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Impact of Certain Pollution Sources on Microbiology and Physicochemical Properties of Borewell water in the Northern Part of Ernakulam District in Kerala, India

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Abstract

The physicochemical and bacteriological properties of borewell water in certain selected areas of Ernakulam District have been studied. Seven different sites were selected for the study and the criteria considered for the selection includes industrial area (BW1), solid waste dumping (BW2), play ground (BW3) oil refineries (BW4), agricultural area (BW5), colony area with poor sanitization facilities (BW6) and sewage discharge (BW7). Various parameters viz., pH, electrical conductivity, total hardness, calcium, magnesium, sodium, total alkalinity, chlorides, sulphates, nitrates, fluorides, total dissolved solids, iron, zinc, total coliforms, fecal coliforms etc. have been determined and have been compared with standard guideline values recommended by BIS and WHO to see the quality and suitability of borewell water. The study reveals the unfavorable influence of various anthropogenic activities and other factors on the physicochemical and bacteriological properties of borewell water. The present investigation indicates the bore well water sample BW3 is safe and fit for human consumption. The water samples BW1, BW2, BW4, BW6 and BW7 are not fit for human consumption but permissible for irrigation purposes. The water sample BW5 is found unsuitable for human consumption and also not safe for irrigation purposes.

Keywords: Borewell water, microbiological and physico-chemical parameters, Northern regions of Ernakulam.

Introduction

"No life without water" is a common saying, as water is the essential requirement of all life supporting activities. Water can be obtained from a number of sources such as wells, ponds, rivers, lakes etc. but unfortunately, clean, pure and safe water exists only briefly in nature and is immediately polluted by prevailing environmental factors and human activities and hence water from most sources is unfit for immediate consumption without some sort of treatment[1]. In our country 70% of the water is seriously polluted and 75% of illness and 80% of the child mortality is attributed to water pollution[2]. Among the various sources of water, ground water is said to be the safest water for drinking and domestic purposes, as it is believed to be least affected by the external anthropogenic, environmentally disturbing activities. The processes of percolation, which results in filtration and purification of water is one of the reasons that ground water is often used as a source of fresh water for human use[3]. About 95% of rural population living in India depends on ground water for domestic use[4].

However during the past decade, widespread reports of ground water contamination have increased public concern about drinking water quality. The quality of water is getting vastly deteriorated mainly due to unscientific waste disposal, improper water management and carelessness towards the environment and this had led to the scarcity of potable surface water. This is followed by several other factors like land use practices, rainfall patterns and infiltration rate which in turn are reported to affect the quality of ground water in an area[5]. The tremendous organic loads imposed by urban sewage and industrial waste constitute a major cause of pollution of natural water bodies[6]. The uses of fertilizers, pesticides and insecticides, lime, septic tank, refuse dumps etc. are the main source of borewells water pollution[7]. It was Nageswara et al.[8] and Ramakrishnaiah et al.[9] who reported that the quality of borewell water is getting deteriorated in major rural centers in India due to pollution caused by population explosion, urbanization and industrialization. As ground water moves along the flow lines from recharge to discharge areas, its chemistry is altering by the effect of variety of geochemical processes[10].

Ernakulam is a very fast developing district in Kerala, India, where a good percentage of the total population is following flat residence system for stay. One of the major problems faced by this population is the shortage of water due to the inconsistent and irregular water supply by the Kerala Water Authority. Therefore people in this category are mainly depending on underground water resources in the form of borewell water without any proper pretreatment. It is therefore necessary that the quality of borewell water should be checked at regular time interval, otherwise due to the use of contaminated drinking water may pose a variety of water borne diseases. Better quality

of water is described by its physical, chemical and biological characteristics. The present study was aimed to analyze and see whether there is any impact on the physicochemical and bacteriological properties of groundwater collected from borewells which are located in and around different pollution causing sources at certain selected areas of Ernakulam District.

Material and Methods

Sampling procedure: Borewell water samples were collected from 7 different selected sites in the northern regions of Ernakulam District during the month of March 2012. The sampling sites and its details are shown in table 1

The water samples were collected in high grade plastic bottles of one liter capacity. Before collection, the plastic bottles were rinsed once with distilled water and then thrice with respective water sample.

Parameters analyzed: The samples collected were brought to the laboratory and the parameters like pH, electrical conductivity (EC), total hardness (TH), calcium, magnesium, total alkalinity (TA), chlorides, sulphates, nitrates, fluorides and total dissolved solids (TDS) were analyzed. The water samples were also analyzed for total coliforms (TC) and fecal coliforms (FC). Standard methods were adopted for the physicochemical analysis of water samples[11]. For microbiological examinations, samples were collected in 250 ml pasteurized sterile bottles (at 121 ^{o}C) and analysis was carried out within 6 hours of sample collection using standard methods outlined in IS 1622[12].

Comparison with BIS and WHO Standards: Physico-chemical parameters analyzed and measured on water samples were compared with BIS, IS: 10500 standards[13] and microbiological parameters with BIS[13] and WHO standards for drinking water[14].

Table 1
Details of Borewell water sample

Sl. No.	Sample Code	Sampling Site	Remarks about the sampling site
1	BW1	Eloor	Borewell located in an Industrial area adjacent to river Periyar
2	BW2	Kalamassery	Borewell closer to solid waste dumping area
3	BW3	Kakkanad	Borewell closer to a Play ground
4	BW4	Irumbanam	Borewell closer to Oil refineries
5	BW5	Tripunithura	Borewell located in an agricultural area
6	BW6	Edappally	Borewell located in a colony area with poor sanitization facilities
7	BW7	North Paravoor	Borewell closer to a domestic sewage waste discharge area

Table-2
Physico-Chemical parameters of water samples collected from Borewell in the Northern regions of Ernakulam district for comparison with BIS, IS: 10500, 1992 standards for drinking water consumption[13]

Sl. No.	Parameter (mg/L)	BIS-1992		Water Sample						
		DL	EL	BW1	BW2	BW3	BW4	BW5	BW6	BW7
1	pH	6.5	8.5	6.83	5.42	6.6	6.92	7.2	7.12	6.85
2	TH (in NTU)	300	600	778	174.3	126.7	935.2	4760	2850	378
3	Calcium	75	200	221.5	93.52	34.18	478.9	1390	364.5	156.8
4	Magnesium	30	100	28.9	18.42	16.24	35.2	363.5	67.5	12.8
5	TA	200	600	113.7	17.63	23.75	134.2	146.7	143.5	138.7
6	Chloride	250	1000	358	128.8	114.3	471.5	6755	1418	738.6
7	Sulphate	200	400	43	11.72	9.41	89.3	18.64	12.6	8.52
8	Nitrate	45	100	4.56	113.63	2.51	121.3	917	28.3	7.33
9	Fluoride	1	1.5	0.12	ND	0.18	0.08	0.12	0.06	0.38
10	EC (in µmhos/cm)	--	--	1760	234	164	2118	3980	2356	874
11	TDS	500	2000	1020	180	120	1640	12873	2830	1150
12	Sodium	-	-	92	74	46	81	218	126	113
13	Iron	0.3	1.0	0.26	1.6	0.18	3.3	0.48	0.12	0.14
14	Zinc	5	15	1.23	0.44	0.38	0.65	0.33	0.51	0.47

Desirable limit (DL); Excessive limit (EL); Not detected (ND)

Results and Discussion

The result obtained from the physicochemical analysis of water samples collected from seven different sites selected in the northern regions of Ernakulam District is given in table 2

pH: pH values of borewell water samples ranged from 5.42 to 7.2. The permissible pH range of water prescribed by BIS[13] is 6.5 to 8.5. With the exception of water samples BW5 and BW6, all the borewell water samples are acidic or slightly acidic in nature whereas the first two are slightly alkaline. The study indicates that the pH of water sample BW2 (5.42) is not safe as they are not within the permissible limit. pH below 6.5 starts corrosion in distribution pipes, thereby releasing toxic metals such as Zn, Pb, Cd, Cu etc. and can cause considerable damage to the water supply system resulting from complex interactions between pH and other physicochemical parameters[15].

Calcium (Ca) and Magnesium (Mg): The desirable and maximum permissible limit of Ca and Mg in drinking water is 75mg/l and 200mg/l and 30mg/l and 100mg/l respectively (BIS, 1992). The values of Ca and Mg in the water samples varied from 34.18mg/l to 1390mg/l and 16.24mg/l to 363.5mg/l respectively. The study shows water sample BW3 with respect to the parameter Ca and BW1, BW2, BW3 and BW7 with respect to Mg have values within the desirable limit. However, water samples BW1, BW4, BW5 and BW6 have Ca values and BW5 has Mg value exceeding the maximum permissible limit and found not safe whereas other samples were exceeding desirable limit but within the maximum permissible limit. The water sample collected from agricultural area at Tripunithura (BW5) has the maximum values recorded in both cases. The high concentration of Ca may be due to deposits of limestone, dolomite etc in the underground[16] or it may be due to agricultural practices and liming in that area. Water containing high calcium is not suitable for washing, bathing, and in the boilers. It causes the formation of concretion in the body and may cause intestinal diseases and stone formation[17]. Magnesium is a beneficial element but toxic at high concentration, cause hardness of water and exerts a cathartic and diuretic action[16].

Total Hardness (TH): The hardness of natural water generally increases as the concentration of calcium and magnesium salt in water increases. Total hardness of different water samples in the present study varied from 126.7 mg/l to 4760mg/l. Bore well water sample BW2 and BW3 exhibited a hardness value well within the limit while all other samples exceeded the maximum permissible limit[13]. The highest hardness level was observed in water sample collected from borewell located in agriculture area at Tripunithura (BW5) whereas the lowest level was observed in water sample collected from bore well near play ground at Kakkanad (BW3).

Total Alkalinity (TA): Alkalinity of water is its capacity to neutralize a strong acid and it is normally due to the presence of bicarbonate, carbonate and hydroxide compound of calcium, sodium and potassium. In the present study, alkalinity values were recorded in the range of 17.63mg/l to 146.7mg/l. The water sample BW5 exhibited maximum alkalinity whereas the minimum was exhibited by BW2 sample. As per the BIS[17], alkalinity values exhibited by all the water samples are well within the desirable limit.

Chloride (Cl): The highest chloride concentration was recorded in water sample BW5 (6755mg/l) and the lowest was in water sample BW3 (114.3mg/l). The study showed that the water sample BW2 and BW3 are well within the desirable limit; water samples BW1, BW4 and BW7 exceeded the desirable limit but recorded within the maximum permissible limit whereas BW5 and BW6 exceeded maximum permissible limit[17]. The excessive chloride in potable water is not particularly harmful and the criteria set for this ion is based primarily on the palatability and its potentially high corrosiveness[18]. The very high concentration of chloride in BW5 may be due to the increased weathering and leaching of sedimentary rocks and soils, improper soil treatment and fertilizer application, farm drainage, domestic waste discharge etc. There is report that at concentration above aesthetic objective, chloride content imparts undesirable tastes to water[19].

Sulphate (SO_4): Sulphate content of water samples varied from 8.52mg/l to 89.3mg/l. Sulphate concentration above the permissible limit can cause gastrointestinal disorders and diarrhea in human beings[20]. The present study clearly indicates that all the water samples have sulphate value within safe limit[13].

Nitrate (NO_3): Excessive concentration of nitrate in drinking water can lead to a disease called methemoglobinemia. The desirable and maximum permissible limit of nitrate concentration in drinking water is 45mg/l and 100mg/l respectively[13]. The highest concentration of nitrate was recorded in water sample BW5 (917mg/l) whereas the lowest value in BW3 (2.51mg/l). The higher nitrate contamination in BW5 sample may be attributed to the unscientific application of nitrogenous fertilizers and manures, which dissolved in rain water and leaches into the ground water[21]. The nitrate concentration value of water sample BW5, BW4 and BW2 exceeded the maximum permissible limit whereas all other water samples have values within the desirable limit.

Fluoride (F): The desirable limit of fluoride in drinking water is 1mg/l and the maximum permissible limit is 1.5mg/l. The concentration of fluoride in water samples analyzed varied from 0mg/l to 0.38mg/l and this clearly indicates that all the water samples have fluoride value well within the safe limit.

Total Dissolved Solids (TDS): According to BIS, water containing TDS value up to 500mg/l is considered desirable for drinking purposes and a maximum of 2000mg/l is permissible under unavoidable situations. In the present investigation it was in the range of 120mg/l to 12873mg/l. Water sample BW2

(180mg/l) and BW3 (120mg/l) exhibited a value well within the desirable limit. BW1 (1020mg/l), BW4 (1640mg/l) and BW7 (1150mg/l) exceeded the desirable limit but within the maximum permissible limit. The water sample BW5 (12873mg/l) recorded maximum TDS value which was followed by water sample BW6 (2830mg/l) and both exceeded maximum permissible limit. According to the ICMR[22] classification of water, BW2 and BW3 are desirable for drinking purposes; BW1, BW4 and BW7 are desirable for irrigation purposes; BW6 is permissible for irrigation whereas BW5 is not even useful for irrigation purposes.

Electrical Conductance (EC): Electrical conductance of water is the ability of water to conduct current. The highest EC value was recorded in water sample BW5 (3980 µmhos/cm) and the lowest EC value in BW3 (164 µmhos/cm) The higher EC value of BW5 and lower EC value of BW3 in the present study may be due to the higher and lower concentration of TDS and ionized substances present in the water samples respectively. It was Aydin[23], who reported direct relationship between EC and TDS in water and similarly there are reports that, a high positive correlation exists between EC and chloride concentration of water[24], higher level correlation significance of EC with many of the water quality parameters, like total alkalinity, sulphates, total hardness, TDS, chlorides, and magnesium[25]. The present study was also in agreement with these observations.

Sodium (Na): Excess sodium in water produces undesirable effects in soil properties and reducing soil permeability[26], because of the fact that sodium reacts with soil and as a result clogging of particles take place, thereby reducing the permeability[27, 28]. As per the WHO guidelines, the maximum allowable concentration of sodium in water is 200mg/l. The study showed that the concentration of sodium in the analyzed samples varied from 46mg/l to 218mg/l. With the exception of BW5 (218mg/l), all the water samples containing sodium concentration is within the permissible limit. The higher concentration of sodium in BW5 may be due to high rate of mineralization in the sediments which caused increased sodium into the nutrient pool there by making more sodium to solubilise in borewell water[29].

Iron (Fe): The concentration of Fe in different water sample varied from 0.14mg/l to 3.3mg/l. According to BIS[13], water containing Fe value up to 0.3mg/l is considered desirable for drinking purposes and a maximum permissible limit of 1mg/l. If the iron concentration in the domestic water supplies exceeds 0.3 mg/l, it becomes objectionable for a number of reasons that are indirectly related to health[30]. The highest Fe concentration was observed in BW4 sample and lowest in BW7. Water samples BW1, BW3, BW6 and BW7 exhibited safe concentration. Water sample BW5 has a Fe value within the maximum permissible limit but exceeded the desirable limit whereas both the water samples BW2 and BW4 exhibited a value above the maximum permissible limit and found not safe. The ingestion of large quantities of iron can result in haemochromatosis, a condition in which normal regulatory mechanisms do not operate effectively, leading to tissue damage due to the accumulation of iron[31].

Zinc (Zn): The highest concentration of Zn in the present study was recorded in the water sample BW1 and the lowest concentration in BW5, which were 1.23mg/l and 0.33mg/l respectively. The desirable and maximum permissible limit of Zn in drinking water as per BIS[13] is 5mg/l and 15mg/l respectively. The result indicates the concentration of Zn in all the samples are well within the desirable limit.

Total coliform and Fecal coliform: Another most common and widespread health risk associated with drinking water is the bacterial contamination caused either directly or indirectly by human or animal excreta. Assessment of indicator bacteria namely coliform bacteria is a convenient way to evaluate potability and sanitary conditions of water bodies. The bacterial species *E.coli* is a typical coliform bacteria traditionally used as hygiene indicator bacteria, and methods for their detection are essential for drinking water regulations all over the world. The result of the bacteriological analysis in the present study shown in table 3 indicates, the total coliform count per 100ml of different water samples ranged from 0 MPN/100ml to 962 MPN/100ml.

Table 3
Microbiology of Borewell water samples collected from various sites in the Northern regions of Ernakulam district for comparison with BIS, IS: 10500 (1992) and WHO (1996) standards for drinking water consumption[13, 14]

Sl. No.	Parameter (mg/L)	Limit as per BIS and WHO guidelines		Water Sample						
		DL	EL	BW1	BW2	BW3	BW4	BW5	BW6	BW7
1	Total coliform (MPN/100 ml)	0/100ml	0/100ml	ND	480	ND	88	ND	962	260
2	Feacal coliform-E.coli (MPN/100 ml)	0/100ml	0/100ml	ND	12	ND	ND	ND	46	ND

Desirable limit (DL); Excessive limit (EL); Not detected (ND)

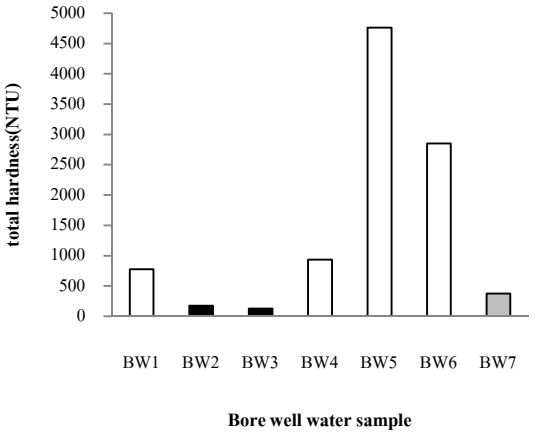

Figure-1 Comparative analysis of TH

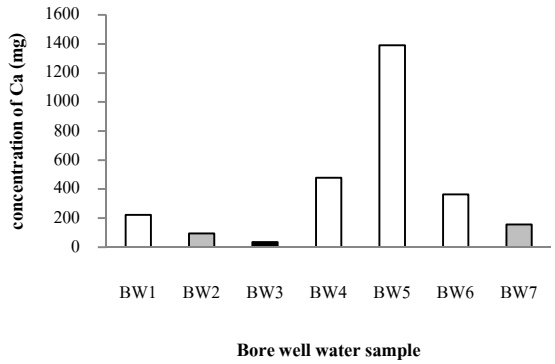

Figure -2 Comparative analysis of Calcium

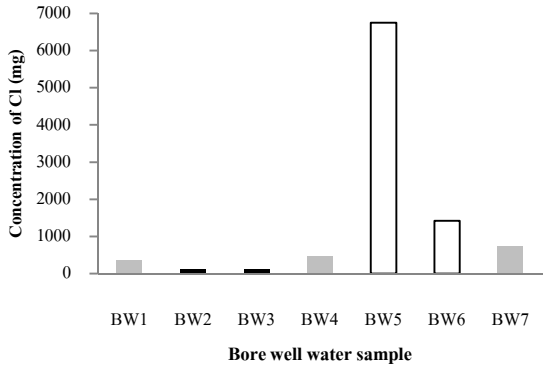

Figure -3 Comparative analysis of Chloride

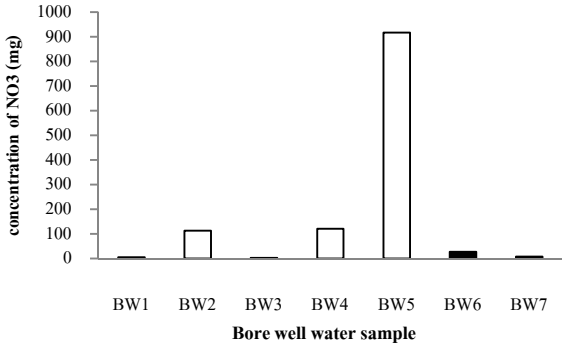

Figure -4 Comparative analysis of NO3

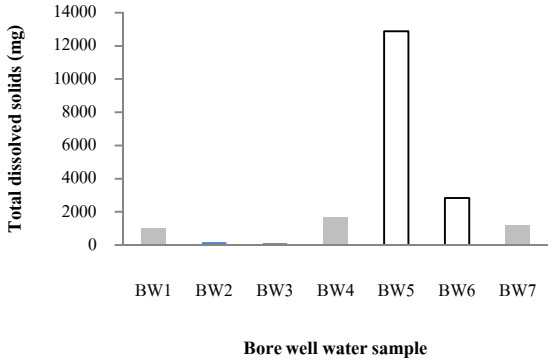

Figure -5 Comparative analysis of TDS

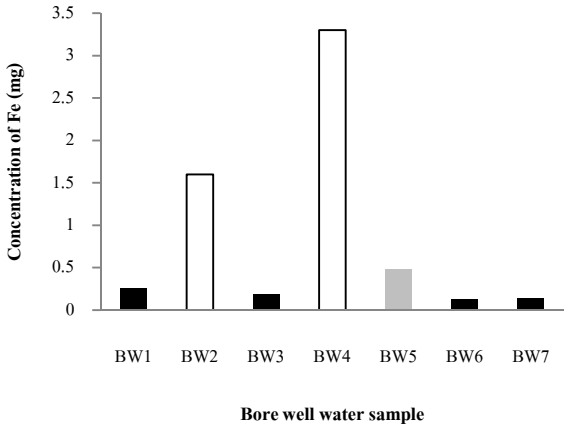

Figure -6 Comparative analysis of Fe

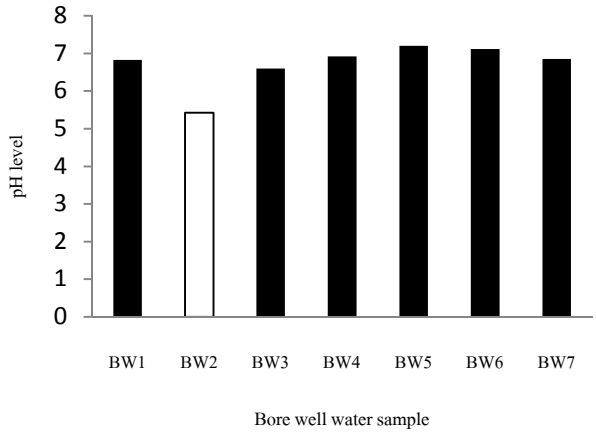

Figure -7 Comparative analysis of pH

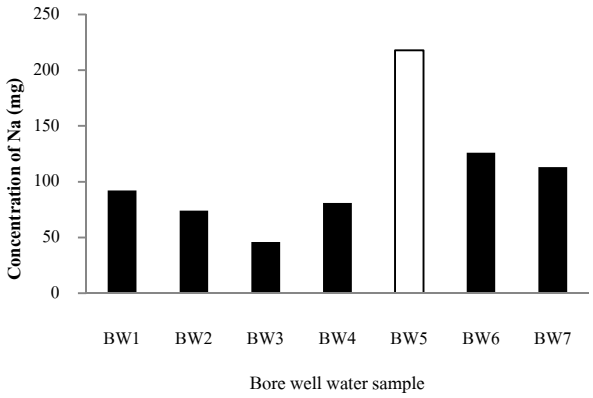

Figure -8 Comparative analysis of Na

Desirable level | Above desirable limit | Above maximum limit

Figure 1- 8
Comparative analysis of major physicochemical parameters of borewell water collected from different sites in the northern regions of Ernakulam District

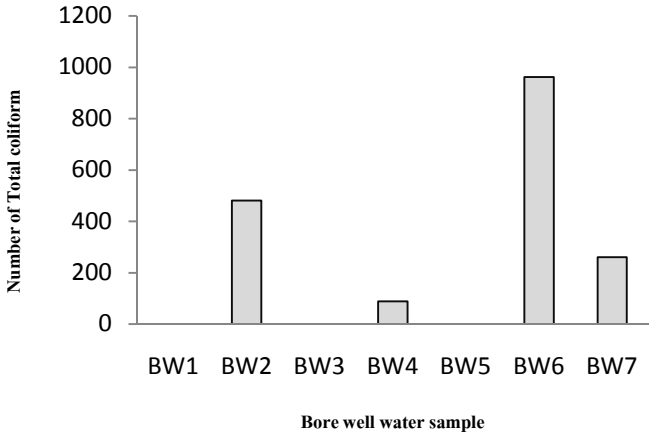

Figure-9 Comparison of Total Coliform in different water sample

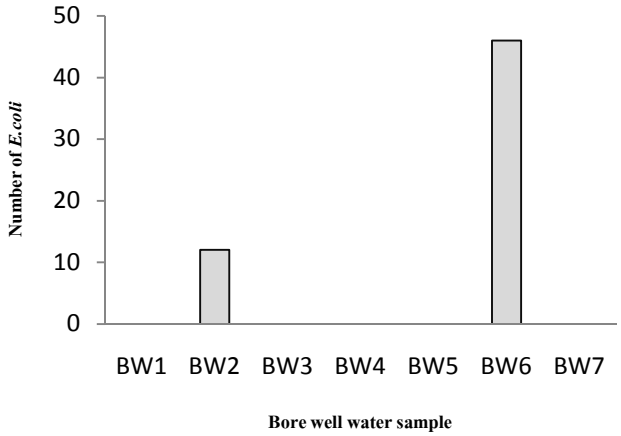

Figure-10 Comparison of E.coli in different water sample

Figure 9 - 10
Comparative analysis of Total coliform and Fecal coliform (*E.coli*) in different water samples collected from borewells in northern regions of Ernakulam District

The borewell water sample BW1, BW3 and BW5 showed no coliform bacterial count whereas in all other samples, presence of coliform bacteria was detected. Presence of coliform bacteria will not likely cause illness, however their presence in drinking water indicates that the disease causing organisms could be in the water system. Even though water sample BW4 and BW7 were identified as having the presence of coliform bacteria, no *E.coli* was detected. However, the water sample collected from borewell (BW2) located near the solid waste discharge at Kalamasery and sample collected from bore well (BW6) located in colony area with poor sanitization facilities at Edappally were identified as having presence of bacteria *E.coli*. Presence of *E.coli* in water sample BW2 and BW6 clearly indicates fecal contamination of either human or animal origin or both which may pose an immediate health risk to anyone consuming the water[32]. As per BIS[13] and WHO guidelines for drinking water, there should not be any coliform bacteria or fecal coliform bacteria detected per 100ml of the given water sample. Considering these guidelines, bore well water samples BW2, BW4, BW6 and BW7 are not fit for human consumption whereas water samples BW1, BW3 and BW5 are safe with respect to bacteriological aspects.

Conclusion

Ground water is generally said to be the safest water among the various sources of water for drinking and domestic purposes. However the present study clearly reveals that several factors like unscientific agricultural practices, domestic and industrial waste discharges, solid waste dumping, poor sanitization measures, geological formations etc. can affect the quality of borewell water. The excessive level of many physicochemical and bacteriological parameters with respect to majority of the borewell water samples studied in the present investigation render them unfit for human consumption and in certain cases (BW5) not even suitable for irrigation purposes, as they are capable of changing the permeability of the soil. With respect to the water sample BW3 which was collected from Kakkanad, all the physicochemical and bacteriological parameters considered for the present study were well within the desirable limit. All other water samples exhibited excessive values for few or more physicochemical parameters compared to BIS standards. The bacteriological standards for drinking water suggested by BIS and WHO were also not satisfactory for water samples BW2, BW4, BW6 and BW7. The presence of fecal contamination in water sample BW2 and BW6 indicates potentially dangerous situation which require immediate attention. Hence it is suggested that water from these sources should be pretreated before consumption.

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