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Full Length Research Paper

Physiochemical evaluation of the drinking water sources from district Kohat, Khyber Pakhtunkhwa, Pakistan

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Safe drinking water is a high priority issue for safeguarding health and well-being of humans all over the world. Both in the urban and rural areas of Pakistan, the quality of drinking water are not being managed properly. Results of various studies provide evidence that most of the drinking-water supplies are physiochemically contaminated. In this study, a detailed investigation of the drinking water sources of both urban and rural areas of Kohat district was carried out to evaluate their suitability for drinking purpose. A total of 54 water samples were collected from the hand pumps, streams, tanks, tube wells and wells, at 15 sampling sites selected of the main population zones. Also, 6 bottled water samples were taken from the market. All these were analyzed for physicochemical parameters including pH, conductivity, total dissolved solids (TDS), total suspended solids (TSS), total solids (TS), chloride (Cl^-), calcium (Ca^{2+}), magnesium (Mg^{2+}), hardness, and alkalinity. The results of parameters showed variations from the WHO and Pakistan standard values for drinking water. Most polluted areas were Shakardara, Lachi and Ara Khail. Among the various sources, wells and tanks were highly polluted while tube wells were found to be the most suitable source for drinking water. The main purpose of this research was to make public awareness of the study areas, to avoid usage of contaminated water for drinking or other domestic uses and to reduce health risks.

Key words: Drinking water, sources, physiochemical evaluation, Kohat.

INTRODUCTION

Water is one of the most precious commodities of life, although it is often taken for granted. It has numerous uses most of which are fundamental to life and society. Water is vital for drinking, without which no man or animal could survive, and is used for maintaining personal hygiene. It is impossible to exhaust all the water supplies of the world, as water is continuously recycled through the hydrological cycle. However, it is possible to degrade the quality of water to the point where it is useless, harmful or sometimes even deadly (Miroslav and Bashkin, 1999). Drinking water quality has been debated throughout the world (Leoni et al., 2005). Generally, discharge of direct domestic and industrial effluent wastes, leakage from improperly maintained septic water tanks and poor management of farm wastes are considered

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as the major sources of water pollution and ultimately of waterborne diseases (Jain et al., 2005). Deterioration of drinking water quality is an issue in many parts of the world. Various research studies have shown that drinking water in many countries does not meet WHO standards (Aydin, 2007; Gupta et al., 2009;Gyamfil et al., 2012).

Pakistan ranks 80th, out of 122 nations of the world, on the basis of water quality (UNESCO, 2002; Azizullah et al., 2011). In Pakistan, drinking water supplies are mainly obtained from surface water sources or the underground aquifers. About 70% of the total drinking water supplies are obtained from underground aquifers. This ratio is further increasing at present (Tahir et al., 1998). Water quality in many areas of Pakistan is also not in accordance to the WHO/Pakistan guidelines for drinking water. It is deteriorating mainly as a result of disposal of the municipal and industrial wastewaters, without proper treatment and also because of the saline drainage flow from agricultural areas (Tahir et al., 1998; Chilton et al., 2001*)*. From the research studies, it is clear that various physiochemical parameters of Pakistan drinking water are not in accordance with the WHO/Pakistan standards for drinking water (Rahman, 1996; Chilton et al., 2001; Malana et al., 2011; Baig et al., 2012; Farid et al., 2012*)*. Polluted drinking water causes outbreak of diseases. In three districts namely Thatta, Badin, and Thar, of southern Sind Pakistan, poor water quality was found responsible for gastroenteritis, diarrhea and vomiting, kidney, and skin problems (Memon et al., 2011).

The present study is aimed at determining the various physical and chemical quality parameters for the drinking water sources of Kohat district, to evaluate their suitability for drinking purposes, in accordance to the WHO/Pakistan standards for drinking water.

MATERIALS AND METHODS

Sampling

A total of 60 water samples were collected from different drinking water sources of both urban and rural areas of district Kohat. It included 54 samples from 15 selected population zones and 6 bottled water from the open market. Clear, clean and dry polyethylene bottles were first rinsed with sample water, at the sampling site and then filled in such a way that no air bubbles were left behind in the bottles. The bottles were then placed in the refrigerator and analyzed for the various quality parameters (APHA, 1998).

Determination of physical parameters

pH was measured by electrometric method (4500-H^+B), using pH meter, Mettler Delta 320, England, while electrical conductivity was determined by laboratory method (2510 B), using conductivity meter, Jenway 4060, England (APHA, 1998). Total solids were measured by drying the samples in oven, Memmert B 54, Schwabach W. Germany, at 103 to 105°C (2540-B). The increase in weight was expressed as mg of total solids per liter of sample.

For total dissolved solids, well mixed sample was filtered through Beckman filter paper and dried in oven (2540-C). The total suspended solids were calculated from the difference between total solids and total dissolved solids (2540-D) (APHA, 1998).

Determination of chemical parameters

Alkalinity was determined in water samples by titration method (2320 B), using methyl orange indicator and standardized sulfuric acid solution (APHA, 1998).

Total hardness was determined as mg $CaCO_3$/L, by EDTA titrimetric method (2340 C), using eriochrome black-T indicator and standardized solution of ethylenediamminetetraacetic acid (EDTA). Calcium hardness was measured by EDTA titrimetric method (3500-Ca B), using murexide indicator and standardized ethylenediamminetetraacetic acid (EDTA) solution. Magnesium hardness was calculated from the difference between the total hardness and calcium hardness (3500-Mg B) (APHA, 1998). Chloride was determined by argentometric method (4500-Cl^- B), using potassium chromate indicator and standard $AgNO_3$ solution (APHA, 1998).

RESULTS AND DISCUSSION

pH

The pH of all water samples ranged between 6.39 and 7.85, the lowest being observed in Shaikhan hand pump while the highest in Hasan abad tube well. The pH values from hand pumps varied between 6.39 and 7.60. For streams, tanks, tube wells and wells these were from 6.76 to 7.76, 6.78 to 7.70, 6.80 to 7.85 and 6.86 to 7.80, respectively. Bottled waters showed the pH values ranging from 6.97 to 7.80 (Table 2, Figure 1). With the exception of Shaikhan hand pump (6.39), pH values of all water samples were in the range of WHO and Pakistan standards (6.50 to 9.20) (Table 1) (WHO, 1996; APHA, 1998; PCRWR, 2005; WHO, 2006). The low pH value of Shaikhan hand pump shows that it is not suitable to be used for human drinking purposes. The low pH values are responsible to cause redness and irritation of eyes in human beings. Also, as pH can affect the extent of corrosion of metals as well as disinfection efficiency of distributing systems, it thus has an indirect effect on health also (WHO, 1986).

Total alkalinity

Total alkalinity of all water samples ranged between 116 and 736 mg/L, the lowest being observed in Aqua bottled water while the highest in Shakardara hand pump. The total alkalinity values of water from hand pumps, streams, tanks, tube wells and wells varied in the range of 336 to 736, 288 to 452, 212 to 504, 276 to 560 and 260 to 530 mg/L, respectively. Bottled waters showed the total alkalinity values ranging from 116 to 243 mg/L (Table 2, Figure 2). Except four samples, the total alkalinity values of all water sources were in the range of WHO (500 mg/L) and

Table 1. Guidelines and standards for quality of drinking water.

S/N	Guideline/standard values for Pakistan				WHO standard
	Property/parameter	Unit	HDL*	MPL**	
1.	pH	---	7.0 - 8.5	6.5 - 9.2	6.5 - 9.2
2.	Electrical conductance	$\mu S/cm^3$	1000.00	1200.00	1200.00
3.	Total solids	mg/L	1000.00	1500.00	1000.00
4.	Total dissolved solids	mg/L	1000.00	1500.00	995.00
5.	Total suspended solids	mg/L	05.00	05.00	05.00
6.	Total hardness as $CaCO_3$	mg/L	200.00	500.00	500.00
7.	Calcium hardness as $CaCO_3$	mg/L	75.00	200.00	250.00
8.	Magnesium hardness as $CaCO_3$	mg/L	30.00	150.00	150.00
9.	Total alkalinity as $CaCO_3$	mg/L	400.00	500.00	500.00
10.	Chloride as Cl^{-1}	mg/L	200.00	600.00	250.00

* Highest desirable level; ** maximum permissible level.

Table 2. Values of physical parameters investigated.

Study area	Source	pH	Conductance ($\mu S/cm^3$)	Solid (mg/L)		
				TDS	TSS	TS
Hasan Abad Shahpur	Hand Pump	6.88	820	514	10	524
	Tube Well	7.85	752	430	2	432
	Well	6.86	778	468	6	474
Jungle Khail	Stream	6.87	812	529	4	533
	Tank	7.18	756	324	26	350
	Tube well	6.89	1034	548	14	562
KDA	Hand pump	7.60	862	642	6	648
	Tank	7.30	734	367	3	370
	Tube well	7.05	822	544	9	553
Myana	Hand pump	6.92	922	587	5	592
	Stream	6.94	661	429	8	437
	Tank	7.24	892	574	7	581
	Tube well	7.40	824	554	2	556
Ali Zai	Hand pump	6.90	662	705	9	714
	Stream	6.76	727	346	4	350
	Tank	7.00	786	465	11	476
	Tube well	7.40	778	561	5	566
	Well	7.00	822	548	3	551
Muhammad Zai	Hand pump	6.80	866	554	8	562
	Stream	7.44	1088	632	9	641
	Tank	6.78	1025	660	2	662
	Tube well	6.84	1044	676	4	680
Uster Zai	Hand pump	6.81	1844	1266	16	1282
	Stream	6.88	645	423	8	431
	Tank	7.41	1018	641	9	650
	Tube well	7.08	732	461	7	468
	Well	6.99	647	408	5	413

Table 2. Contd.

College Town	Hand pump	7.20	942	530	6	536
	Tank	7.15	1094	569	11	580
	Tube well	6.80	892	476	6	484
Shaikhan	Hand pump	6.39	896	585	3	588
	Tank	6.92	1174	762	4	766
	Tube well	6.94	1324	819	19	838
Belitang	Hand pump	7.05	1192	771	7	778
	Tank	7.20	114	721	5	726
	Tube well	7.10	1232	812	2	814
	Well	7.80	1280	867	13	880
Gumbat	Hand pump	7.30	940	554	2	556
	Tank	6.80	890	723	7	730
	Tube well	7.40	860	668	3	671
	Well	7.80	1080	767	11	778
Dara Adam Khail	Hand pump	7.20	810	620	8	628
	Tank	6.95	888	526	2	528
	Tube well	6.82	744	616	4	620
Ara Khail	Tank	7.00	1180	857	15	872
	Tube well	7.15	1245	801	4	805
	Well	7.77	3010	1690	18	1708
Lachi	Hand pump	7.40	7016	3984	70	4054
	Tank	7.38	1194	754	6	760
	Tube well	7.00	7788	7728	88	4516
Shakadara	Hand pump	7.30	1748	1088	54	1142
	Stream	7.76	1029	643	7	650
	Tank	7.70	1024	605	9	614
	Tube well	7.39	1012	635	6	641
Bottle Water	Nestle	6.97	303	242	2	244
	Wah	7.30	479	298	4	301
	Country	7.50	500	322	4	326
	Mitchell's	7.60	326	188	1	189
	Kinza	7.50	477	260	4	264
	Aqua	7.80	216	196	3	199

Pakistan (400 to 500 mg/L) standards (Table 1) (WHO, 1996; APHA, 1998; PCRWR, 2005; WHO, 2006).

Four samples showed high total alkalinity values. These include two sources of Lachi hand pump (556 mg/L) and tube well (560 mg/L) and two sources of Shakardara hand pump (736 mg/L) and tank (504 mg/L). High alkalinity values, usually above 500 mg/L, are always associated with high pH values, high hardness and high dissolved solids. This has adverse effects especially on hot water systems, water heaters, boilers and heat exchangers. In these, the excessive scale reduces the transfer of heat to the water, resulting in greater power consumption for less productivity (WHO, 1986).

Electrical conductance

The electrical conductance values of all water samples were found in the range of 16 to 7788 µs/cm^3, the lowest being observed in Aqua bottled water while the highest in Lachi tube well. The electrical conductance values of water from hand pumps, streams, tanks, tube wells and wells varied in the range of 662 to 77016, 645 to 812, 734

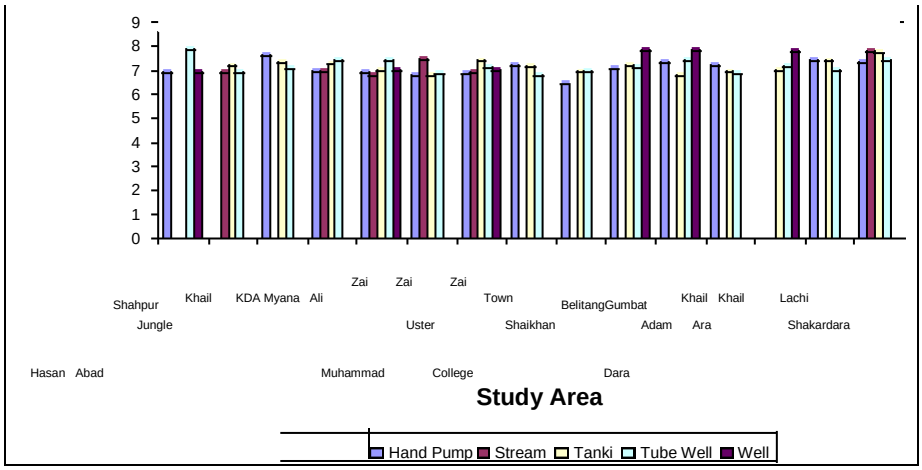

Figure 1. pH of water samples.

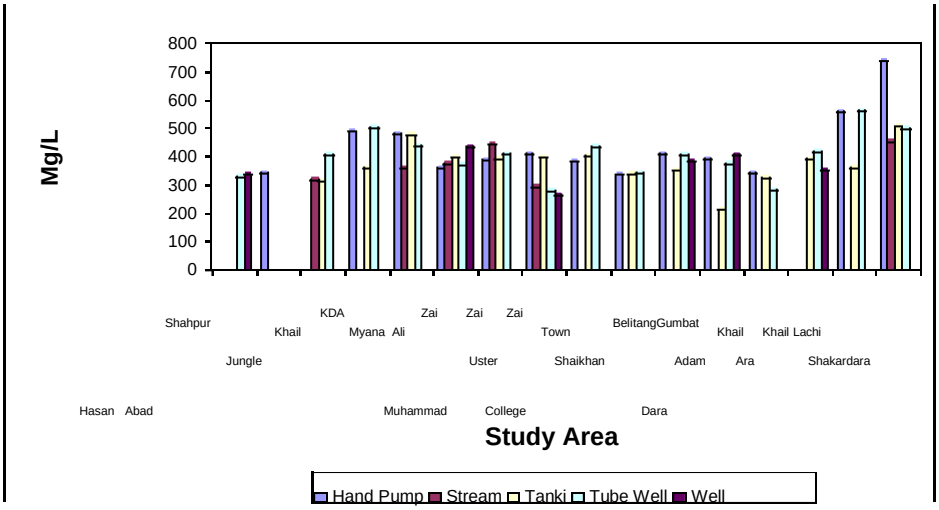

Figure 2. Total alkalinity of water samples.

to 1194, 732 to 7788 and 647 to 3010, respectively.

Bottled waters showed the electrical conductance values ranging from 216 to 500 µs/cm^3 (Table 2, Figure 3). Except eight samples, the electrical conductance values of all other 52 samples water were in the range of WHO 1200 µs/cm^3) and Pakistan (1000 to 1200 µs/cm^3) (standards (Table 1) (WHO, 1996; APHA, 1998; PCRWR, 2005; WHO, 2006).

Eight samples of high electrical conductance values include two sources of Lachi hand pump (7016 µs/cm^3) and tube well (7788 µs/cm^3), Belitang tube well (1232 µs/cm^3) and well (1280 µs/cm^3), Ara Khail tube well (1245 µs/cm^3) and well (3010 µs/cm^3), hand pump of Uster Zai (1844 µs/cm^3) and tube well of Shaikhan (1324 µs/cm^3). The high electrical conductance values above 1200 µs/cm^3 are the direct indication of the increase in the amount and mobility of ions in various drinking water sources. These are the ions which come from the break-down of different compounds and are able to conduct electricity. Thus, we can say that electrical conductance is the indirect measure of the presence of dissolved solids in water resources. The dissolved solids may be chloride, nitrate, sulphate, phosphate, sodium, magnesium, calcium, and iron. Thus, electrical conductance can be used as an indicator of water pollution (Hem, 1985).

Total dissolved solids

The TDS values of all water samples varied in the range of 188 to 4428 mg/L, the lowest being observed in Mitchell's bottled water while the highest in Lachi tube well. The TDS values of water from hand pumps, streams, tanks, tube wells and wells varied in the range of 514 to 3984, 346 to 643, 324 to 857, 430 to 4428 and

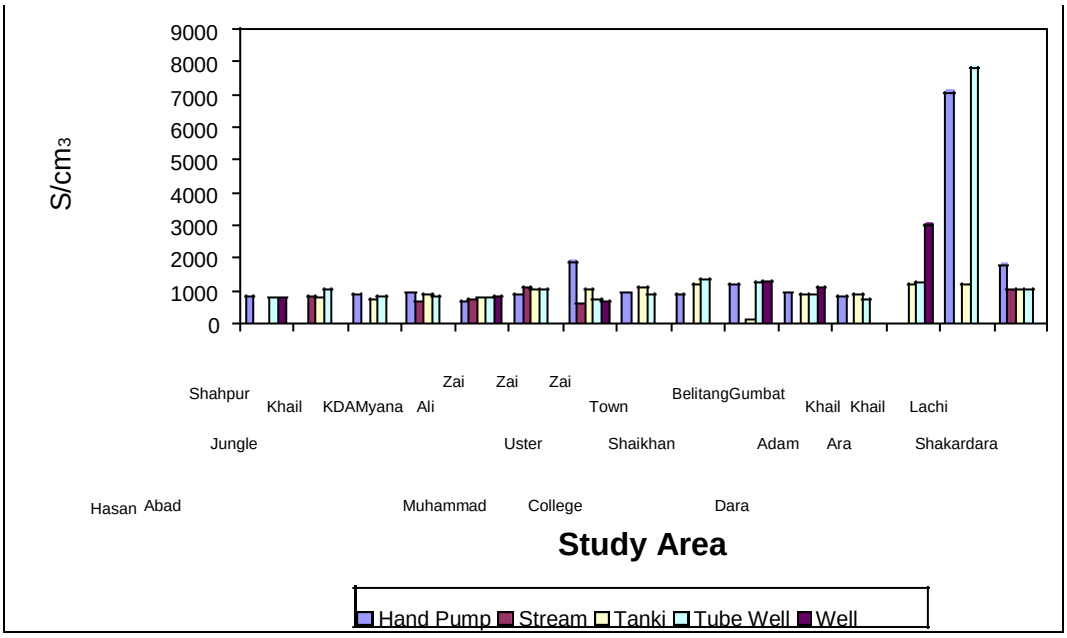

Figure 3. Electrical conductance of water samples.

408 to 1690 mg/L, respectively. Bottled waters showed the TDS values ranging from 188 to 322 mg/L.

Except five samples, the TDS values of all other 55 samples of water were found in the range of WHO (995 mg/L) standard for drinking water. Only three samples out of 60 were found to have high TDS values than Pakistan (1500 mg/L) standard (Tables 1 and 2, Figure 4) (WHO, 1996; 2006; APHA, 1998; PCRWR, 2005) .

The samples of high TDS values include Lachi hand pump (3984 mg/L) and tube well (4428 mg/L), Arakhail well (1690 mg/L), Shakardara hand pump (1088 mg/L) and Uster Zai hand pump (1266 mg/L).

Total suspended solids

The TSS values of all water samples varied in the range of 1 to 88 mg/L, the lowest being observed in Mitchell's bottled water while the highest in Lachi tube well. The TSS values of water from hand pumps, streams, tanks, tube wells and wells varied in the range of 2 to 70 mg/L, 4 to 9 mg/L, 2 to 26 mg/L, 2 to 88 and 3 to 18 mg/L, respectively. Bottled waters showed the TSS values ranging from 1 to 4 mg/L (Table 2, Figure 5).

The TSS values of more than 50% samples (34 out of 60) were found to be higher than the WHO and Pakistan standard (5 mg/L) for drinking water (Table 1) (WHO, 1996; APHA, 1998; PCRWR, 2005; WHO, 2006). However, only 4 samples of these 34 are having high TSS values than 20 mg/L. These highly polluted samples include Jungle Khail tank (26 mg/L), Lachi hand pump (70 mg/L) and tube well (88 mg/L) and Shakadara hand pump (55 mg/L).

Total solids

The TS values of all water samples varied in the range of 190 to 4516 mg/L, the lowest being observed in Mitchell's bottled water while the highest in Lachi tube well. The TS values of water from hand pumps, streams, tanks, tube wells and wells varied in the range of 524 to 4054L, 350 to 650, 350 to 872, 432 to 4516 and 413 to 1708 mg/L, respectively. Bottled waters showed TS values ranging from 190 to 326 mg/L (Table 2, Figure 6). The TS values of 5 samples were found higher than the WHO (1000 mg/L) standard for drinking water (Table 1) (WHO, 1996; APHA, 1998; PCRWR, 2005; WHO, 2006). The TS values of only 3 samples were found higher than the Pakistan (1500 mg/L) standard for drinking water (Table 1) (WHO, 1996; APHA, 1998; PCRWR, 2005; WHO, 2006). The highly polluted samples include Lachi hand pump (4054 mg/L) and tube well (4516 mg/L), and Shakadara hand pump (55 mg/L) (Table 2, Figure 6).

The presence of high levels of TDS, TSS and TS in drinking water is not acceptable due to the resulting taste and excessive scaling in water pipes of the water distribution systems. Water with very low concentrations of solids is also unacceptable to consumers because of its insipid taste, often resulting corrosion to water supply systems (WHO, 1996).

Ca hardness

Ca hardness values of all water samples were found in the range of 16 to 484 mg/L, the lowest being observed in Mitchell's bottled water while the highest in Lachi tube

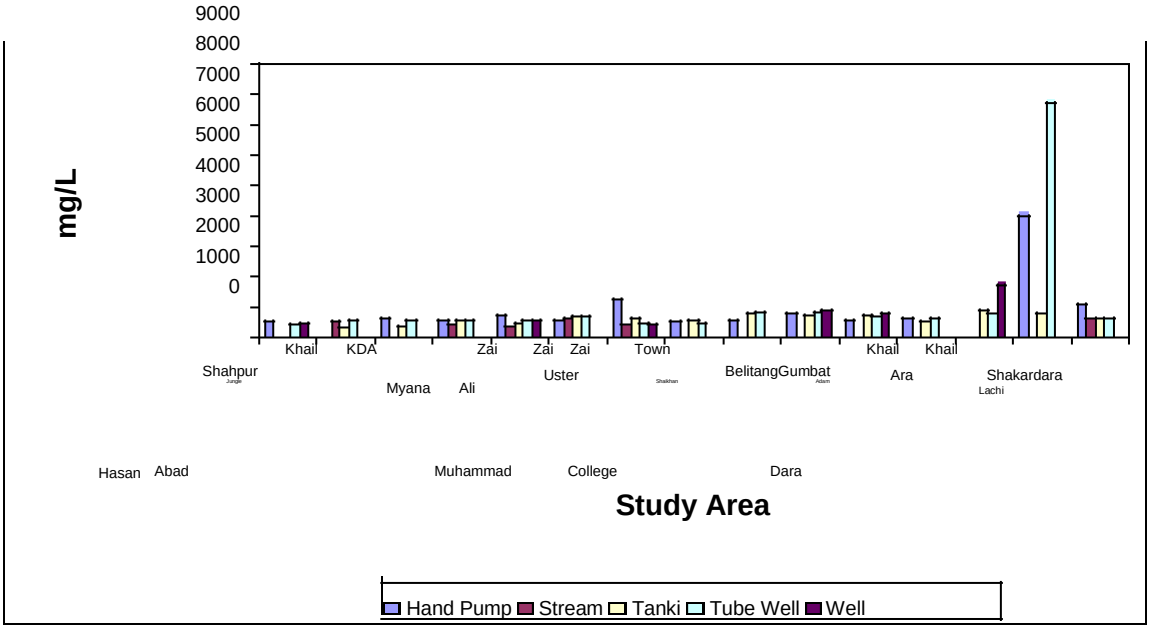

Figure 4. Total dissolved solids in water samples.

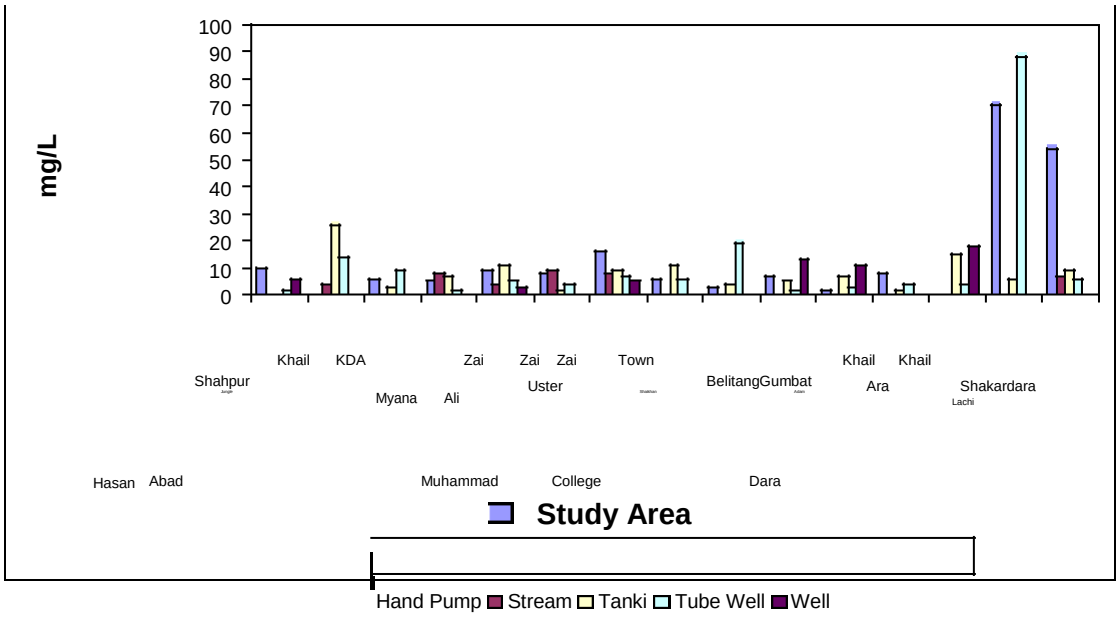

Figure 5. Total suspended solids in water samples.

well. Ca hardness from hand pumps, streams, tanks, tube wells and wells varied in the range of 88 to 448, 84 to 294, 29 to 322, 96 to 484 and 160 to 280 mg/L, respectively. Bottled waters showed the Ca hardness values ranging from 16 to 100 mg/L (Table 3, Figure 7).

The Ca hardness values of 18 samples were found higher than the WHO (250 mg/L) and Pakistan (75 to 200 mg/L) standards for drinking water (Table 1) (WHO, 1996; APHA, 1998; PCRWR, 2005; WHO, 2006). The highly polluted samples with Ca hardness values above 400 mg/L include Lachi hand pump (448 mg/L) and tube well (484 mg/L), and Usterzai hand pump (440 mg/L).

Mg hardness

Mg hardness values of all water samples varied in the range of 24 to 404 mg/L, the lowest being observed in Aqua bottled water while the highest in Lachi hand pump. The Mg hardness values of water from hand pumps, streams, tanks, tube wells and wells varied in the range of 108 to 404, 104 to 218, 112 to 236, 108 to 400 and 92 to 216 mg/L, respectively. Bottled waters showed the Mg hardness values ranging from 24 to 192 mg/L. The Mg hardness values of 28 samples were found higher than the WHO (150 mg/L) and Pakistan (80 to 150 mg/L)

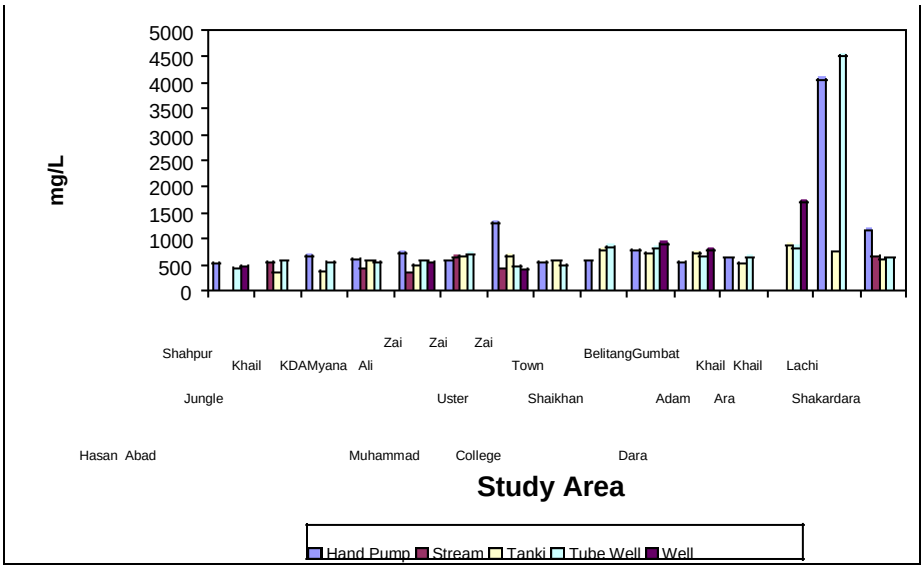

Figure 6. Total solids in water samples.

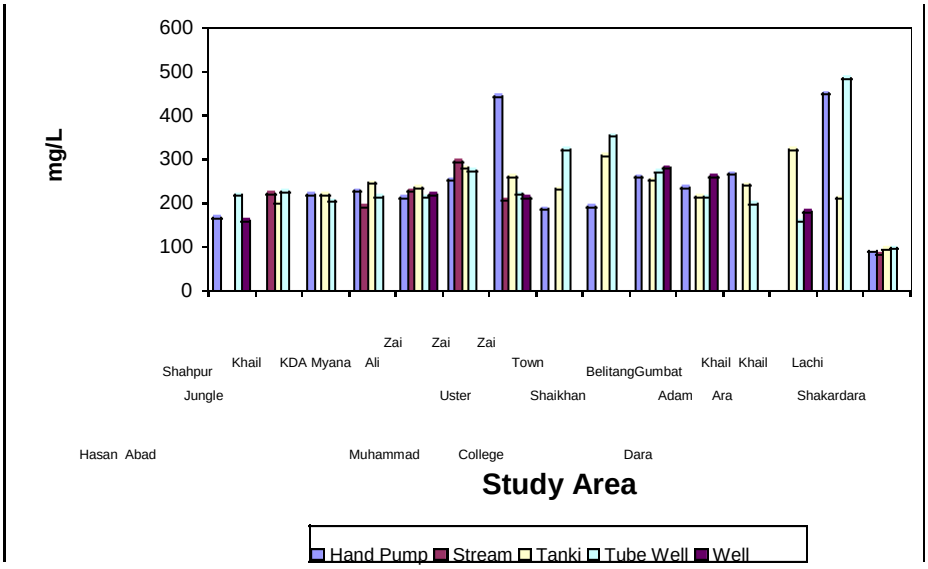

Figure 7. Calcium hardness in water samples.

standards for drinking water (Table 1) (WHO, 1996; APHA, 1998; PCRWR, 2005; WHO, 2006). The highly polluted samples with Mg hardness values above 250 mg/L, include Lachi hand pump (404 mg/L) and tube well (400 mg/L), and Usterzai hand pump (344 mg/L) (Table 3, Figure 8).

Total hardness

Total hardness values of water samples were found in the range of 64 to 884 mg/L, the lowest being observed in Aqua bottled water while the highest in Lachi hand pump. streams, tanks, tube wells and wells varied in the range of 176 to 852, 188 to 512, 178 to 500, 224 to 884 and 300 to 480 mg/L, respectively. Bottled waters showed the total hardness values ranging from 64 to 260 mg/L (Table 3, Figure 9). Five samples were found to have high values of total hardness than WHO (500 mg/L) and Pakistan (400 to 500 mg/L) standards for drinking water (Table 1) (WHO, 1996; APHA, 1998; PCRWR, 2005; WHO, 2006). The polluted samples with high total hardness values include Lachi hand pump (852 mg/L) and tube well (884 mg/L), Muhammadzai stream (512

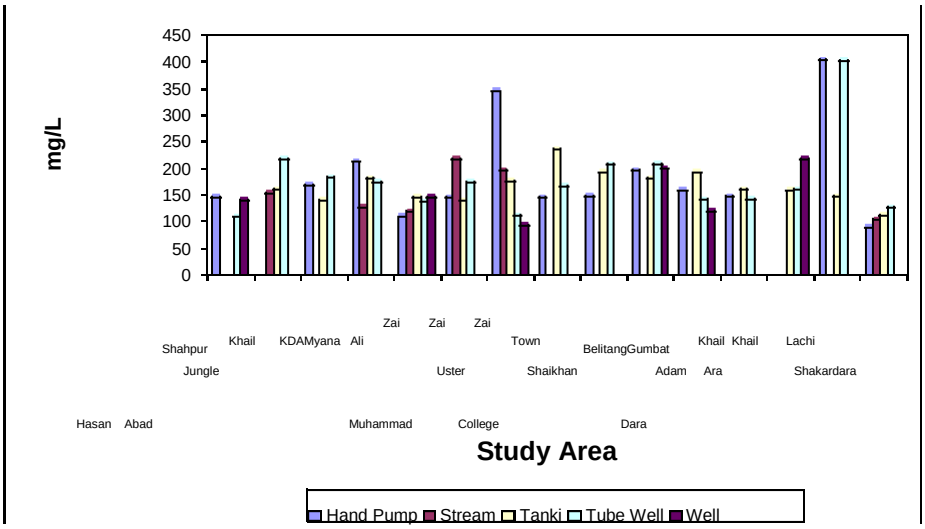

Figure 8. Magnesium hardness in water samples.

Table 3. Values of chemical parameters investigated (mg/L).

Study area	Source	Total alkalinity	Chloride	Hardness as $CaCO_3$		
				Ca hardness	Mg hardness	Total hardness
Hasan Abad Shahpur	Hand pump	340	35	164	144	308
	Tube Well	328	32	216	108	324
	Well	336	33	160	140	300
Jungle Khail	Stream	316	40	220	152	372
	Tank	312	34	200	160	360
	Tube well	404	55	224	216	440
KDA	Hand pump	488	234	218	168	396
	Tank	360	220	216	140	356
	Tube well	500	250	204	184	388
Myana	Hand pump	480	150	228	212	440
	Stream	360	110	188	128	316
	Tank	472	200	244	180	424
	Tube well	438	166	214	174	388
Ali Zai	Hand pump	360	40	212	108	320
	Stream	372	140	228	120	348
	Tank	396	150	236	144	380
	Tube well	366	138	214	136	350
	Well	432	150	216	144	360
Muhammad Zai	Hand pump	384	110	252	144	396
	Stream	440	182	294	218	512
	Tank	392	140	280	140	420
	Tube well	408	150	272	172	444
Uster Zai	Hand pump	408	240	440	344	784
	Stream	288	108	208	196	404
	Tank	396	128	260	176	436

Table 3. Contd.

	Tube well	276	78	220	112	332
	Well	260	68	212	92	304
	Hand pump	380	96	186	146	332
College Town	Tank	400	92	232	236	468
	Tube well	430	54	320	166	486
	Hand pump	336	78	188	148	336
Shaikhan	Tank	336	142	308	192	500
	Tube well	340	140	352	208	560
	Hand pump	408	178	260	196	456
Belitang	Tank	348	130	252	180	432
	Tube well	404	152	268	208	476
	Well	380	167	280	200	480
	Hand pump	390	138	234	158	392
Gumbat	Tank	212	154	214	192	406
	Tube well	374	144	214	142	356
	Well	404	176	260	120	380
	Hand pump	340	64	265	148	413
Dara Adam Khail	Tank	320	70	240	160	400
	Tube well	280	130	198	142	340
	Tank	392	120	322	158	480
Ara Khail	Tube well	412	140	160	160	320
	Well	348	264	180	216	396
	Hand pump	556	1280	448	404	852
Lachi	Tank	360	130	212	148	360
	Tube well	560	1420	484	400	884
	Hand pump	736	120	88	88	176
Shakadara	Stream	452	150	84	104	188
	Tank	504	40	92	112	178
	Tube well	496	140	96	128	224
	Nestle	136	73	80	36	116
	Wah	224	37	100	160	260
Bottle Water	Country	196	50	44	64	108
	Mitchell's	143	30	16	144	160
	Kinza	243	39	28	192	220
	Aqua	116	32	40	24	64

mg/L), Shaikhan tube well (560 mg/L) and Usterzai hand pump (784 mg/L).

By keeping in view the interaction of hardness with other factors, such as pH and alkalinity, it has been determined that water with hardness above 200 mg/L causes scale deposition in pipes of the distribution systems and also the increased soap consumption. On the other hand, soft water, with hardness less than 100 mg/L, is having a greater tendency to cause corrosion of pipes, and this is resulting in the presence of certain heavy metal ions, like cadmium, copper, lead, and zinc, in drinking water. The degree to which this corrosion and solubilization of me-tals will occur is again dependent upon the pH, alkalinity, and dissolved oxygen concentration

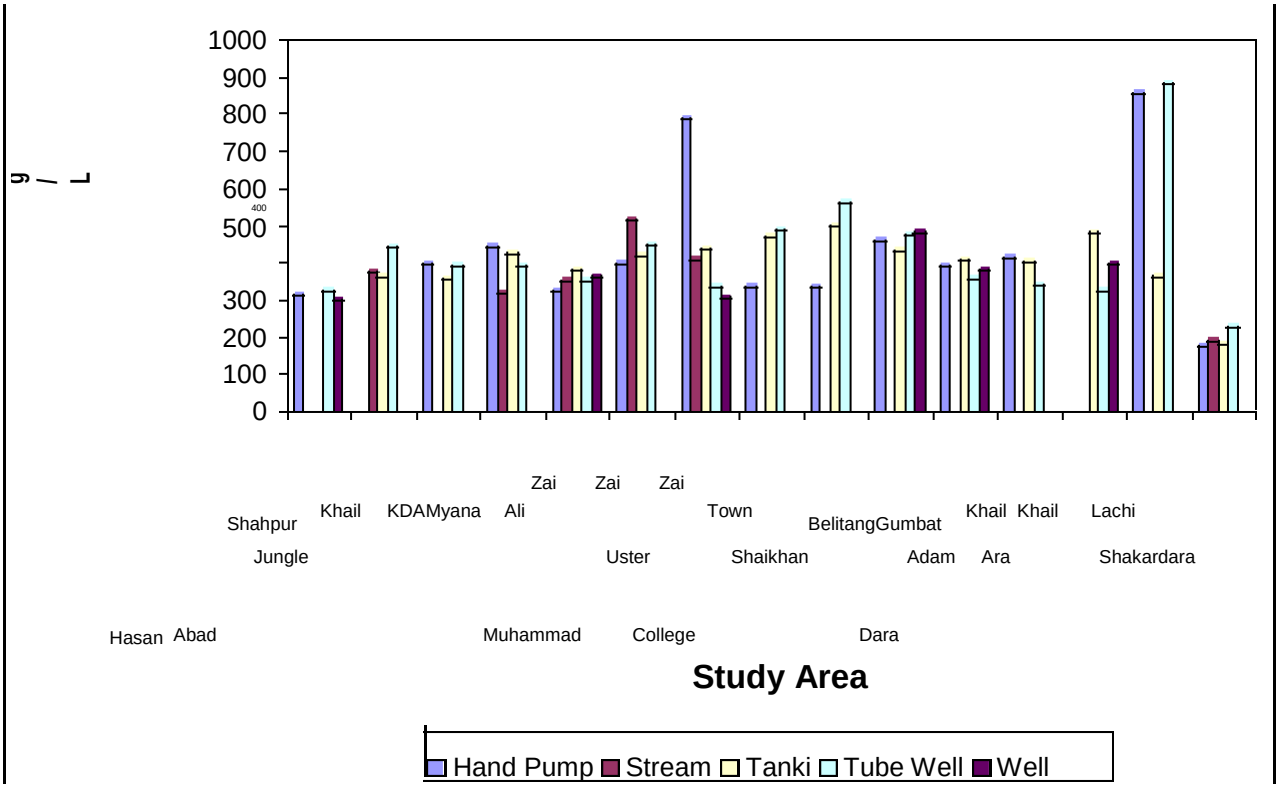

Figure 9. Total Hardness in water samples.

(WHO, 1996).

Chloride

The concentration of chloride in all water samples varied in the range of 30 to 1442 mg/L, the lowest being observed in Mitchells bottled water while the highest in Lachi tube well. The Cl^- content values of water from hand pumps, streams, tanks, tube wells and wells varied in the range of 35 to 1280, 40 to 182, 34 to 220, 32 to 1420 and 33 to 264 mg/L, respectively. Bottled water showed the Cl^- content values ranging from 30 to 73 mg/L (Table 3, Figure 10). The Cl^- content values of 4 samples were found higher than the WHO (250 mg/L) standard for drinking water while only 2 samples showed high concentration of Cl^- than Pakistan (200 to 600 mg/L) standard for drinking water (Table 1) (WHO, 1996; APHA 1998; PCRWR, 2005; WHO, 2006). The polluted samples include Lachi hand pump (1280 mg/L) and tube well (1420 mg/L), Arakhel well (264 mg/L), Uster Zai hand pump (240 mg/L) and KDA hand pump (234 mg/L).

The electrical conductivity of water is increased by chlorides. Corrosion of metal pipes is also increased, because chloride reacts with metal ions to form soluble salts, resulting in the increase levels of metals in drinking water. Lead pipes form a protective oxide layer, but chloride increase galvanic corrosion and cause pollution. Chlorides also increase the rate of pitting corrosion of metal pipes. Thus, chlorides also cause water pollution indirectly (WHO, 1996).

Conclusions

Results showed that drinking water sources of Kohat district are polluted. The most polluted areas are Shakardara, Lachi and Ara Khail. In these areas, all the sources were found polluted, thus it may be concluded that water pollution is related to the areas. In the city regions, no serious threats were found. Among the various sources, wells and tanks were found highly polluted. These are not well protected sources and are thus polluted by several means. Tube wells were found to be the most suitable source for drinking water in Kohat. In these sources as no storage is involved, the chance of water contamination is less. All the bottled waters analyzed were found to have lower values of various parameters than WHO/Pakistan standards.

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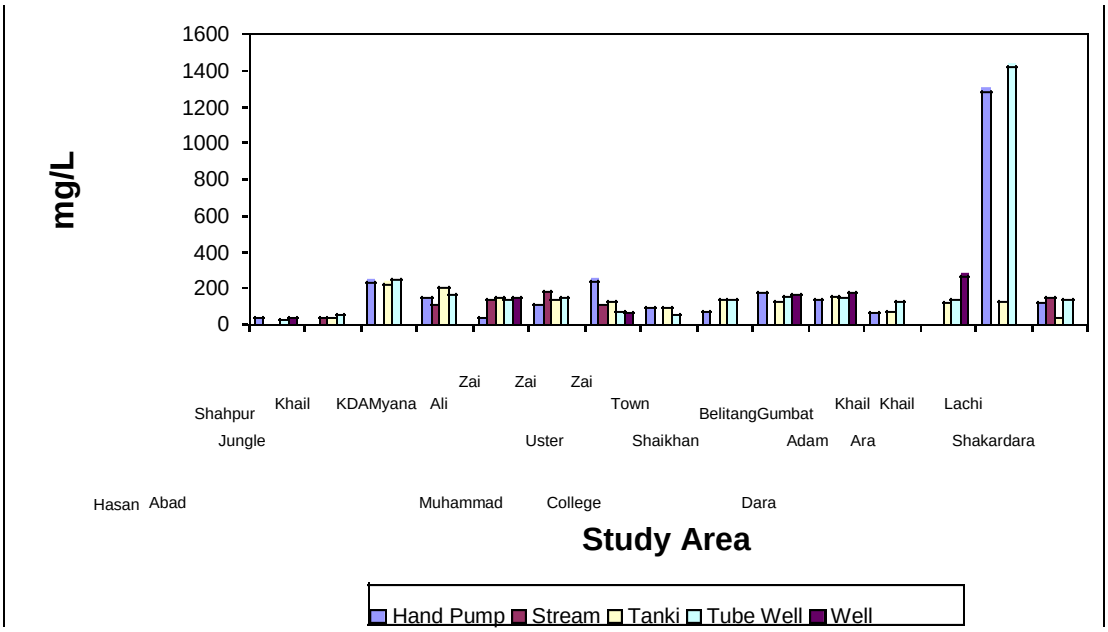

Figure 10. Chloride in water samples.

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