Physicochemical Profile of Ground Water in Bahawalpur City, Pakistan: Hazardous Aspects

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Summary: Analysis of ground water of Bahawalpur city, Pakistan, has been made to evaluate its suitability for domestic use. Water samples from populated areas of the city were subjected to various physicochemical investigations. Physical properties of ground water were assessed by determining color, odor, electrical conductivity (EC), total dissolved salts (TDS), alkalinity, hardness and dissolved oxygen (DO). Whereas, its chemical nature was evaluated by estimating pH, Cl^-, F^-, NO_3^-, SO_4^{-2}, Cl^-, F^-, essential (Na, K, Ca, Mg) and heavy (Fe, Ni, Cr, As, Pb) metals. The presence of *coliform* bacteria was also checked and 75% samples were found contaminated. The analysis of physicochemical data, with reference to PSI and WHO standards, revealed that some of the estimated parameters were well within the limit, while others exceeded hydrochemical standards. The data was also subjected to correlation study to check the association among estimated parameters. Relation of important water quality parameters with pH was sketched graphically to understand variation in their amount with the change in pH. The study suggests proper treatment of ground water to ensure citizen's safety from hazardous effects associated with elevated concentration of toxic components.

Introduction

Water is vital among the minerals required for human nutrition. Only 3% of total water is available for human use; out of which 90% exists in the form of glaciers, icecaps and snow fields, while remaining 10% is available as surface and ground water [1]. One third of world's population uses ground water for drinking purposes [2], which is continuously getting contaminated by several means like application of fertilizers, dumping of sewage or industrial wastes [3]. These materials continuously add different type of pollutants such as surfactants, pharmaceuticals and heavy metals in subsurface environment, which get dispersed in ground water aquifer and may remain its part for next many years [4]. As a result, water is reported to be contributing nearly 80% of total diseases including diarrhea, hepatitis, dental caries, oral hygiene and anemia in children [5].

In context of the above mentioned facts, physicochemical and microbiological features of drinking water are required to be regularly studied to ensure its good quality. Recently, issues regarding quality of drinking water from southern Sindh [5], Lahore, Kasur [6], Muzaffargarh [3], Rohri [7] and Jamshoro [8] have been highlighted.

In continuation of these series of investigations, a work was planned to examine the quality of drinking water in Bahawalpur City. Bahawalpur is a thickly populated historical city adjacent to Cholistan desert [9] and is a famous place for tourists, especially coming for hunting. So, presence of large number of inhabitants, tourists and having different environment than other cities of Pakistan motivated the authors to compile a report on comprehensive analysis of water of this city. Up to best of our knowledge, no report describing characteristics of groundwater of Bahawalpur city is presented so far. The hydrochemical data presented in this article is discussed with reference to WHO [10] and Pakistan standard institution (PSI) drinking water quality standards [11] to ensure the suitability of ground water for domestic use (Fig. 1).

Results and Discussion

Water Quality Parameters

The results of water quality evaluation parameters including pH, EC, TDS, Alkalinity, Hardness, Nutrients (NO_3^-, SO_4^{2-}, Cl^-, F^-) and bacterial assessment are summarized in Table-1, while Table-3 contains descriptive statistics of data.

The pH of all the samples was found within the range recommended by WHO (6.5-8.5) and PSI drinking water quality standards (6.5-9.2). The pH value of 85% samples was just below or above 8.0 indicating alkaline nature of ground water. Such type of water may exhibit bitter taste and corrosive property [12]. Electrical conductivity values for all the samples, including mean value were found greater than permissible limit of WHO for drinking water. High EC may be due to high concentration of electrolytes, TDS, that may be attributed to high salinity, mineral contents and lower water table [8].

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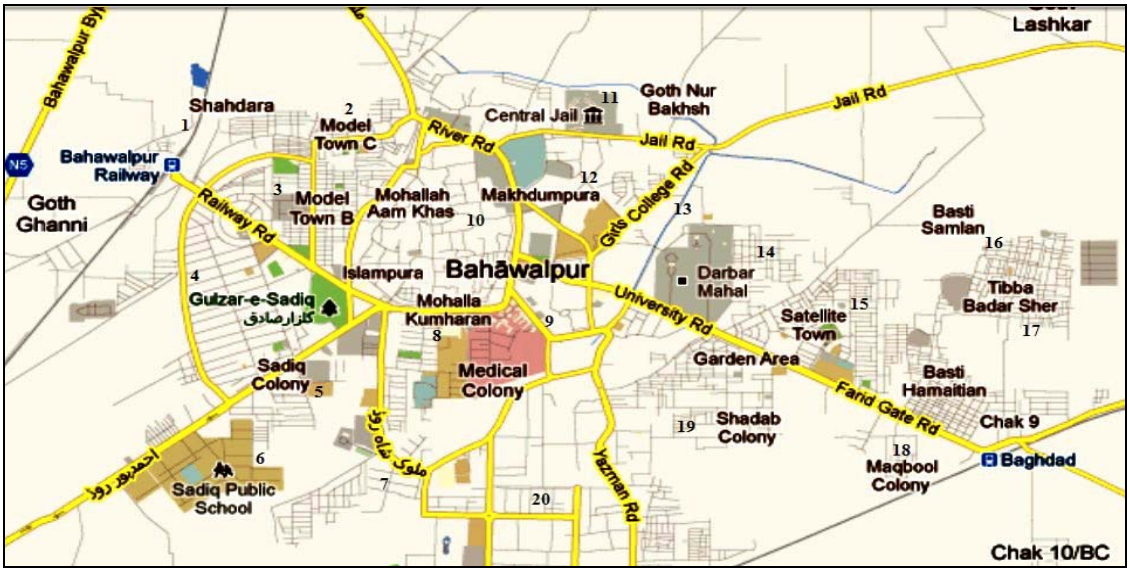

Fig.1: Map of Bahawalpur City, Pakistan.

Table-1: Estimated water quality parameters for ground water in Bahawalpur city.

Sample No	pH	EC	TDS	Alkalinity	Hardness	DO	NO^{3-}	SO_4^{2-}	Cl^-	F^-	Coliform/ *E.Coli*
1	8	697	446	2	171	3.2	0.13	119	45	2.04	-
2	7.9	1158	739	3.4	285	1.9	0.26	295	138	0.21	+
3	8.1	2261	1447	5.5	320	0.9	0.55	661	135	0.69	-
4	7.8	881	931	4.2	450	0.6	0.1	201	94	1.34	+
5	7.3	1459	633	4.6	185	2.7	3.45	364	130	2.98	+
6	8.2	989	745	6.1	450	1.9	5.68	217	91	0.76	+
7	7.8	1500	904	4.4	614	0.7	9.54	406	222	1.29	+
8	8	1354	102	7.3	487	1.4	4.92	393	242	1.54	+
9	7.3	1458	907	3.9	441	6.1	0.93	331	186	2.45	+
10	8.2	1349	847	4.6	212	0.5	7.29	466	104	2.72	+
11	8.1	984	610	2.8	261	0.4	0.16	293	124	1.62	-
12	7.9	1268	1107	5.1	195	1	1.2	316	263	0.56	+
13	8	881	690	3.6	260	4.6	0.2	86	91	1.66	+
14	7.8	507	874	4.2	300	2.9	0.12	392	130	2.49	-
15	7.9	425	442	3.1	116	4.2	0.9	89	117	0.88	-
16	8.3	1864	954	2.8	412	0.6	4.77	237	314	1.11	+
17	7.6	1722	980	4.7	215	2.2	3.49	389	90	2.4	+
18	8.2	624	939	3.7	180	1.3	0.34	392	211	0.79	+
19	7.9	663	980	3.8	455	0.8	7.75	378	20	3.66	+
20	8.2	421	1051	7.2	356	0.6	3.47	479	119	2.64	+

EC is in mS/cm and all other parameters are in mg/L, while - and + shows absence and presence of Coliform/ *E.coli* respectively.

Table-2: Metal contents in ground water samples from Bahawalpur city.

Sample No	Na	K	Ca	Mg	Fe	As	Cr	Ni	Pb
1	86	3.4	42	27	3.3	0.07	<0.001	<0.001	<0.01
2	159	7.9	68	51	1.82	0.08	<0.001	0.004	<0.01
3	280	12.5	84	29	3.47	0.05	0.007	<0.001	<0.01
4	145	6.6	102	81	0.71	0.04	<0.001	<0.001	<0.01
5	355	7.5	40	80	4.96	0.016	0.006	0.03	<0.01
6	168	7.9	56	121	0.45	0.21	0.004	<0.004	<0.01
7	278	11.4	147	69	0.2	0.011	0.009	<0.009	<0.01
8	199	10.5	96	111	2.21	0.16	0.008	0.07	<0.01
9	242	8.77	142	113	4.23	0.19	0.004	0.003	<0.01
10	251	9.6	124	32	0.1	0.03	<0.001	<0.001	<0.01
11	355	3.9	95	210	0.54	0.001	<0.001	<0.001	<0.01
12	357	7.9	46	49	3.09	0.06	<0.001	<0.001	<0.01
13	229	7.5	64	34	2.48	0.18	<0.001	<0.001	<0.01
14	230	6.9	74	26	1.75	0.05	<0.001	<0.001	<0.01
15	73	6.9	62	30	5.28	0.007	<0.001	<0.001	<0.01
16	176	12.5	155	166	0.19	0.003	<0.001	<0.001	<0.01
17	52	6.7	64	24	3.41	0.22	<0.001	0.02	<0.01
18	219	8.1	128	142	0.54	0.06	<0.001	<0.001	<0.01
19	86	3.1	26	30	5.21	0.02	<0.001	<0.001	<0.01
20	147	9.9	66	125	3.71	0.003	0.002	<0.001	<0.01

All the values are in milligram per liter (mg/L).

In the present study, TDS values of maximum samples fall within the permissible limit. Only 15% samples were found to be containing total dissolved salts greater than safe limit of WHO and PSI. Test for TDS indicates the presence of number of substances in water, e.g. chloride, sulfate, nitrate, and many more [13]; that may cause gastrointestinal exasperation [4]. Hardness of water may be due to high amounts of Ca, Mg and Fe. No sample of the study area was found exceeding maximum allowable limit prescribed for hardness by WHO and PSI. Therefore, investigated water samples don't possess potential to instigate heart diseases in residents [14].

The concentration of nitrates in all the water samples was found lower than tolerable limit of WHO and PSI drinking water standards. In case of sulfates, 75% samples were found falling above permissible range of WHO (200 mg/L). Upon comparison with PSI standards, concentration of sulfates in 85% samples was above the minimum acceptable limit (200 mg/L) and only 20% samples exhibited higher than maximum allowable limit (400 mg/L). The mean value of sulfates is also greater than WHO and minimum acceptable limit of PSI standards. Ingestion of such huge amounts of sulfates may lead towards diarrhea or laxative problems in humans [15].

The results reveal that 10 and 20% samples contain chloride greater than WHO limit (250 mg/L), and PSI minimum acceptable limit (200 mg/L), respectively. Whereas, no sample was above maximum allowable limit (600 mg/L). The concentration of chlorides, more than 200 mg/L, can induce bitter taste in water and is sign of threat to living beings in study area. Fluoride plays an imperative role in reducing dental caries; however after excessive intake of fluorides from water, people may become victim of enamel and skeletal fluorosis as well as bone fracture [16]. The concentration of fluoride in 55% samples violated the tolerable limit of WHO and PSI drinking water quality standards (1.5 mg/L in both), even the mean value also exceeded both the standards.

The concentration of fluoride in drinking water depends upon several factors including pH, TDS, alkalinity, temperature and depth of water source [17]. Being the most important parameter to interpret the water chemistry, pH [8] is plotted against concentration of fluoride (Fig. 2), which demonstrated that higher concentration of fluoride is present in water samples having high pH i.e. the alkaline water accommodates large amount of fluoride. Similar trend was also observed while plotting other water quality parameters like TDS, hardness, chlorides and sulfates against pH (Fig. 3).

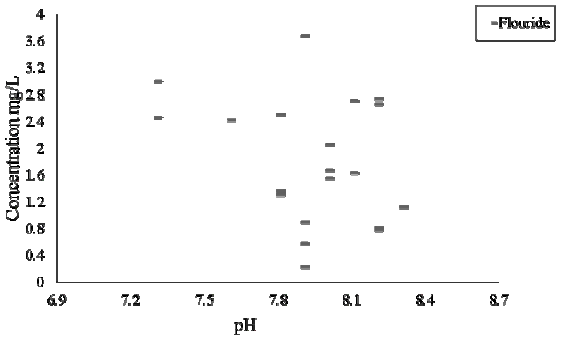

Fig. 2: Relationship of fluoride content in ground water with pH.

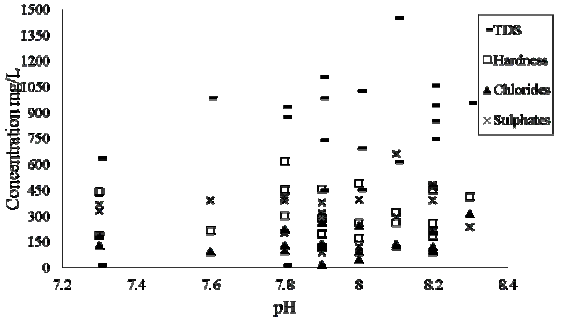

Fig. 3: Relationship of different water quality parameters with pH.

Metal Contents

Essential (Na, K, Ca, Mg) and heavy (Fe, As, Ni, Pb) metals play vital role in biological functions of human body, but these are necessary in calculated amount to pursue life metabolism. Table-2 shows concentration of metal contents estimated in ground water samples from Bahawalpur city.

Table-3: Descriptive statistics of analytical data of ground water samples.

Variables	Min.	Max.	Mean.	Median.
pH	7.3	8.3	7.95	7.9
EC	421	2261	1123	989
TDS	442	1447	816.4	847
Alkalinity	2	7.3	4.35	4.2
Hardness	116	614	318.25	285
DO	0.4	6.1	1.925	1.35
NO^{3-}	0.1	9.54	2.76	0.93
SO_4^{2-}	86	661	325.2	331
Cl^-	20	242	143.3	124
F^-	0.21	3.66	1.69	1.54
Na	52	357	204.3	199
K	3.1	12.5	7.97	7.9
Ca	26	155	84.05	68
Mg	24	210	77.5	51
Fe	0.1	5.28	2.38	2.34
As	0.001	0.22	0.073	0.05

Half of the investigated samples were found to have sodium more than WHO safe limit (200 mg/L) in drinking water, while mean value was slightly above WHO standard. Existence of Na in the form of chlorides and sulfates, greater than the standard value, may alter the taste of water and may instigate high blood pressure and hypertension in humans [18]. Only 10% samples were found with greater potassium content, but mean was lower than the values given in WHO drinking water quality guideline (12 mg/L). In PSI drinking water quality standards, the values for sodium and potassium are not mentioned. The people of Bahawalpur may face problem of diuretic and high blood pressure after long term use of water loaded with excessive potassium.

Calcium is the basic structural component of bone, teeth and soft tissues and is also involved in many metabolic processes in the body. Intake of heavy amounts of calcium, for short period, does not induce any adverse effects to the body; however humans exposed to Ca for long time may come across hypercalcemia, urinary tract calculi and calcification in soft tissues like kidneys and in arterial walls besides suppression of bone remodeling [18]. The concentration of Ca in 30% samples was greater than the recommended value of WHO (100 mg/L), while comparison with PSI standards revealed that 45% samples contain Ca content above the minimum acceptable concentration (75 mg/L) but none of the samples exceeded maximum allowable level (200 mg/L). On the other hand, mean value was lower than WHO standard but greater than minimum acceptable limit of PSI. Magnesium, being an essential element, is significantly involved in cardiac and vascular functions; its increased concentration in blood may cause vasodilation, improve blood circulation by decreasing vascular resistance and many other positive impacts on human health [19]. Magnesium concentration in 55% samples was above the safe limit of WHO (50 mg/L) and PSI standards minimum acceptable concentration (50 mg/L), while 10% samples exhibited the maximum allowable limit of PSI standards (150 mg/L). The mean value is greater than WHO minimum acceptable limit.

Trace elements in drinking water are renowned to have adverse as well as beneficial consequences depending upon concentration. Concentration of iron, arsenic, chromium, nickel and lead was determined in all the samples. No guideline about iron (Fe) is available in WHO curriculum about drinking water quality. Iron concentration in 85% (0.3 mg/L) and 65% (1 mg/L) samples was above the minimum acceptable and maximum allowable limit, respectively; even mean value was above PSI proposed standards. The presence of iron in drinking water may be due to the presence of organic matter; the substances present in organic matter possess the ability to reduce iron from Fe^{+3} to Fe^{+2}, and as a result further oxidation of Fe^{+2} is inhibited, which causes an increase in concentration of iron in water. Many toxic effects may appear in human body due to intake of iron via food or drink. The formation of hydroxyl radicals and intracellular iron deposit in a typical kidney cell, due to these Fe^{+2} ions, may harm kidney cells. The excess amount of iron may accelerate the formation of free radicals resulting in instigation of mutagenicity, nephrotoxicity and renal carcinoma [20].

High amount of iron in water indicates the presence of arsenic, [21] which is true for our study as well, where 75% and 40% samples were found exceeding safe limit laid down by WHO (0.01 mg/L) and PSI (0.05 mg/L), respectively. The mean value also violated both the standard limits. The chronic/ acute toxicity and carcinogenic nature of arsenic is known [2] and some evidences have confirmed that its carcinogenic potential, in humans, is greater than in animals [22]. Generally inorganic arsenic, i.e. As(III) is 60 times hazardous than organic arsenic, i.e. As(V), which gets converted to As(III) upon reduction; which is difficult to remove from drinking water [6]. The concentration of all other heavy metals was found below the limit approved by WHO and PSI.

Fig. 4 and 5 portray the relationship between pH and concentration of essential and heavy metals in water samples respectively and indicate higher metal concentration in water samples having pH between 7.8-8.2 i.e. at high pH, the concentration of all the metals is high. These findings are in conflict with the results given in some of the previous studies [23].

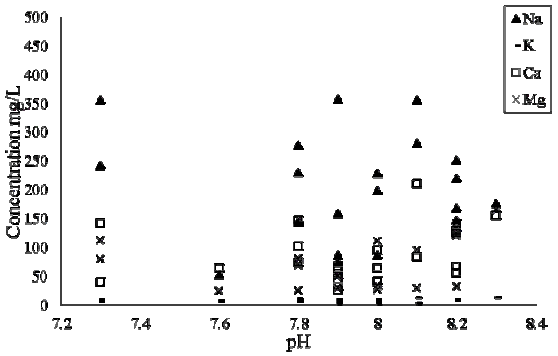

Fig. 4: Relationship of essential metal contents in ground water with pH.

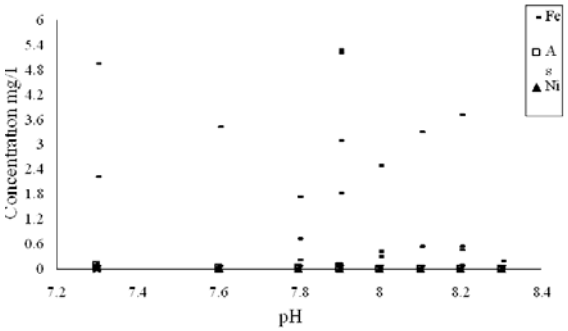

Fig. 5: Relationship of heavy metal contents in ground water with pH.

Bacterial Identification

Municipal sewage or animal slurry may contaminate environment by producing pathogenic organisms, which are specifically indicated by *coliform* bacteria. Therefore bacterial assessment is considered as an important indicator of water quality, where sewage is discharged i.e. within cities [24]. Generally, these bacteria are not harmful but other microbes along with these bacteria may cause short-term effects like diarrhea, cramps, nausea and headache [25]. In the study area, 75% samples contain *coliform* bacteria, which is a sign of threat.

Correlation among Investigated Parameters

Correlation matrix of estimated parameters for ground water of Bahawalpur city was also evaluated. Most of the investigated parameters were found to had slightly negative or positive correlation with each other and none of them exhibited correlation in strong way.

Experimental

Sampling

Samples from 20 different locations, within the city, were collected. For dissolved oxygen estimation, samples were collected in vacuum dried ambert colored glass bottles and stored in ice box followed by shifting to laboratory and storage at 4 °C until analyzed. For the quantification of metals, samples were collected separately in polyethylene bottles having 0.2 mL concentrated nitric acid per 100 mL of sample; as preservative [5].

Analytical Investigation

Standard analytical procedures were followed for the determination of physical and chemical parameters of quality evaluation. Some parameters like pH, TDS, EC were estimated on the sampling site, using potable pH meter (Jenway 3505, UK) and conductivity meter (inolab, Germany). Alkalinity was determined by titration with strong acid using phenolphthalein and methyl orange as indicators; in the same way carbonates and bicarbonates were estimated. For hardness assessment, volumetric titration was done with ethylenediaminetetracetic acid using eriochrome black T as indicator. The amount of nitrates, sulfates and phosphates was determined by spectrophotometric method using brucine, gum acacia and ammonium molybdate reagents, respectively. Chloride concentration was estimated by argentometric titration and fluoride spands method using colorimeter. Winkler's method of iodometric titration was used to determine dissolved oxygen. Essential metals like calcium and magnesium were estimated by complexometric titration while sodium and potassium were quantified using flame photometer (Sherwood 410, UK). The concentration of heavy metals was determined by atomic absorption spectrometer using air-acetylene flame for combustion with single-element hollow cathode lamp [26-28]. The presence of *Escherichia coliform* bacteria in all the water samples was checked using maconkeys broth (MB) kits. Appearance of yellow or yellowish color confirmed the presence of *coliform* bacteria and formation of purple or reddish color indicated their absence [29].

Statistical Analysis

Statistical analysis of results was conducted in terms of descriptive statistics and Pearson correlation matrix using Microsoft Excel 2010 for windows.

Conclusion

The present study indicates much higher values of EC and TDS than WHO and PSI standards that may lead towards many health issues. The population in this city may be the victim of problems associated with high concentration of fluoride ions as 55% samples contain fluoride more than allowable limit. Similar is the case with iron and arsenic i.e. 85% samples contain iron above safer limits and 75% samples possess arsenic above human tolerable limit, which may contribute towards severe health dilemma. One more threatening factor is that pH of all the samples fall in alkaline range, which favors the accommodation of high amount of components and it is justified with the relationship between pH and their concentration. This research work provokes concern about the evaluation of ground water quality

having drinking interest in other regions adjacent to desert; it also recommends the implementation of any treatment process according to the chemistry of water in order to remove high concentration of sulfates, fluoride, iron and arsenic.

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