Potable Water Quality Characteristics of the Urban Areas of Peshawar (Pakistan) Part 2: Well Water

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Summary: Quality characteristics of 30 samples collected from dug wells, open wells and hand pumps of some urban and adjoining areas of Peshawar (Pakistan) were chemically evaluated and the results were compared with WHO potable water quality standards. The studies indicate an increasing trend in magnesium content than calcium. These studies reveal that magnesium in 18 out of 30 samples is higher than calcium as compared to the previously reported results, where quality characteristics of tube well waters were undertaken. Tube well waters reported in part-1 of the studies were found to be less polluted compared to the well water in the present studies. These is due to the fact that wells are shallow (<40 feet) compared to tube wells (≥ 350 feet) and are therefore more vulnerable to pollution than tube wells. The general public opinion about the water quality has also been discussed.

Introduction

Aquatic pollution in Pakistan is mainly due to increasing anthropogenic and agricultural activities, fast urbanization, rapid industrial development, poor sanitation system and unhygienic practices by general public [1,2]. A number of diseases are caused by consuming water of poor quality [3, 4]. According to a community health study [2], 30 % of all reported cases of illnesses and 40 % of deaths in Pakistan are due to water-borne diseases. Poor quality of water for human consumption may be either due to the presence of harmful bacteria and absence or excessive electrolyte concentration [5]. In NWFP, more than half of six million population of Peshawar, Mardan, Charsadda and Nowshera Districts have no access to clean drinking water. The remaining half draws their water from some 590 tube wells [6]. Most of the wells are shallow and are liable to contamination from the surrounding sources such as toilets, underground damaged sewerage lines, seepage/percolation of contaminated water etc.

Efforts have been made in the past to evaluate and characterize water of different localities of NWFP for human consumption. The water quality of District Abbotttabad was studied by Hussain [7] who concluded that due to bacteriological contamination, the water of the area was injurious to human health. The potable water of Peshawar, Kohat and D.I. Khan [8] were also evaluated and water of some areas of these districts was found to be unsafe for human consumption. Akhtar *el al.* [9] carried out chemical analyses of water samples from 15 plains, 9 hilly stations and 6 river/Dams in NWFP and found that half of the drinking water samples showed high levels of Na^+, K^+ and TDS contents whereas those collected from hilly areas were found deficient in Iodine, the main cause *of goitre.* Khan *el al.* [10] reported the quality characteristics of potable water of Mardan city and concluded that the presence of higher level of COD, higher conductivity, higher level of magnesium and sulphate rendered the water unfit for human consumption. Khan *et al.* [11] studied the physico-chemical characteristics of sub-surface water of Haripur area and concluded that the increased industrial and agricultural activities in the area might cause water pollution in the long run.

Nitrates and nitrite contamination of sub-surface water in some areas of NWFP have also been conducted [12], which indicate that higher concentrations of these contaminants are due to rapid agricultural activities in these areas. In Punjab, the nitrate concentration of underground water in 1967 was found to be less than 3 mg/L [13], however a later study [14] has indicated nitrate concentration of shallow ground water in the range of 2-450 mg/L.

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Nitrate contents in some areas of NWFP has also been studied by Khwaja *et al.* [15], Bangash [16] and Wasim [17].

Recently, it has been found (unpublished data) that potable water of a localized area of Khyber Agency (FATA) contains excessive fluoride content which has created early tooth decay problems among children under 18 years of age. The preliminary results of these studies have indicated that the concentration of fluoride is as high as 30 mg/L, which is almost 20 times higher than WHO permissible limits of 1.5 mg F/L [18]. Another incident of eruption of water-borne diseases due to contaminated potable water occurred in Hyderabad (Pakistan) during the month of May 2004, which resulted several deaths besides a number of casualties.

Recently, presence of arsenic was reported [19] in the drinking water of some areas of Mardan and D. I. Khan, which is required to be investigated before appearance of its ill effects on human beings. The most recent study on the water quality of Peshawar was conducted by Shakirullah *et al.* [20], in which tube well water of the surrounding areas of Peshawar were examined. The main findings of this paper was that COD level in 9 samples out of 28 were above the WHO permissible limits. This was associated with the seepage of domestic and industrial effluents.

In the present investigation, quality characteristics of potable water from wells in the urban and adjoining areas of Peshawar were evaluated and compared with those collected from the tube wells conducted previously [21]. Details of the investigations undertaken and results obtained are described and discussed in this paper.

Results and Discussion

General public opinion presents a bird eye view about the quality of any product. Therefore, the opinion of general public is always sought and is very much respected due to the true picture presentation. Table-1 presents the location of sampling, the state of surrounding and the public opinion. The information contained in Table 1 indicates that the public opinion about the quality of water samples 1,4, 10 and 17 were not satisfactory. The public opinion about the rest of samples was not objectionable. There were complaints about the water quality of Sufaid Dheri water (sample 1) in the past and there were casualties in 1999 [21]. The results were presented by Aziz and Khan [21] who discussed the complete scenario in detail with the support of laboratory investigation of water quality.

Table-1: Local and state of surroundings of water samples collected from Dug wells, open wells or pumps.

Sample No.	Location	State of surroundings
1.	Sufaid Dheri	Populated Area
2.	Nawan Kali	Populated Area
3.	Achini	Village
4.	Darra	Populated Area
5.	Nazir Abad	Near Grave yard
6.	Sango	Hand Pump (5 houses)
7.	Bara	Village Open Well/Dug Well
8.	Bara gate	Populated Area
9.	Ganj	Populated Area
10.	Regi Lalma	Open Area
11.	Board Colony	Populated Area
12.	Bagh-e-Naran	Park (Tape Water)
13.	Kachi Abadi	Village Area
14.	Bahader Khel	Village (Hand Pump)
15.	Garhi Qamar Din	Village
16.	Warsak Road	Village
17.	Hazar Khwani	Bus Stand
18.	Shahi Bagh	Park (Tape water)
19.	Radio Pakistan	Populated Area
20.	Katcheri	Populated Area
21.	Kohat Adda	Bus Stand
22.	Lal Kurti	Populated Area
23.	Shaheen Camp	Cantt. Area
24.	Taj Abad	Village (Open Well)
25.	Nishtar Abad	Populated Area
26.	Haji Camp	Populated Area
27.	Shaheen Town	Populated Area
28.	Army Stadium	Public Park
29.	Defense Colony	Populated Area
30.	Hasan Garhi	Populated Area

Darra is a hilly populated area and most of the water that percolates underground, carry signify-cant amount of salts, therefore the quality of water could be objectionable as substantiated by the people. Sample No. 10 collected from Regi Lalma which is an open area situated a little away from city area. It is expected that this water should have been satisfactory. Yet, the public opinion about this water was not satisfactory. Regi Lalma is the area where several large occasional water channel (Khwar) pass through. During rainy seasons, the agriculture run off

Table-2: Physical and chemical parameters of potable water samples

Sample No.	pH	Elect. Conduc-tivity µS/cm	Turbidity (NTU)	Total Dissolve Solids (mg/L)	Total Hardness as $CaCO_3$ (mg/L)	Calcium as $CaCO_3$ (mg/L)	Magne-sium as $CaCO_3$ (mg/L)	Total Alk. as $CaCO_3$ (mg/L)	Bicar-bonate HCO_3^{-1} (mg/L)	Chloride as Cl^{-1} (mg/L)	Sulphate as SO_4^{-2} (mg/L)	Nitrate as NO_3^{-1} (mg/L)
1	7.06	300	3.8	445	318	130	200	210	210	40	80	7.4
2	6.56	320	3.2	497	360	129	231	192	192	36	56	7.8
3	7.10	390	3.1	530	392	152	240	196	196	85	52	7.1
4	6.72	400	2.6	422	290	110	180	181	181	22	36	6.8
5	6.89	380	2.7	463	340	124	216	172	172	42	39	7.3
6	6.90	340	2.6	416	320	126	194	176	176	32	29	6.8
7	7.05	380	2.9	436	332	118	214	185	185	26	34	6.9
8	6.5	350	3.0	500	200	110	210	180	180	30	36	7.2
9	6.9	400	3.2	410	300	115	198	117	117	25	40	7.6
0	6.5	339	2.6	470	330	140	219	170	170	70	40	6.3
1	6.6	315	1.5	400	218	120	190	130	130	35	36	5.5
2	6.3	295	1.8	410	310	135	209	111	111	30	39	5.5
3	6.7	200	1.3	339	320	130	210	115	115	25	38	4.2
4	5.8	330	1.2	370	304	105	180	90	90	20	30	3.1
5	6.3	395	1.2	420	280	120	170	80	80	35	25	3.8
6	6.6	380	2.1	380	290	137	150	95	95	60	35	3.9
7	5.8	380	2.5	398	250	140	120	98	98	50	40	5.5
8	5.9	395	2.3	400	200	110	110	100	100	45	38	5.1
9	6.3	400	1.5	415	195	150	120	950	950	40	45	06
:0	6.7	380	0.5	420	200	170	135	110	110	50	31	3.7
:1	7.8	290	2.9	338	220	130	150	125	125	40	37	5.8
:2	6.7	300	3.0	298	210	135	135	130	130	35	38	6.1
:3	7.3	310	2.1	300	235	140	130	190	190	40	45	7.8
:4	7.9	320	2.8	500	240	125	140	200	200	45	45	5.6
:5	7.5	295	3.1	500	280	225	155	180	180	40	43	4.8
:6	6.5	330	4.4	480	235	170	145	180	180	50	48	4.5
:7	5.6	290	2.9	348	240	190	130	290	290	53	40	4.3
:8	6.8	300	2.1	330	280	180	138	280	280	48	35	5.4
:9	6.5	340	3.55	400	330	200	125	230	230	40	70	5.5
:0	5.7	280	4.5	440	335	215	210	240	240	38	60	3.8
Mean	6.65	337.47	2.57	415.83	308.83	139.30	172.87	190.10	190.10	40.90	42.00	5.70
± St. Dev.	0.57	48.01	0.93	60.97	41.35	29.10	39.20	153.62	153.62	13.92	11.76	1.38

P-alkalinity as $CaCO_3$ (that is CO_3^{-2} and OH^- alkalinities) and Nitrite (NO_2^{-1}) are absent in all samples

passes through these areas which might have been contributing toward imparting objectionable taste to the underground water. Another reason could be the geological activity for the poor quality of water, however no clear-cut reason to this effect is known. Hazar Khawani is a populated village, the water of which also bears objectionable taste. This area is either mainly a graveyard or adjacent to a large graveyard. The underground water may be contaminated by the organic matter due to putrefaction of dead bodies. This could be regarded as the main reason to this effect.

Physical and chemical analyses of water samples are presented in Table-2, 3 and 4 present a comparison among some analytes of the present studies with the reported results [20]. Table-5 presents WHO potable water quality standards [18].

pH is one of the parameters that determine the acidic or alkaline nature of water. The data in Table 2 indicates that Shaheen Town (sample 27) has the lowest pH value of 5.6 which is below the WHO permissible range of 6.5-9.2. pH in samples 12, 14-15, and 17-19 is <6.5, whereas rest of the samples were within the WHO permissible limits. The electrical conductivity of all the samples was ≤400 µS/cm. Only samples 4, 9 and 19 have the highest electrical conductivity of 400 µS/cm. Electrical conductivity determine the conduction of salts ions and gives estimates of the salts present.

Calcium carbonate is one of the most abundantly found mineral in water. Most of the analytes like calcium, magnesium, alkalinities are reported as salts equivalents to $CaCO_3$. Calcium concentrations in all the samples are within the WHO

limits (i.e. <250 mg $CaCO_3$/L). Turbidity determines the suspension in samples. The highest turbidity was found in sample 30 (Table 2) which is 4.5 NTU. Samples with turbidity ≥3.0 are 1-3, 8-9, 12, 14-15, 17-19, 22, 25-26, and 29-30. Such suspension could be due to presence of bacteria and/or insoluble matter however other reasons could also be contributing to this effect.

Total dissolved solids (TDS) indicate the presence of salts that are in soluble form and may cause temporary or permanent hardness. The WHO limit for TDS is 500 mg/L. The data in Table 2 indicates that only sample 3 contain 530 mg TDS/L. The TDS of rest of samples; lie with in the permissible limit. Total hardness, which is mainly due to the presence of salts of calcium and magnesium, is however exceeding the limits. The WHO suggests that magnesium as $CaCO_3$ should not exceed 150 mg/L, the data in Table 2 reveal that the concentration of magnesium as $CaCO_3$>150 mg/L in samples 1-16, 25 and 30. The highest value recorded is 240 mg/L in sample 3. The lowest value of Mg as $CaCO_3$ is 110 mg/L in sample 18. It is a normal trend that in most cases, Mg^{+2} concentrations are less than Ca^{+2} in potable waters. A similar trend [10] has also been observed in the potable water of Mardan City (Pakistan) and adjoining areas where magnesium content compared to calcium was higher than the WHO permissible limit both in bore and tube well water. Similar situation exists in the present study indicating that magnesium concentration is more than the calcium content. Calcium as $CaCO_3$ is less than magnesium as $CaCO_3$ in 1-16 samples and in samples 21 and 24 of Peshawar adjoining areas.

In another study on potable water of district Bannu, Pakistan [22] it has also been indicated that the higher magnesium content (above the WHO permissible limits) alongwith higher levels of COD, conductivity, nitrite and sulphate contents make waters of both wells and hand pumps unfit for human consumption.

It has been reported previously [21] that all tube well waters of Peshawar were safe for human consumption as all the analytes were found to be within the WHO permissible limits. Besides this, the study [21] also negates the presence of the decreasing concentration of nitrate in the potable water of Peshawar. The study [21] also indicated that Ca^{+2} concentration generally used to be more than the Mg^{+2} concentrations. In the present study about 18 samples out of 30, the Mg^{+2} concentrations is higher than the calcium. This is one of the main differences between the present and past study [21]. This could be attributed to the fact that due to the more depth of the tube well water of Peshawar, the Ca^{+2} is more than that of the present study. The wells which arc shallow (<40 ft.) compared to tube well, which some times reaches to over 400 feet, are more vulnerable to pollution and the present results with regard to Mg^{+2} is an evidence of this situation.

It has been reported previously [23] that when Sulphate concentration is ≥250 mg/L, then the concentration of magnesium as Mg^{+2} should not exceed 30 mg/L. Synergistically, when SO_4^{-2} is more than 250 mg/L and Mg^{+2} concentration is more than 30 mg/L, then it is more likely that the water would be laxative in nature. In the present case, although magnesium as $CaCO_3$ concentration is more than 150 mg/L (36.0 mg/L as Mg^{+2}), the Sulphate concentration is <250 mg/L in all samples. However, it is not clear why the normal trend was not followed with regard to magnesium concentration. This situation could be attributed to the nature of soil which might be due to the presence of more magnesium salts as compared to calcium. However, this is required to be confirmed further.

Alkalinity is mainly caused by OH^-, CO_3^{-2} and HCO_3^- salts, although other analytes are also responsible. P-alkalinity determines OH^-, CO_3^{-2} salts and was found to be present in almost all the samples. pH and alkalinities have a relationship [21] that when pH is ≤8.3, then OH^- and CO_3^{-2} alkalinities are absent. In such a case, the total alkalinity (M-alkalinity) is due to HCO_3^-. Chloride concentration in all samples is less than 250 mg/L which is within the WHO permissible limits [18]. All the samples were devoid of nitrite which indicate the absence of bacteria and fresh pollution. Nitrates were also within the WHO limits, the concentration of NO_3^- varied between 3.1 in sample 14 and 7.8 in samples 2 and 23.

The data in Table 3 shows a comparison of some of the analytes between the tube well and well water of Peshawar. It was difficult to compare water quality from both sources (i.e. wells and tube wells) of a location due to the non-availability of wells in municipality areas; therefore the nearest possible wells were selected. The soil strata changes with

Table-3:Comparison of some analyses of the present studies with the previously reported results [21]

	Area*	*Study*	pH	Concentration (mg/L) TDS	Total Hardness**	Ca^{+2}	Mg^{+2}	Cl^-	SO_4^{-2}	NO_3^-
1.	Nishtar Abad (25)	Present	7.50	500.00	380.00	90.00	37.20	40.00	43.00	48.00
	Sikandar Pura (1)	Previous	6.00	180.20	171.76	47.27	13.90	18.68	25.12	16.50
2.	Shaheen T'own (27) PCSIR (39)	Present	5.60	348.00	320.00	76.00	31.20	53.00	40.00	4.30
		Previous	7.20	342.13	430.36	54.54	71.57	31.14	30.19	32.00
3.	Shahi Bngh (I8)	Present	5.90	400.00	220.00	44.00	26.40	45.00	38.00	5.10
	Din Bahar (I3)	Previous	6.67	328.46	369.80	72.72	45.81	37.36	70.12	30.00
4.	Taj Abad (24) Danishabad (35)	Present	7.90	500.00	265.00	50.00	33.60	45.00	45.00	5.60
		Previous	7.18	216.19	225.47	43.63	28.36	40.23	40.23	11.10
5.	Hazar Khwani (17)	Present	5.80	398.00	260.00	56.00	28.80	40.00	40.00	5.50
	Hazar Khwani (22)	Previous	7.37	279.62	279.79	61.81	30.54	59.21	59.21	25.00
6.	Gunj (9)	Present	6.90	410.00	313.00	46.00	47.52	40.00	40.00	7.60
	Gunj Gate (9)	Previous	6.68	292.24	319.14	65.45	37.90	60.16	60.16	3.70
7.	Bara Gate (8)	Present	6.50	500.00	320.00	44.00	50.40	36.00	36.00	7.20
	Landi Arbab (19)	Previous	6.80	324.21	225.79	69.90	12.50	35.13	35.23	30.00

* The No. in parenthesis denotes sample numbers in the reported studies
** as $CaCO_3$

Table-4:Overall comparison of different analytes in potable water of Peshawar (present and past studies)

Parameters	Previous study [21]	Present study
pH	7.06 ± 0.45	6.65 ± 0.57
Elect. Conductivity (μS/cm)	315.58 ± 57.28	337.47 ± 48.01
Turbidity (NTU)	0.73 ± 0.42	2.57 ± 0.93
Total Dissolve Solids (mg/L)	284.57 ± 51.16	4 15. 83 ± 60.97
Total Hard ness as $CaCO_3$ (rng/L)	306.23 ± 70.64	308.83 ± 4I.35
Calcium as $CaCO_3$ (mg/L)	154.03 ± 30.58	139.30 ± 29.10
Magnesium as $CaCO_3$ (mg/L)	150.13 ± 56.13	172.87 ± 39.20
Bicarbonate as HCO_3^{-1} (mg/L)	187.84 ± 25.87	190.10 ± 153.62
Chloride as Cl^{-1} (mg/L)	31.41 ± 10.55	40.90 ± 13.92
Sulphate as SO_4^{-2} (mg/L)	49.43 ± 16.15	42.00 ± 11.76
Nitrate as NO_3^{-1} (mg/L)	19.21 ± 10.58	5.70 + 1.38

distance, therefore variations in the concentrations of different analytes is expected. Inspite of all these facts, it is possible to compare results of water samples in an area within ½ km radius. Although, the data in Table 3 is quite diverse due to the aforesaid reasons, the results, in spite of some exceptions suggest that well water are generally more saline than the tube well waters, reported previously [21]. The TDS of the samples substantiate this effect. TDS of all well waters is higher than the tube well waters. pH of most of the well waters is less or comparable with tube well waters. Marked decrease noted in pH of well water at Shaheen Town and Hazar Khwani areas is due to presence of graveyard in the area. Chloride is high in well water with the exception of Bara area (5 out of 6 areas). Amazingly NO_3^- is less in well waters compared to tube well waters except in Gunj area. This could be attributed that wells are protected from agricultural run of whereas tube wells receive water from a depth where the soluble nitrates from different sources through seepage and percolation reaches the underground waters. Soil strata could also be responsible for the higher NO_3^- concentration.

The data in Table 4 compares the overall water quality of Peshawar, irrespective of the source. The data indicate that well water is more saline than tube well waters. The results suggest that although overall pH of well water has decreased, other analytes have shown significant increase except calcium as $CaCO_3$ which was found to be slightly increased. Similarly NO_3^- has also been found to be decreased (Table 4). The results also substantiates that overall magnesium content in well water of Peshawar compared to tube well waters have increased.

Table-5: WHO potable water quality standards [18]*

Analytes	Standards
Colour	Colourless
Odour	Odourless
Taste	Tasteless
Electrical Conductivity	400 μ mhos/cm
pH	6.5-9.2
Total Dissolved Solids	500 mg/L
Chloride as Cl^-	250 mg/L
Nitrate as NO_3^-	45 mg/L
Nitrite as NO_2^-	0.1 mg/L
Total Hardness as $CaCO_3$	500 mg/L
Calcium as $CaCO_3$	250 mg/L
Magnesium as $CaCO_3$	150 mg/L
Sulphate as SO_4^{--}	250 mg/L
P-Alkalinity as $CaCO_3$	300 mg/L
M-Alkalinity as $CaCO_3$	1.5 mg/L

* Relevant to the present study

Experimental

Sampling and chemical evaluation

Thirty sampling points were randomly selected for sampling which included the samples collected from Dug wells, open wells and hand pumps. The samples were collected in 1.5-L properly washed and cleaned plastic containers. Before sampling, the containers were rinsed with the sample water thrice and then filled with the sample. General public opinion about the water quality was also recorded during sample collection. pH and conductivity were measured on the spot with a portable pH meter (Corning, USA) and conductivity meter (Jenway, England) respectively. All precautionary measures were observed while filling up the sample bottles and in their transport and storage. The wells and hand pumps in different localities of Peshawar were selected on the basis that these were the sole source of drinking water for the inhabitants of the area.

All the reagents used were of Analytical grade. Chemical evaluation of each sample was carried out following the standard methods [24]. Total dissolved solids (TDS) were determined by evaporation of sample at 105°C. Total hardness including calcium and magnesium were determined by complexometric EDTA titration method. The alkalinities were determined by titration method using standard H_2SO_4 (0.02 N) following standard methods [23].

Chlorides were determined by titration with silver nitrate (0.041 N) solution using potassium chromate as indicator. Sulphate was measured by back titration with 0.01 M standard EDTA solution [25].

Nitrate and nitrite were determined by visible spectrophotometeric methods using a U.V. spectrophotometer (U-2000 Hitachi, Japan). The appropriate wave lengths for nitrate and nitrite were 220 nm and 543 nm respectively using standard methods [23].

Conclusions

On the basis of 14 physical and chemical characteristic of 30 samples collected from the urban area of Peshawar, it is evident that the presence of higher level of TDS. magnesium concentration in some of the samples make the water unfit for human consumption. Results also indicate that magnesium concentration compared to calcium in almost all samples was high showing an increasing trend in magnesium content. The result show that well waters are more saline than tube well waters. The conclusion drawn in this study is supported by statement of the inhabitants that gastrointestinal problems are common in these areas due to consumption of these waters. It is therefore suggested that water should be boiled before drinking to kill most of the bacteria and remove some of calcium and magnesium by converting their soluble bicarbonates into insoluble carbonates.

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