Ground Water Quality Mapping and Surveillance for Safe Water Supply in Bahadrabad Block, District Hardwar, Uttarakhand

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Abstract*-The ground water quality of Bahadrabad Block in District Hardwar (Uttarakhand) has been examined to see the suitability of ground water for drinking water supply. Fifty two ground water samples from various abstraction sources were collected and analysed for various water quality constituents. The hydro-chemical and bacteriological data was analyzed with reference to BIS and WHO standards, ionic relationships were studied, hydrochemical facies were determined and water types identified. The concentration of total dissolved solids exceeds the acceptable limit of 500 mg/L in 42.3% of the samples analyzed but the values are well within the permissible limit of 2000 mg/L. The alkalinity values exceed the acceptable limit of 200 mg/L in 76.9% of the samples but these are also within the permissible limit of 600 mg/L. From the hardness point of view, more than 80% of the samples exceed the acceptable limit of 200 mg/L but these are also within permissible limits. Two samples of the study area exceed the acceptable limit of 45 mg/L for nitrate. Higher concentration of nitrate at these locations may be attributed due to improper sanitation and unhygienic conditions around the structures. Other constituents like chloride, sulphate and fluoride are within the acceptable limits. The bacteriological analysis of the ground water samples indicates bacterial contamination at few locations. Inadequate maintenance of hand pumps, improper sanitation and unhygienic conditions around the structure may be responsible for bacterial contamination in ground water of the region and is a cause of concern. It is recommended that the water drawn from such sources should be properly disinfected before being used for drinking and other domestic purposes. The results of the study will be of immense use to the planners, scientists and engineers concerned with the management and protection of ground water quality in Bahadrabad Block of District Hardwar (Uttarakhand).

I. INTRODUCTION

Ground water forms the major source of water supply for drinking purposes in most part of the country. It is particularly important as about 90% drinking water supply in rural areas is met from ground watetr, where population is widely dispersed and the infrastructure needed for treatment and transportation of surface water does not exist. Unfortunately, the availability of ground water is not unlimited nor it is protected from deterioration. In most of the instances, the extraction of excessive quantities of ground water has resulted in drying up of wells, damaged ecosystems, land subsidence, salt-water intrusion and depletion of the resource. Ground water quality is being increasingly threatened by agricultural, urban and industrial wastes. It has been estimated that once pollution enter the subsurface environment, it may remain concealed for many years, becoming dispersed over wide areas of ground water aquifer and rendering ground water supplies unsuitable for consumption and other uses. The rate of depletion of ground water levels and deterioration of ground water quality is of immediate concern in major cities and towns of the country.

The creation of new state of Uttarakhand has posed many challenges for the planners and policy makers. For sustainable development of a society it is essential that the natural resources are made use of, in judicious manner for the benefit of not only existing population but also to meet the needs and aspiration of future generations. Drinking water is one such precious commodity for which a planned strategy is needed not only for immediate demands but for sustainability for the future needs also. A large part of the state of Uttarakhand lies in the hills, where distribution of drinking water supply and its quality is a major problem needing immediate attention. About 90% of the rural population of this region depend upon the natural springs for their daily water demand. However, due to population pressure, unplanned construction, garbage disposal and change in land use patterns, the water of these springs is becoming contaminated besides declining the discharge of these springs.

In context of the above scenario, it is essential to monitor and evaluate drinking water quality and its suitability before it is used for drinking purpose. In this paper, ground water quality of Bahadrabad Block in District Hardwar has been studied with the objective to examine the suitability of ground water for drinking purpose.

II. STUDY AREA - BAHADRABAD BLOCK, DISTRICT HARDWAR

District Hardwar is a part of the Indo-Gangetic plains and lies between latitude 29°30' to 30°20' N and longitude 77°40' to 78°25' E in the State of Uttarakhand (Fig. 1). The District Hardwar occupies an area of about 2,360 km2. It is the largest district of Uttarakhand (population wise) and 10th (area wise). As per the 2011 census, the population of the District Hardwar is 18,90,422 with 10,05,295 males and 8,85,127 females. Location of different blocks in District Hardwar is shown in Fig. 2.

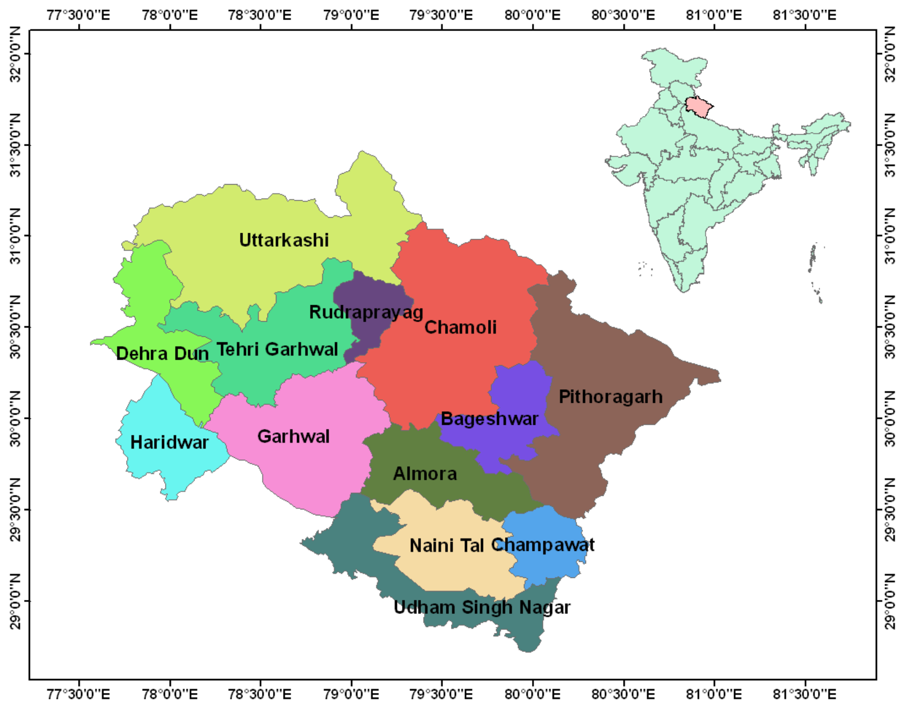

Fig. 1. Location of Different Districts in Uttrakhand State

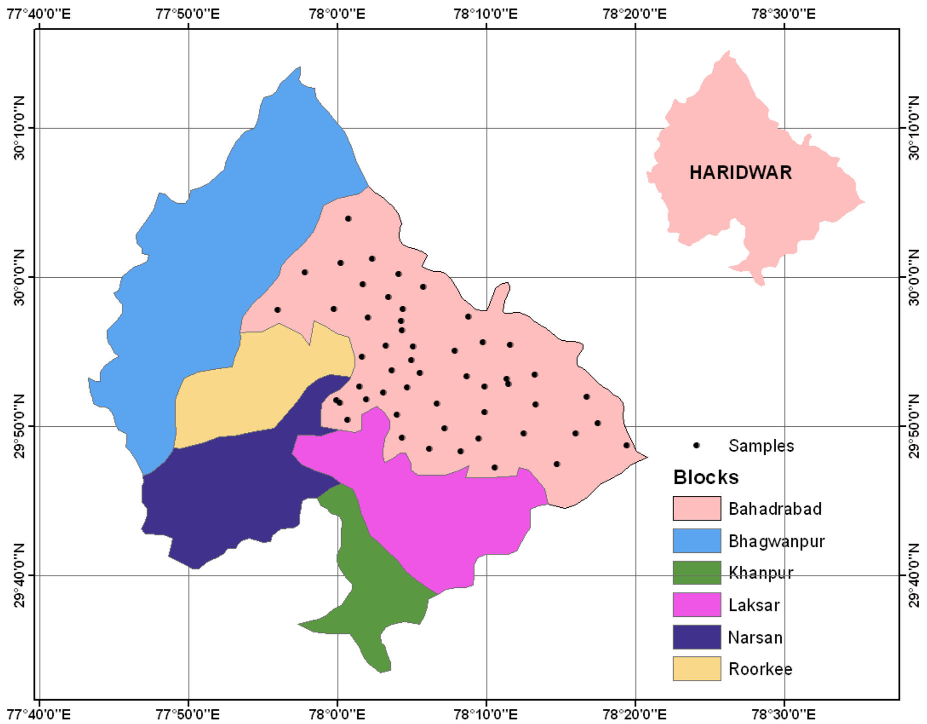

Fig. 2. Location of Different Blocks in Haridwar District

The climate of the area is as that of the greater part of subcontinent and is characterized by moderate type of subtropical monsoonic climate. The average annual rainfall in the region is about 1000 mm, major part of which is received during the monsoon period. The major land use is agriculture and there is no effective forest cover. The soils of the area are loam to silty loam and are free from carbonates.

The ground water conditions in the region are influenced by the varying lithology of the subsurface formation. It has been observed that the strata exhibit great variation both laterally and vertically due to the general fluviatile nature of the deposit of Indogangetic plains. The most common ground water structures in the area are shallow and deep tube wells. Dug wells are also used as source for drinking water, but to a lower extent. The ground water body is contained in fine to coarse-grained sands recharged by rainfall. Other sources of ground water replenishment are infiltration from rivers, canals and return flow from irrigation and inflow from the neighboring areas.

III. EXPERIMENTAL METHODOLOGY

Total 52 ground water samples from Bahadrabad Block in District Hardwar were collected during June 2013 from various abstraction sources at various depths covering extensively populated area, commercial, industrial, agricultural and residential colonies so as to obtain a good areal and vertical representation (Fig. 3.). All the collected samples were preserved by adding an appropriate reagent (Jain and Bhatia, 1988; APHA, 1992). The hand pumps and tube wells were continuously pumped prior to the sampling, to ensure that ground water to be sampled was representative of ground water aquifer. The water samples for bacteriological analysis were collected in sterilized high density polypropylene bottles covered with aluminium foils. All the samples were stored in sampling kits maintained at 4oC and brought to the laboratory for detailed chemical and bacteriological analysis. The source and depth wise distribution of samples are given in Table 1.

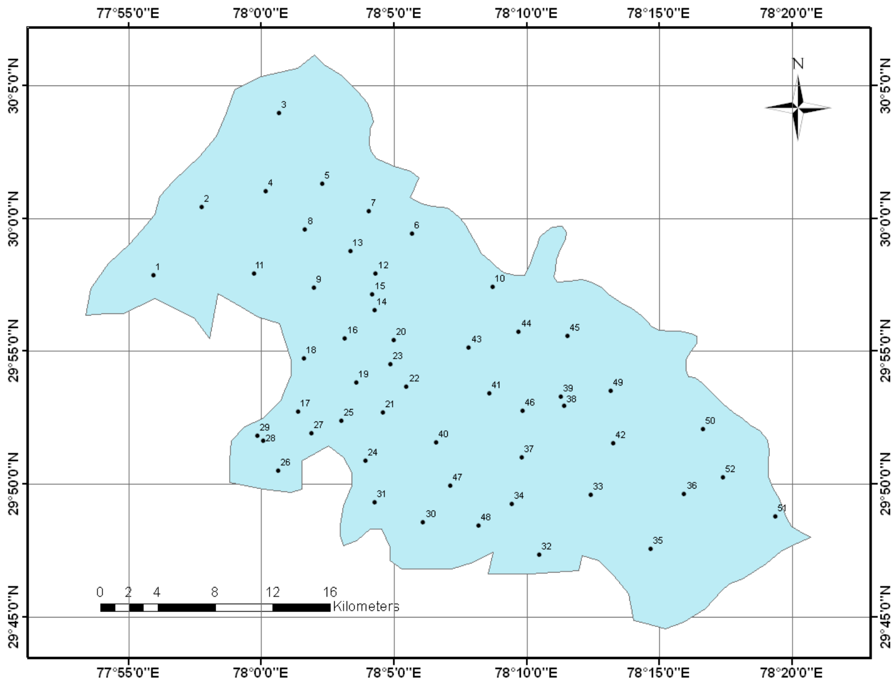

Fig. 3. Location of Sampling Points in Bhadrabad Block

Table 1. Source and Depth Wise Distribution of Sampling Sites in Bahadrabad Block

Source structure	Depth range			Total number
	< 0-20 m	20-40 m	> 40 m	
Hand Pumps	3,6,12,17,18,19,21, 22,23,24,25,28,30, 31,34,35,36,38,40, 45,48	2,5,7,11,13,15, 16,26,27,32,37,39, 41,42,43,44,46,47, 49	1,8,9,10,14,29, 50	47
Tube Wells	-	-	4,20,33,51,52	5
Total	21	19	12	52

The physico-chemical analysis was performed following standard methods (Jain and Bhatia, 1988; APHA, 1992). Ionic balance was determined, the error in the ionic balance was within 5%. Total coliforms and fecal coliforms were determined by membrane filtration technique using M-Endo and M-FC Agar respectively.

IV. Results and Discussion

The Bureau of Indian Standards (BIS) earlier known as Indian Standards Institution (ISI) has laid down the standard specifications for drinking water during 1983, which have been revised and updated from time to time. In order to enable the users, exercise their discretion towards water quality criteria, the maximum permissible limit has been prescribed especially where no alternate source is available. The national water quality standards describe acceptable and permissible limits for various water quality constituents required to be evaluated to assess suitability of water for drinking purpose (BIS, 2012).

The hydro-chemical data for the pre-monsoon samples collected from Bahadrabad Block in District Hardwar are presented in Table 2.

Table 2. Hydro-chemical Data of Ground Water Samples of Bahadrabad Block

Characteristics	Min	Max	Average
pH	6.39	8.35	7.26
Conductivity, µS/cm	279	1592	782
TDS, mg/L	179	1019	501
Alkalinity, mg/L	93	412	263
Hardness, mg/L	152	518	269
Chloride, mg/L	0.17	187	20
Sulphate, mg/L	1.5	123	33
Nitrate, mg/L	0.1	67	10
Fluoride, mg/L	ND	0.54	0.22
Sodium, mg/L	3.4	122	21
Potassium, mg/L	1.3	45	7.2
Calcium, mg/L	23	103	61
Magnesium, mg/L	9	64	28

N = 52

The pH values in the ground water of Bahadrabad Block are mostly confined within the range 6.39 to 8.35. The pH values of almost all the samples are well within the limits prescribed by BIS (2012) and WHO (1996) for various uses of water including drinking and other domestic supplies. The conductivity values in the ground water vary from 279 to 1592 µS/cm during pre-monsoon season with about 20% samples having conductivity value above 1000 µS/cm. The maximum conductivity value of 1592 µS/cm was observed at Village Shivdaspur (Hand Pump, 17 m depth).

In natural waters, dissolved solids consists mainly of inorganic salts such as carbonates, bicarbonates, chlorides, sulphates, phosphates and nitrates of calcium, magnesium, sodium, potassium, iron etc. and small amount of organic matter and dissolved gases. In the present study the values of total dissolved solids (TDS) in the ground water varies from 179 to 1019 mg/L indicating low mineralization in the area. More than 50% of the samples analysed were found within the acceptable limit of 500 mg/L and about 50% samples were found above the acceptable limit but are within the permissible limit of 2000 mg/L. The TDS content at deeper levels (>40 m depth) is comparatively low and lies well within desirable limit of 500 mg/L. The TDS distribution map is shown in Fig. 4. Water containing more than 500 mg/L of TDS is not considered desirable for drinking water supplies, though more highly mineralized water is also used where better water is not available. For this reason, 500 mg/L as the acceptable limit and 2000 mg/L as the permissible limit has been suggested for drinking water (BIS, 2012). Water containing TDS more than 500 mg/L causes gastrointestinal irritation (BIS, 2012). No sample of Bahadrabad Block crosses the permissible limit of 2000 mg/L.

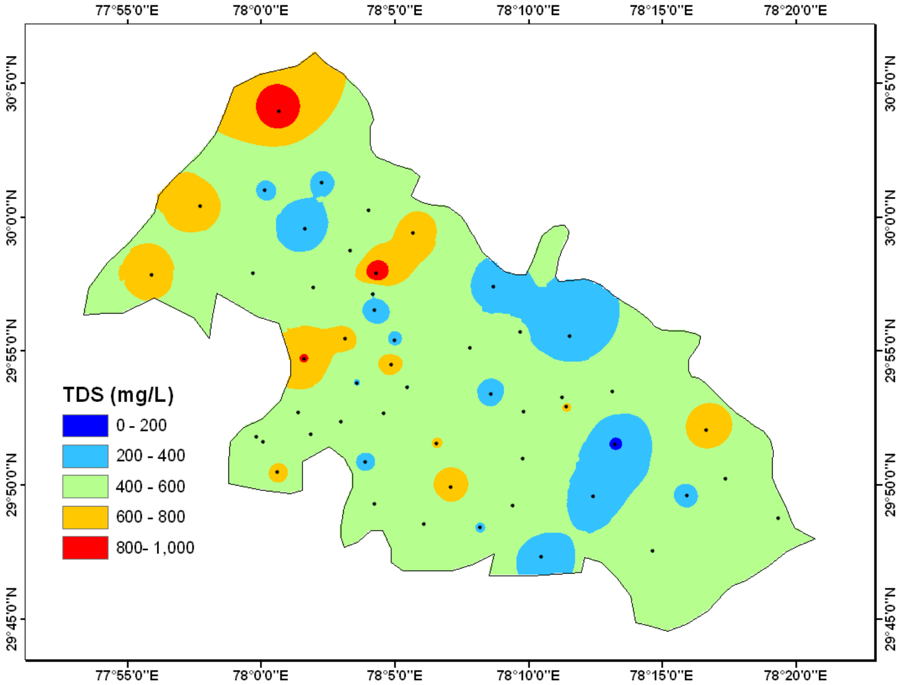

Fig. 4. TDS Distribution in Ground Water of Bahadrabad Block

The presence of carbonates, bicarbonates and hydroxides are the main cause of alkalinity in natural waters. Bicarbonates represent the major form since they are formed in considerable amount from the action of carbonates upon the basic materials in the soil. The alkalinity value in the ground water varies from 93 to 412 mg/L. About 23% of the samples of the study area fall within the acceptable limit of 200 mg/L and remaining about 77% of the samples crosses the acceptable limit but are within the permissible limit of 600 mg/L. No sample of the study area crosses the permissible limit of 600 mg/L. The high alkalinity may be due to the action of carbonates upon the basic materials in the soil.

Calcium and magnesium along with their carbonates, sulphates and chlorides make the water hard. A limit of 200 mg/L has been recommended as acceptable limit for potable water (BIS, 2012). The total hardness values in the study area range from 152 to 518 mg/L. About 15% of the samples of the study area fall within the acceptable limit of 200 mg/L and remaining about 85% of the samples exceed the acceptable limit but are well within the permissible limit of 600 mg/L.

The acceptable limit for calcium and magnesium for drinking water are 75 and 30 mg/L respectively (BIS, 2012). In ground water of the study area, the values of calcium and magnesium varies from 23 to 103 mg/L and 9.0 to 64 mg/L respectively. In ground water, the calcium content generally exceeds the magnesium content in accordance with their relative abundance in rocks. The increase of magnesium is quite proportionate with calcium.

The concentration of sodium in the study area varies from 3.4 to 122 mg/L. The violation of BIS limits could not be ascertained for sodium as no permissible limit of sodium has been prescribed in BIS drinking water specifications. Ground water with high sodium is not suitable for irrigation due to sodium sensitivity of crops/plants.

The concentration of potassium in ground water of Bahadrabad Block varies from 1.3 to 45 mg/L. Potassium is an essential element for humans, plants and animals and derived in food chain mainly from vegetation and soil. The main sources of potassium in ground water include rain water, weathering of potash silicate minerals, use of potash fertilizers and use of surface water for irrigation. It is more abundant in sedimentary rocks and commonly present in feldspar, mica and other clay minerals. The Bureau of Indian Standards has not included potassium in drinking water standards. However, the European Economic Community (EEC, 1980) has prescribed guideline level of potassium at 10 mg/L in drinking water. As per EEC criteria, about 10-15% of the samples of the study area exceed the guideline level of 10 mg/L. Though potassium is extensively found in some of igneous and sedimentary rocks, its concentration in natural waters is usually quite low. This is due to the fact that potassium minerals offer resistance to weathering and dissolution. Higher potassium content in ground water is indicative of ground water pollution.

The concentration of chloride in the study area varies from 0.17 to 187 mg/L. The limits of chloride have been laid down primarily from taste considerations. A limit of 250 mg/L chloride has been recommended as desirable limit for drinking water supplies (BIS, 2012; WHO, 1996). However, no adverse health effects on humans have been reported from intake of waters containing even higher content of chloride. No sample in the study area crosses the desirable limit of 250 mg/L.

The sulphate content in ground water generally occurs as soluble salts of calcium, magnesium and sodium. The sulphate content changes significantly with time during infiltration of rainfall and ground water recharge, which mostly takes place from stagnant water pools and surface runoff water collected in low lying areas. The concentration of sulphate in the study area varies from 1.5 to 123 mg/L, which are well within the acceptable limits prescribed for drinking water supplies.

The nitrate content in Bahadrabad Block varies from 0.1 to 67 mg/L. Excess nitrate content in drinking water is considered dangerous for its adverse health effects. The occurrence of high levels of nitrate in ground water is a prominent problem in many parts of the country. About 95% of the samples in Bahadrabad Block shows nitrate content within the acceptable limit of 45 mg/L. Only two sample of the study area exceeds the acceptable limit of 45 mg/L. The nitrate distribution map is shown in Fig. 5. The higher level of nitrate at the two locations may be attributed to the improper sanitation and unhygienic conditions around the structure.

Nitrate is effective plant nutrient and moderately toxic. A limit of 45 mg/L has been prescribed by WHO (1996) and BIS (2012) for drinking water supplies. Its concentration above 45 mg/L may prove detriment to human health. In higher concentrations, nitrate may produce a disease known as methaemoglobinaemia (blue babies) which generally affects bottle-fed infants. Repeated heavy doses of nitrates on ingestion may also cause carcinogenic diseases.

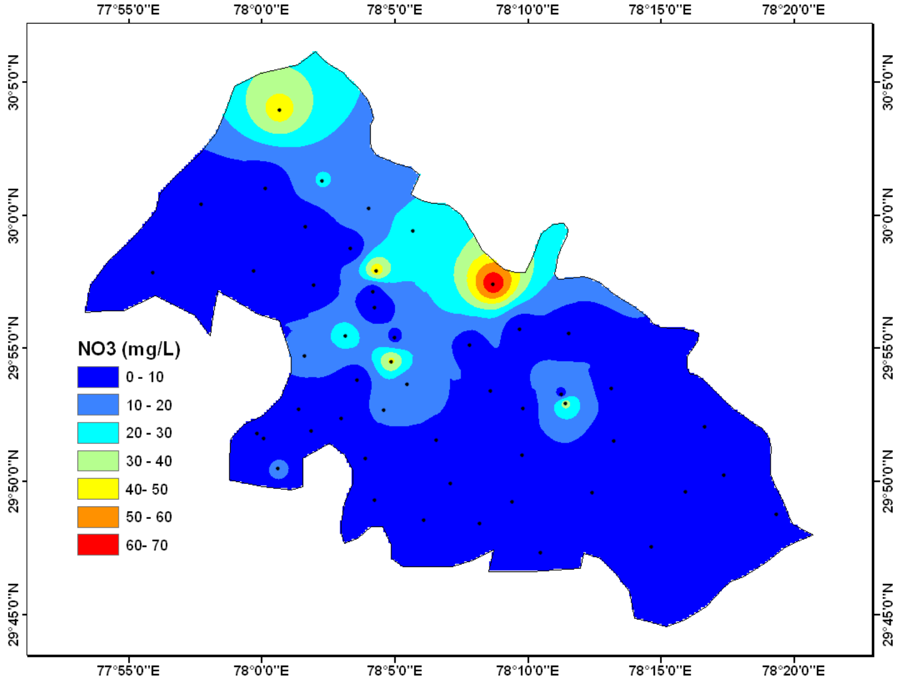

Fig. 5. Nitrate Distribution in Ground Water of Bahadrabad Block

The fluoride content in the ground water of Bahadrabad Block varies from ND to 0.54 mg/L and lies well within the acceptable limit of 1.0 mg/L in all the samples. The presence of fluoride in ground water may be attributed to the localized effects of natural sources. The fluoride is present in soil strata due to the presence of geological formations like fluorspar, fluorapatite, ampheboles such as hornblinde, trimolite and mica. Weathering of alkali, silicate, igneous and sedimentary rocks specially shales contribute a major portion of fluorides to ground waters. In addition to natural sources, considerable amount of fluorides may be contributed due to man's activities. Fluoride salts are commonly used in steel, aluminium, bricks and tile-industries. The fluoride containing insecticides and herbicides may be contributed through agricultural runoff. Phosphatic fertilizers, which are extensively used, often contain fluorides as impurity and these may increase levels of fluoride in soil. The accumulation of fluoride in soil eventually results in its leaching due to percolating water, thus increase fluoride concentration in ground water.

The study has clearly indicated that the concentration of total dissolved solids exceeds the acceptable limit of 500 mg/L in about 40% of the samples analyzed but the values are well within the permissible limit of 2000 mg/L in all the samples. The alkalinity values exceeds the acceptable limit of 200 mg/L in about 75% of the samples but the values are well within the permissible limit of 600 mg/L. The total hardness values exceed the acceptable limit of 200 mg/L in about 80% of the samples. The nitrate content exceeds the acceptable limit of 45 mg/L in two samples. The fluoride content is well within the acceptable limit in all the samples analyzed. The violation of BIS limit could not be ascertained for sodium and potassium as no permissible limit of sodium and potassium has been prescribed in BIS drinking water specifications.

The coliform group of bacteria is the principal indicator of suitability of water for domestic, industrial or other uses. The density of coliform group is the criteria for the degree of contamination and has been the basis for bacteriological water quality standard. In ideal situation all the samples taken from the distribution system should be free from coliform organisms and the following standards have been recommended for bacteriological quality of drinking water (BIS, 2012):

S.No.	Organisms	Requirement
i)	All water intended for drinking: a) E.coli or thermotolerant coliform bacteria	Shall not be detectable in any 100 ml sample
ii)	Treated water entering the distribution system: a) E.coli or thermotolerant coliform bacteria b) Total coliform bacteria	Shall not be detectable in any 100 ml sample Shall not be detectable in any 100 ml sample
iii)	Treated water in the distribution system: a) E.coli or thermotolerant coliform bacteria b) Total coliform bacteria	Shall not be detectable in any 100 ml sample Shall not be detectable in any 100 ml sample

The presence of faecal colifirms in ground water indicates a potential public health problem, because faecal matter is a source of pathogenic bacteria and viruses. The ground water contamination from faecal coliform bacteria is generally caused by percolation from contamination sources (domestic sewage and septic tank) into the aquifers and also because of poor sanitation. Shallow wells are particularly susceptible for such contamination. The indiscriminate land disposal of domestic waste on surface, improper disposal of solid waste, leaching of waste water from landfill areas, further aggravate the chances of bacterial contamination in ground water. The results of bacteriological analysis of ground water samples of Bahadrabad Block are given in Table 3.

Table 3. Bacteriological Contamination in Ground Water of Bahadrabad Block

Range Total Coliform per 100 ml	No. of samples	%
Nil	37	71.2
< 10	3	5.8
10-20	8	15.4
21-30	2	3.8
31-40	1	1.9
41-50	-	-
51-100	-	-
> 100	1	1.9

The bacteriological analysis of the ground water samples collected from Bahadrabad Block indicates bacterial contamination at few locations. Inadequate maintenance of hand pumps, improper sanitation and unhygienic conditions around the structure may be responsible for bacterial contamination in the ground water of the region and is a cause of concern. The water from such sources should be properly disinfected before being used for drinking and other domestic purposes.

V. Conclusions and Recommendations

The ground water quality varies from place to place and with the depth of water table. The ground water abstraction sources and their surroundings should be properly maintained to ensure hygienic conditions and no sewage or polluted water should be allowed to percolate directly to ground water aquifer. Proper cement platforms should be constructed surrounding the ground water abstraction sources to avoid direct well head pollution and surrounding surface area should be frequently chlorinated by use of bleaching power. The hand pumps and wells, which have been identified as having suspected water quality should be painted red to indicate and warn the public that the water drawn from the source is not fit for human consumption. In the absence of alternate safe source of water, the water with excessive undesirable constituents must be treated with specific treatment process before its use for human consumption. The untreated sewage and sewerage flowing in various open drains are one of the causes of ground water quality deterioration. Proper under ground sewage system must be laid in inhabited areas and the untreated sewage should not be allowed to flow in open drains to avoid any further contamination of ground water.

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