collected from a pond in Diamond Harbour (Table 2).

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 [16] but it varies and can have a higher concentration where cast iron, steel or galvanised iron pipes are used for water distribution [27]. Presence of iron in water promotes growth of undesirable iron bacteria that result in deposition of slimy coating in the piping [27, 20, 28]. Elevated iron levels in water can impart objectionable taste and colours [16]. The highest estimated iron concentration in this study recorded in a sample collected from open water source of Namkhana pond approximately 2 mg/l followed by another sample collected from Amta (Howrah) pond estimating about 1.5 mg/l (Table 2).

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 [20]. According to Wyatt *et al*., [29] 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 [30-33]. 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 [27]. The concentration of fluoride levels detected in water samples in different zones of West Bengal ranged within 0.1-0.5 mg/l (Table 2).

Table 2. Comparison of the selected chemical parameters of water sample collected from different sources in different areas of certain districts of West Bengal

Location	Source	District	pH	Salinity (ppt)	TDS mg/l	Iron mg/l	Fluoride mg/l
Namkhana	Pond	South 24-Parganas	7.3	0.146	189	2	0.5
Madarihat	Tap	South 24-Parganas	8.06	0.723	456	0.3	0.4
Diamond Harbour	Tap	South 24-Parganas	8.83	0.612	775	0	0.3
Diamond Harbour	Pond	South 24-Parganas	8.15	1.20	1480	0.5	0.4
Subhobuddhipur	Pond	South 24-Parganas	8.00	0.264	340	0.7	0.4
Baruipur	Tube well	South 24-Parganas	8.30	0.476	613	0.1	0.4
Sonarpur	Tap	South 24-Parganas	8.27	0.376	442	0	0.3
Dankuni	Tube well	Hooghly	7.75	0.432	378	0.3	0.4
Serampore	Tap	Hooghly	8.03	0.357	442	0.4	0.5
Chinsura	Pond	Hooghly	8.12	0.443	336	0.4	0.4

Chandan Nagar	Domestic Reservoir	Hooghly	7.78	0.134	331	0.3	0.4
Amta	Tube well	Howrah	8.75	0.355	512	0.3	0.3
Amta	Pond	Howrah	8.35	0.314	414	1.5	0.3
Bally	Pond	Howrah	8.45	0.237	489	0.3	0.4
Memary	Well	Burdwan	7.56	0.145	312	0.5	0.5
Shaktigarh	Domestic container	Burdwan	7.42	0.167	334	0.4	0.5
Rabindra Nagar	Tap	North 24- Parganas	8.40	0.409	540	0.1	0.45
Belghoria	Pond	North 24- Parganas	8.19	0.118	150	0.4	0.4
Dumdum	Pond	Kolkata	7.98	0.511	666	0.5	0.4
Taltala	Tap	Kolkata	8.10	0.121	155	0.1	0.1
Goabagan Lane	House-hold bottles	Kolkata	7.93	0.124	158	0	0.2
Beliaghata	Tube-well	Kolkata	7.89	0.119	178	0.5	0.3
Anandapur	Tube-well	Kolkata	8.26	0.456	456	0.6	0.5

3.3. Comparative study of the bacterial contamination of the sample water collected

According to WHO estimate [34] a large population of human death in developing countries are attributed to the consumption of water contaminated with microbial pathogens capable of causing diseases. The infective organisms including the bacteria, viruses, fungi, protozoa are the main causative agents which when contaminate the drinking water sources caused due to mixing of the human excreta with the drinking water supplies [35]. The indicator bacterial species that are mainly used as a tool for detection faecal contamination of potable water are the coliform bacteria which are regarded as a group belonging to the genera *Escherechia*, *Citrobacter*, *Klebsiella* and *Enterobacter*, but other genera including *Serratia* and *Hafnia*. The two groups of coliform bacteria belonging to faecal and environmental constitute the total coliform occurring in sewage water as well as environmental natural water bodies. Certain bacterial species belonging to total coliform group are associated with human faeces as for example *E. coli* and the bacteria serve as an indicator strain signifying faecal contamination if detected an a drinking water sample. Total coliforms are generally detected using 100 ml of sample water utilizing the property of acid production from lactose or enzyme β-galactosidase. Microbiological methods including MPN (Most Probable Number) and P/A tests (Presence/Absence) are generally employed for the coliform detection in drinking water

[27,36-38]. 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). Coliforms are detected in a variety of places including open water sources as well as municipal supply taps and household storage containers in different districts of West Bengal including Kolkata district (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* [39].

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.*, [40] 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* or *Salmonella* or *Citrobacter* species in sample water collected from different sources belonging to different districts of West Bengal (Table 3). 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 collected from different districts of West Bengal detected *V. cholerae* as well as *V. parahaemolyticus* strains (Table 3).

Table 3. Comparison of the bacterial contamination types in water samples collected from different sources in certain districts of West Bengal

Location	Source	District	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
Namkhana	Pond	South 24-Parganas	(-)	(+) *E. coli*	(-)
Madarihat	Tap	South 24-Parganas	(-)	(-)	(+) *V. cholerae*
Diamond Harbour	Tap	South 24-Parganas	(-)	(-)	(+) *V. cholerae*

Diamond Harbour	Pond	South 24-Parganas	(+)	(+) *Salmonella, Citrobacter*	(-)
Subhobuddhipur	Pond	South 24-Parganas	(+)	(+) *Salmonella, Citrobacter*	(+) *V. cholera*
Baruipur	Tube well	South 24-Parganas	(+)	(+) *E. coli*	(-)
Sonarpur	Tap	South 24-Parganas	(+)	(+) *E. coli*	(-)
Dankuni	Tube well	Hooghly	(-)	(+) *E. coli*	(-)
Serampore	Tap	Hooghly	(-)	(-)	(-)
Chinsura	Pond	Hooghly	(-)	(+) *Citrobacter*	(+) *V. parahaemolyticus*
Chandan Nagar	Domestic Reservoir	Hooghly	(-)	(+) *E. coli*	(-)
Amta	Tube well	Howrah	(+)	(+) *E. coli*	(+) *V. parahaemolyticus*
Amta	Pond	Howrah	(+)	(+) *E. coli*	(+) *V. cholerae*
Bally	Pond	Howrah	(-)	(-)	(-)
Memary	Well	Burdwan	(-)	(+) *Salmonella*	(-)
Shaktigarh	Domestic container	Burdwan	(-)	(-)	(-)
Rabindra Nagar	Tap	North 24-Parganas	(+)	(+) *E. coli*	(+) *V. parahaemolyticus*
Belghoria	Pond	North 24-Parganas	(+)	(+) *E. coli*	(-)
Dumdum	Pond	Kolkata	(+)	(+) *Salmonella, Citrobacter*	(+) *V. parahaemolyticus*
Taltala	Tap	Kolkata	(-)	(-)	(+) *V. cholerae*
Goabagan Lane	House-hold bottles	Kolkata	(+)	(+) *E. coli*	(+) *V. cholerae*
Beliaghata	Tube-well	Kolkata	(-)	(+) *E. coli*	(-)
Anandapur	Tube-well	Kolkata	(+)	(+) *E, coli*	(-)

4. DISCUSSION

In the present study the water sample chosen for analyses included water samples used for human uses and consumptions in day to day activities. The sources of water collections included open water bodies mainly ponds or wells or lakes used for human activities, municipal drinking water supply taps as well as household containers used for temporary of

storage of drinking water. The storage of drinking water is also an important aspect for quality of water assessment. Previous studies reported that the stored drinking water from house hold sources located in thickly populated areas are likely to acquire coliform and other indicator microorganism during storage either in the storage tanks or domestic containers if not proper hygiene is not maintained. Moreover the pollutant affecting the physical and chemical parameters of drinking water are dependent on the pipes and fittings through which the water is distributed [41] affecting the quality of the water at the consumption level In congested areas of different districts of West Bengal contamination of drinking water supplies with the sewage effluents may occur due to leakages of pipe lines draining sewage wastes or supplying drinking water affecting the quality of water and it may be one of the major concern in areas coliforms as well as enteric pathogenic bacteria are detected. The mixing of sewage and drinking water has a high probability in areas where the pipelines carrying sewage water and the pipelines supplying drinking water run side by side mainly noticed thickly populated cities of West Bengal. The loss of natural colour of water in an indication of the microbial growth as a result of contaminating organic matters as also the leaching of iron from the pipes supplying the water [27]. The survey work conducted in this study showed that turbidity in water sources where proper vigilance should be kept for any microbial growth.

The sample water collected from ponds and tube-wells from areas like Namkhana, Chinsura, Amta, Belgharia, Beliaghata, Anandapur (Table 1) when tested an unobjectionable odour was detected in those samples in contrast to sample collected from either tap or household bottles in different localities. Thus the presence of odour in those samples signified the presence of microbial, chemical and physical contaminants of water (Table 1). The conductivity of water guide value is 400 μS/cm [20]. 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. It is recorded that sample collected from Diamond Harbour pond as well as tap source showed a very high conductivity value much higher value than the permissible limit (Table 1).

The pH parameter of the tested water samples 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 certain open water bodies mostly ponds where the value exceeds the normal limit.

Total Dissolved Solids (TDS) comprise inorganic salts including Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}, HCO_3^{-}, Cl^{-} and SO_4^{2-} 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 [27,48-51]. The sample water tested in this study covering certain thickly populated districts of West Bengal the TDS concentration is within the acceptable limit of 500 mg/l [16] in majority of the sample tested except the samples from Diamond Harbour pond where beyond acceptable limit concentration have been detected in this study (Table 2).

Iron is an essential element in human nutrition and the optimum daily requirement of iron ranged from about 10 to 50 mg/day [42]. It has been estimated that Iron concentration greater than 1.0 mg/l in potable water sample affects its palatability. According to WHO estimate iron concentration below 0.3 mg/l is recommended [43]. Natural water contains variable amounts of iron and in ground water it is normally present in the ferrous or bivalent

from (Fe^{2+}) [44]. The iron concentration estimated in the sample collected from different districts of West Bengal are more or less within the acceptance range with certain exceptions but the highest concentration was recorded in the Namkhana pond (Table 2). Another important agent affecting water quality is Fluoride and its concentration in water sample alter the utility of sample water. Fluoride concentration greater than 1.5 ppm or mg/l is responsible for human diseases including dental or skeletal fluorosis if consumed. In contrast concentration of about 0.5 ppm is necessary for the prevention of dental caries. The maximum permissible limit of fluoride in drinking water is 1.5 ppm or mg/l and highest desirable limit is 1.0 ppm [45,44]. Previous survey reported 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 [46,44]. In the present study conducted in different districts in of West Bengal, India, the concentration of fluoride in the water sample tested is within the permissible limit (Table 2).

The faecal coliform group of bacteria comprises mainly the member of the group *Escherichia coli* (*E. coli*) that is considered as a beneficial organism residing in the human intestines. The presence of *E. coli* or other thermotolerant coliform bacteria in drinking water indicates that the water is contaminated with sewage effluents and thus the presence of coliform bacteria species serve as an indicator organism in the detection of faecal contamination in sample water sources. Thus the presence of positive coliform test in water sample under investigation signifies the possibilities of contamination of harmful pathogenic enteropathogens rendering the water not suitable for human consumption before suitable purification. According to World Health Organization (WHO) guidelines [47], *E. coli* or thermotolerant coliform bacteria should not be detectable in any water intended for drinking. Some water-borne pathogenic diseases include typhoid fever, viral, and bacterial gastroenteritis, hepatitis A cholera etc. and the source of all these diseases may be attributed to the consumption of contaminated water.

The presence of faecal contamination is an indicator that a potential health risk exists for individuals exposed to this water [47]. In the present study the presence/absence of coliforms are determined in sample water collected in certain areas of certain thickly populated districts of West Bengal. Extensive study conducted in different water samples collected from open water bodies like ponds, wells, including municipal taps as well as household storage and a significant detection of coliforms are identified (Table 3).

The use of those water samples are not suitable for human consumptions and special emphasis should be given for proper time to time monitoring as well as purification of the water sources. The sample collected from house hold bottles or tube wells showing positive coliform bacteria signified either there is contamination in the supply tank from where the water is kept and also the container where it is stored or underground contamination respectively. 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. The detection of *Salmonella* species indicates the possibilities of infection of typhoid if consumed untreated (Table 3).

Moreover the occurrence *Vibrio* species particularly *V. cholera* in certain samples investigated (Table 3) calls for immediate purification of those water sources since consumption of those contaminated water samples may lead to the development epidemic outbreak of cholera which might prove fatal for human survival.

5. CONCLUSIONS

The comparative study conducted in various districts of West Bengal on potable sample water collected from a variety of sources ranging from open water bodies covering ponds or lakes or wells to municipal taps and domestic storage containers it is evident that most of the sources of domestic water as well as open and ground water sources in certain congested areas are contaminated with harmful bacterial strains capable of causing enteric diseases if consumed untreated. The physical and chemical parameters that govern the quality of the water as well as its palatability also showed remarkable high concentration of certain agents much greater than the WHO acceptance limit particularly in open water bodies like ponds in certain areas under investigation. The potable water sources where detectable concentration of physical, chemical as well as bacterial contaminations are recorded surveillance are of utmost need and routine monitoring and purification of those areas are absolutely necessary for healthy living of people of those areas who are using or consuming water from those sources. If the contaminated water sources are left untreated they 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. Extensive analyses showed that the municipal tap water sources are more or less contaminated in all aspects in comparison to the open water bodies signifying the fact the local anthropogenic effects are a major source for polluting the open water bodies like ponds or lakes or wells. So social awareness campaign should be conducted in those areas so as to aware local people regarding the sources of water pollution as well as the health hazards associated with consumption of such polluted water. The bacteriological contamination in municipal supply water may be attributed to the fact of leakage of pipelines that can enhance the chances of mixing of sewage water with the drinking water supplies. Thus periodical monitoring of the pipelines should be undertaken to eradicate the contamination. Moreover basic treatment of the water both at the community or household level by chemical disinfectants, ultrafiltration devices, UV-fitted filters or simply boiling untreated water before consumption should also be promoted that can mitigate water related human diseases that are increasing at an alarming rate in the present scenario. Moreover the people residing in the economically backward areas government as well as non-government intervention should be carried out for supply of purified water but also to aware those people regarding the ill-effects of drinking water pollution.

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