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Assessment of Physicochemical and Biological Properties of Groundwater in Urban Setting of Belagavi: A Cross-Sectional Study

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Abstract: Contamination of groundwater is one of the major environmental issues faced at present due to indiscriminate disposal of sewage, industrial, and chemical waste without proper treatment. This contamination may affect physical, chemical, and biological variables of groundwater. Hence, the aim was to assess the physicochemical and biological properties of groundwater in an urban setting of Belagavi. A total of 30 water samples were collected from open wells in different places by purposive sampling technique. Physicochemical properties, including pH, total alkalinity, turbidity, total dissolved solids (TDS), electrical conductivity (EC), total hardness, chloride ion, and carbon dioxide were assessed using standard methods. Microbiological analysis was done using standard microbroth dilution technique. The obtained values were compared with standard values set by the World Health Organization (WHO) standards and the Bureau of Indian Standards (BIS) for drinking water. Physicochemical properties of the study samples: pH, TDS, total alkalinity, chloride content, turbidity, and calcium and magnesium hardness were within the standard limits set by WHO and BIS; while, EC and bicarbonate hardness were not within the permissible limits. Microbial analysis showed the presence of *Escherichia coli* in 29 samples and the most probable number (MPN) of the samples was > 180 cfu/100 mL. Although most of the physicochemical properties of the groundwater were within the WHO and BIS standards, the microbiological analysis-MPN assay showed the presence of bacterial contaminants in most of the groundwater samples. Even though groundwater from most of the wells studied were contaminated, they can be revived as good sources of water provided the water is processed before consumption.

Keywords: Bellary nala, Belagavi, biological properties, groundwater, physicochemical properties, potability.

INTRODUCTION

Groundwater is the major source of water supply for agriculture, industrial, and domestic activities. Nearly 90% and 50% of water use in rural and urban areas, respectively, is based on groundwater [1]. However, currently, serious groundwater crisis is prevailing in India due to excessive over-extraction and contamination [2].

Groundwater sources are getting contaminated due to human interference, such as waste dumping and effluent and sewage discharge without proper treatment. Municipal and industrial wastes, application of fertilizers, herbicides, pesticides, burning of coal, leaching from coal–ash tailings, and mining activity further add to contamination of groundwater. Also, few parts of various states of India are contaminated by inland and coastal salinity, arsenic, fluoride, iron, and nitrate [3, 4]. These different sources of contamination may influence physical, chemical, and biological variables of groundwater [3, 4]. Physicochemical contaminants include heavy metals, trace metals, total suspended solids, and turbidity [5]. Microbiological contaminants include *Pseudomonas aeruginosa*, *Salmonella species*, *Escherichia coli*, and *Helminths,* which cause many diseases, such as typhoid, diarrhoea, and dysentery [6].

In Karnataka, the arsenic level of groundwater is beyond the permissible limit of 10 parts per billion (ppb). Other factors that affect the groundwater quality in Karnataka include sewer leakage, faulty septic-tank operation, landfill leachates, and fluoride contamination through solvent action of water on the rocks as well as soil of the earth's crust (>–1.5 mg/L) [1, 7, 8]. As a result, physicochemical and biological characteristics of water are altered [7, 9, 10]. In our study we focused on groundwater in Belagavi city of Karnataka, wherein the entire sewage is directed to Bellary nala, which is linked through gutters and sewer lines. The Bellary nala, once a perennial stream carrying fresh water, has now turned into a sewer drain all along its course.

People in this community, due to lack of proper knowledge, are consuming this poor-quality water without being aware of the adverse health issues [11]. Therefore, it is essential to understand the impact of wastewater on groundwater quality of the riparian areas [4, 11]. Since very few studies have been done in this region regarding water quality, the present study was conducted to assess the physicochemical and biological properties of the groundwater in the urban setting of Belagavi.

MATERIALS AND METHODS

Study area and sample collection

This one and half year (August 2016–February 2018) cross-sectional study was carried out in the urban setting of Belagavi, Karnataka. A total of 30 water samples were collected between February and October 2017 from open wells in different places (Shahunagar, Shrinagar, Anjnay nagar, Virabhadra nagar, Shivaji nagar, Azhad nagar, Nehru nagar, Subhash nagar, Police quarters, Gokul nagar, Godshet road, Bangla camp area, Gandhi nagar, Vishweshwarayya nagar) of Belagavi by purposive sampling technique. Borewells, closed wells, and industrial contaminated wells were excluded from this study. All the samples were collected 30 cm underneath the water surface. Samples were collected in high-grade plastic bottles of 1.5–2 L capacities, which were cleaned twice with purified water. The sterilized bottles were used for microbiological testing and the collected sample was used within 2–3 h. The collected samples were sent to the laboratory for physical, chemical, and microbial analysis. All the parameters were calculated with 95% confidence interval (CI) and 10% precision.

Physicochemical analysis

The pH, electrical conductivity (EC), and total dissolved solids (TDS) in the water sample were determined using pH meter (HACH 31Qd, USA) conductivity meter, and TDS meter (HACH 2100Q, USA). TDS comprises of inorganic salts such as calcium (Ca), magnesium (Mg), potassium, sodium, bicarbonates, chlorides, and sulfates. The turbidity measurements were done using a Nephelometer. The presence of carbon dioxide was determined by titrating the water sample against 0.05 N standard sodium hydroxide solution using phenolphthalein as an indicator. The alkalinity of the water sample was determined by titrating the water sample against 0.02 N standard sulfuric acid using phenolphthalein and methyl orange as indicators. Chloride ion concentration was determined by titrating the water sample against 0.014 N standard silver nitrate solution using potassium chromate as an indicator. Total hardness was measured by ethylene diamine tetraacetic acid titrimetric method using enrich Rome Black T as an indicator. Ca and Mg hardness was measured by ethylene diamine tetraacetic acid titrimetric method using ammonium purpurate as an indicator [12].

Microbiological analysis

The multiple-tube procedure using double strength MacConkey broth was used to determine the most probable number (MPN) of coliform organisms. All the tubes were incubated at 37ºC for 24–48 h. The MPN was obtained according to the standard methods for the examination of water and wastewater [12]. The confirmation of coliform test was performed by culturing MacConkey positive tubes into MacConkey agar media. Furthermore, the additional biochemical tests were conducted from MacConkey agar colonies: Gram staining was used to identify the morphology and probable isolates; other tests such as oxidase test, motility test, catalase test, and IMViC (I: indole test; M: methyl red test; V: Voges–Proskauer test; C: citrate test) tests were also performed.

Statistical analysis

SPSS v21 was used to analyze the data. The results obtained were compared with World Health Organization (WHO) standards and Bureau of Indian standards (BIS) [13, 14].

RESULTS

Table-1 represents water quality analysis report of Belagavi. A total 30 water samples were assessed for physicochemical properties. The physical parameter, pH, ranged between 6 and 8 with a mean of 7.00 ± 0.525. Chemical properties: EC ranged between 126 and 1400 µS/cm with a mean of 575.53 ± 302.81 µS/cm. TDS ranged between 74 mg/L and 799 mg/L with a mean of 317.27 ± 175.664 mg/L. Collected samples showed the absence of carbon dioxide. Bicarbonates ranged between 28 mg/L and 440 mg/L, with a mean of 158.27 ± 116.375 mg/L. Total alkalinity ranged between 28 mg/L and 440 mg/L, with a mean of 158.27 ± 116.375 mg/L. Turbidity ranged between 5 NTU and 10 NTU, with a mean of 7.108 ± 1.50 NTU. Chloride ions ranged between 24 mg/L and 258 mg/L, with a mean of 86.63 ± 64.084 mg/L. Ca hardness ranged between 38 mg/L and 320 mg/L, with a mean of 121.80 ± 86.725 mg/L, Mg hardness ranged between 10 mg/L and 160 mg/L, with a mean of 55.33 ± 35.663 mg/L. Total hardness ranged between 60 mg/L and 440 mg/L, with a mean of 223.33 ± 99.098 mg/L.

Of all properties assessed, pH, TDS, total alkalinity, chloride content, turbidity, and Ca and Mg hardness were within the standard limits set by the WHO and BIS. Microbial analysis showed the presence of *E. coli* in 29 samples. All the 29 samples exceeded the recommended standards set by the WHO and BIS i.e. 0.0 cfu/100 mL. The coliforms present in all the 29 samples were > 180 cfu/100 mL.

Table-1: Water quality analysis report of Belagavi

Site #	pH	EC µS/cm	TDS (mg/L)	CO_2 (mg/L)	HCO_3^- (mg/L)	Total alkalinity (mg/L)	Chloride (mg/L)	Turbidity, (NTU)	Ca hardness (mg/L)	Mg hardness (mg/L)	Total hardness (mg/L)
S # 1	6.56	494.8	253.2	0	52	52	86.09	5.06	48	31.23	176
S # 2	6.78	495.1	259.4	0	50	50	84.09	7.10	46.4	29.67	168
S # 3	6.38	401.2	208.1	0	54	54	92.1	5.04	52.8	33.96	192
S # 4	6.42	511.8	266.9	0	52	52	66.07	8.14	44.8	24.2	144
S # 5	6.49	413.1	216.1	0	48	48	66.07	6.03	46.4	23.81	144
S # 6	7.4	626.4	326.6	0	146	146	46.05	8.02	96	51.72	308
S # 7	7.26	626.2	328.6	0	92	92	52.06	9.02	80	52.7	296
S # 8	7.05	427	223	0	94	94	24.03	10.01	75.2	40.2	240
S # 9	6.91	506.5	261.1	0	90	90	62.07	6.02	80	50.758	288
S # 10	7.01	301.8	156.1	0	60	60	54.06	7.18	48	29.28	168
S # 11	7.9	346.7	179.1	0	28	28	74.08	7.04	60.8	32.98	196
S # 12	6.99	508.1	261.1	0	58	58	48.05	6.14	41.6	22.05	132
S # 13	7.3	681.3	355.9	0	106	106	102.11	8.79	46.4	24.83	148
S # 14	7.4	312	177	0	160	160	34.75	9.13	160	80	240
S # 15	7.42	581	329	0	280	280	89.35	7.12	170	70	240
S # 16	7.91	588	334	0	240	240	89.35	9.01	190	10	200
S # 17	7.82	647	367	0	250	250	109.21	8.42	194	46	240
S # 18	6.99	432	244	0	164	164	49.64	9.04	130	30	160
S # 19	6.95	463	263	0	124	124	94.32	5.16	70	70	140
S # 20	6.8	323	184	0	130	130	36.73	7.12	76	54	130
S # 21	6.53	496	282	0	170	170	54.6	5.16	70	70	140
S # 22	7.02	492	279	0	120	120	56.59	7.02	160	40	200
S # 23	5.93	432	247	0	80	80	71.48	6.59	120	40	160
S # 24	7.75	1150	656	0	400	400	198.57	9.45	280	160	440
S # 25	7.48	1230	704	0	360	360	258.148	6.03	320	120	440
S # 26	7.21	1310	745	0	440	440	238.29	5.19	310	110	420
S # 27	6.94	1400	799	0	360	360	248.22	6.89	300	120	420
S # 28	6.89	126	74	0	60	60	29.78	5.12	38	22	60
S # 29	7.11	429	245	0	220	220	24.82	7.35	140	80	220
S # 30	6.86	515	294	0	260	260	59.27	5.86	160	90	250

S, Sample; *EC*, Electrical conductivity; *TDS*, Total dissolved solids; *Ca*, Calcium; *Mg*, Magnesium; HCO_3^-, Bicarbonates; CO_2, Carbon dioxide

DISCUSSION

Since ages, groundwater has been considered as a safe source of drinking water. However, nowadays, the quality of drinking water is deteriorating [15]. Therefore, the present study focuses on physicochemical and biological properties of the groundwater samples collected from the study area and was compared with WHO and BIS standards [13, 14].

The pH is a measure of acidity or alkalinity of the water substances [16]. pH of all the water samples in our study were within the limits indicating that water was between slightly acidic and slightly alkaline. The variation in pH of the water samples might be due to the site of sample collection. The pH values recorded for water samples in our study is within the permissible limits of WHO and BIS (6.5–8.5) [13, 14]. Whereas, few other studies in different regions reported that groundwater is slightly acidic to neutral [17, 18].

EC is directly related to the concentration of ionized substances in water and problems of excessive hardness [19]. According to WHO and BIS, the desirable limit of conductivity is 600 µS/cm. In contrast, the conductivity in our study ranged between 126 – 1400 µS/cm at 25ºC [13, 14]. Similarly, a study conducted by Naik *et al*., recorded EC values ranged between 242 µS/cm and 2373 µS/cm at 25ºC [11]. This high concentration of EC values may be due to anthropogenic and lithologic composition and high concentrations of ionic constituents in the water bodies [11].

TDS are the organic and inorganic salts present in water, which indicate the salinity behaviour of the groundwater [1]. TDS value (74–799 mg/L) observed in our study was within the WHO and BIS standard limits (100–2000 mg/L) [13, 14]. Similar study by Quid et al. reported TDS levels between 549 mg/L and 12860 mg/L [16]. TDS levels > 600 mg/L is not desirable for consumption. However, short-term or intermittent use is allowable up to 1500 mg/L. Increased concentration of TDS makes the water less palatable and causes gastric irritation, especially in people suffering from kidney diseases, heart diseases, and constipation [11].

Bicarbonates, carbonates, and hydroxides contribute to the alkalinity of water [17]. These constituents may result from the dissolution of mineral substances in the soil and atmosphere [15]. In our study, the alkalinity of the water samples was within the WHO and BIS (200–600 mg/L) standards [13, 14]. Similarly, a recent study by Singh et al. found the alkalinity range of 245–627 mg/L [9]. However, alkalinity alone may not be harmful for human consumption. Moreover, in certain cases, alkalinity < 100 mg/L and ~ 600 mg/L is acceptable [14].

The combination of chlorine gas with metal results in chlorides. Small amounts of chlorides are required for normal cell functions in the plant and animal life [20]. Although high concentrations of chlorides may not deteriorate the health, interaction with sodium makes the water saltier [17, 20]. However, in our study, the chloride ions in most of the water samples (24–258 mg/L) were less than the WHO and BIS (250–1000 mg/L) permissible limits and was considered satisfactory [13, 14]. A similar study conducted by Purandara *et al*., [4] reported that the chloride ions ranged between 97 and 108 mg/L [4].

Turbidity is another key parameter to determine the quality of groundwater [5]. The turbidity imparted in the groundwater might be due to the suspended particles and undesirable substances [11]. However, the turbidity in our study was within the nephelometric turbidity units (NTU), set by the WHO standards and BIS (5–10) for groundwater [13, 14]. This indicates that the water samples in our study were free of suspended and colloidal matter. Studies reported that, though the turbid water is not aesthetic, there is no harm in human consumption [11].

The hardness in the groundwater is caused due to the presence of an excess of Ca, Mg, and bicarbonates or combination of these [21]. Ca and Mg in all the samples in our study area were within the permissible limits of the WHO (Ca: 10–500 mg/L; Mg: 50–100 mg/L) and BIS (Ca: 75–200 mg/L; Mg: 30–100 mg/L) for drinking water, except bicarbonates [13, 14]. Ca ions occur in groundwater through the decomposition of sulphate, phosphate, and silicate materials and due to the dissolution of carbonate minerals [22]. Whereas, the presence of Mg may be due to geological sources, such as dolomite, biotite, and pyroxenes in the basement rocks [23]. In our study, bicarbonate ions in groundwater were not within the WHO and BIS standards; this may be due to the coal combustion residue from thermal power plants [13, 14, 24]. However, the total hardness found in our study was within permissible limits of the WHO (300–600 mg/L) and BIS (200–600 mg/L) [13, 14].

The presence of coliform is one of the most important microbiological parameters to determine the quality of drinking water [17]. Of the 30 water samples collected, 29 samples showed the presence of *E. coli*. And the coliforms present in the samples were > 180 cfu/100 mL. It shows that the raw water seems to be moderately polluted due to various anthropogenic activities. Hence, pretreatment is essential for drinking purposes [25]. Even though it is pretreated with chlorine, coliforms in the infected wells render the water distasteful and may cause waterborne diseases, such as hepatitis, typhoid, diarrhoea, and dysentery [26].

CONCLUSION

Although most of the physicochemical properties of the groundwater were within the WHO and BIS standards, the microbiological analysis—MPN assay showed the presence of bacterial contaminants in most of the groundwater samples. Even though groundwater from most of the wells studied were contaminated, they can be revived as good sources of water provided the water is processed before consumption. As water is a safe commodity and, moreover, wells are getting polluted nowadays, it is crucial to prevent pollution of groundwater and essential to assess potability of groundwater periodically.

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