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Physicochemical investigation of the drinking water sources from Mardan, Khyber Pakhtunkhwa, Pakistan

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A total of 39 drinking water sources were analyzed for important physicochemical parameters to evaluate their suitability for human consumption. Samples were collected from the ground water supplies (tube wells, open wells and hand pumps) of highly populated 13 union councils from the urban area of district Mardan. Physical parameters studied include temperature, color, taste, odor, total dissolved solids (TDS), pH, electrical conductivity (EC), and turbidity. The chemical parameters analyzed were, total hardness, calcium (Ca), magnesium (Mg), bicarbonate (HCO_3) and alkalinity. Results showed that EC of 38%, taste of 23%, hardness of 20% and TDS of 15% samples were not in the permissible ranges specified by the World Health Organization (WHO) and Pakistan recommended standards for drinking water. The deterioration of various drinking water sources were found to be dependent upon the geological strata of the area, waste sources and damaged outlived distribution system passing through sewage lines.

Key words: Drinking water, Mardan, physicochemical investigation, World Health Organization (WHO).

INTRODUCTION

Water is an essential element for life. Fresh water comprises 3% of the total water on earth but only a small percentage (0.01%) of this fresh water is available for human consumption (Hinrichsen and Tacio, 2002). Safe drinking water is the basic need for safeguarding the health and well-being of humans all over the world (Ahmad, 2005). Being the most drinking fluid by living things and universal solvent, water is often a potential source of causing infections (Joyce et al., 1996). Nearly 75% of the world wide communicable diseases are water borne (Shengji et al., 2004). World Health Organization (WHO) declares that in developing countries, 80% of all human diseases are water borne (Abera et al., 2011).

Drinking water quality has been debated throughout the world (Thurman et al., 1998; Leoni et al., 2005). Generally the major sources of water pollution and ultimately of waterborne diseases are considered to be the direct discharge of domestic and industrial effluent wastes, leakage from water tanks and poor management of farm wastes (Jain et al., 2005; Huttly, 1990). Various researchers have shown that drinking water in many countries does not meet WHO standards (Aydin, 2007; Gupta et al., 2009; Gyamfil et al., 2012).

Water pollution is one of the major threats to public health in Pakistan. Drinking water quality is poorly managed and monitored. It is deteriorating mainly as a result of disposal of the municipal and industrial wastewaters and also because of the saline drainage flow from agricultural areas (Tahir et al., 1998; Chilton et al., 2001). Polluted drinking water causes outbreak of

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diseases. Recently in three districts of Sind province, namely Thatta, Badin, and Thar, poor water quality was found responsible for gastroenteritis, diarrhea and vomiting, kidney, and skin problems (Memon et al., 2011). Pakistan was hit by serious floods in the year 2010 which also reported to have deteriorated the quality of drinking water quality of the area (Baig et al., 2012a). Other research studies in the past have shown that various quality parameters of Pakistan drinking water are not in accordance to the WHO/Pakistan standards (Rahman 1996; Chilton et al., 2001; Malana and Khosa, 2011; Farid et al., 2012; Khan et al., 2012a, b, c; Khan et al., 2013).

The increasing pollution of drinking water sources in Pakistan and the consequent effects on human health and the environment is an issue of great concern. In our previous study, ground water sources of district Mardan was found polluted with Faecal coliform and *Escherichia coli*. The major cause of contamination was found to be the susceptibility of drinking water sources to intrusions from the nearest contamination sources (Khan et al., 2012a). The present study aimed at physicochemical investigation of drinking water sources of urban Mardan, as a continuation of our previous work, to confirm and strengthen our previous results on drinking water pollution and draw valuable recommendations to solve the problem.

MATERIALS AND METHODS

Sampling

A total of 39 ground water samples were collected from domestic tube wells (DTW), open wells (OW) and hand pumps (HP) of the selected high populated 13 union councils from the urban area of district Mardan. All samples were studied in triplicate, thus making a total of 117 samples analyzed. Information on district Mardan and identification of the sampling regions by GPS is cited in Khan et al. (2012a). Detailed survey of the water supply sources and contamination sources traced are mentioned in Table 1. Clear, clean and dry polyethylene bottles were used for samples collection, following standard procedures, properly tagged and stored in refrigerator before analysis for various quality parameters (Lenore et al., 1998; Khan et al., 2013).

Physical parameters

Temperature was measured directly by using centigrade thermometer at the sample collection point. Color, odor and taste of the water samples were measured with sense organs. pH was measured by electrometric method, using pH meter, Mettler Delta 320, England, while electrical conductivity was determined by laboratory method, using conductivity meter, Jenway 4060, England. Total dissolved solids were measured by drying the filtered sample in oven, Memmert B 54, Schwabach W. Germany, at 103-105°C. The increase in weight was expressed as mg of total dissolved solids per liter (Lenore et al., 1998; Khan et al 2013).

Chemical parameters

Total hardness was determined as mg $CaCO_3$/L, by EDTA titrimetric method, using eriochrome black-T indicator and standardized solution of ethylenediamminetetraacetic acid (EDTA). Calcium hardness was measured by EDTA titrimetric method, using murexide indicator and standardized ethylenediamminetetraacetic acid (EDTA) solution. Magnesium hardness was calculated from the difference between the total hardness and calcium hardness. Bicarbonate was measured by HCl titration while alkalinity was obtained as mmol/L, by dividing the bicarbonate values over 50 (Lenore et al., 1998; Khan et al., 2012a; Khan et al., 2013).

RESULTS AND DISCUSSION

Physical parameters

Temperature of the drinking water sources analyzed ranged between 24.2 and 32.3°C. Temperature is the indirect indicator of contamination. High temperature provides suitable environment for microbial growth. Color, odor and taste are the direct indicators of chemical contaminations. According to WHO standards, there should be no color, odor or taste in drinking water (Table 2) (WHO, 1996; Lenore, 1998; WHO, 2003; PCRWR, 2005; WHO, 2006: NSDWQ, 2008).

Out of the total 39 samples, one sample was found to show faint yellow color (Table 3). The source of the sample was open well of Mohallah Bara Khankhel where water table was 60 ft deep and the source was at 100 ft depth. The surrounding possible contamination sources found were garbage place and gutter, which are at 45 ft distance (Table 1). Thus the color of the sample may be attributed to the soluble metal ions, as this sample also showed high conductivity and TDS.

Odor is undesirable in drinking water which may be due to excessive organic and inorganic contamination. According to WHO and Pakistan standards, drinking water should be free of odor. From Table 3, none of the samples showed any objectionable odor which means that all water sources is clear and safe for human consumption. Taste in water arises due to excess of inorganic or organic salts, or other organic molecules. Total of 9 samples (23%) showed objectionable taste. The sources of these samples were open wells (03), domestic tube wells (03), hand pumps (02) and one public water supply scheme. Of the open wells, two were very shallow with water table 7-8 ft, while the other was 60 ft deep. All the other samples with objectionable taste were having water table in the range of 20-160 ft. The surrounding contamination sources were also quite away from these sources, which meant that the water table strata carry the metallic salts dissolved into the water sources, thereby showing slight taste. In case of public water supply scheme, the objectionable taste may be deduced from its damaged outlived distribution system passing through sewage lines.

Turbidity in water is because of the presence of suspended particles of clay or silt and colloidal organic materials. According to WHO guidelines, maximum acceptable value for turbidity is 5 NTU. Only one sample,

Table 1. Sampling and information of contamination sources of the study areas.

Water supply sources						Sources of contamination			
Code	**WSS type**	**Age**	**Lining**	**Depth (ft)**	**Water table (ft)**	**Source type**	**Age**	**Lining**	**Distance from WSS (ft)**
A-1	DTW	1986	GI pipe	30	25	S. waste	1986	Bricks/cement	15
A-2	HP	1979	PVC pipe	28	20	S. waste /Sewerage line	1975	Bricks/mud	1
A-3	DTW	2001	GI pipe	60	55	Latrine	2001	Bricks/cement	6
A-4	DTW	1990	GI pipe	100	30	Latrine/Sewerage line	1989	Bricks/cement	16
A-5	DTW	2009	GI pipe	85	50	S.waste/Latrine/Sewage/Graveyard	1980	Bricks/cement	7
A-6	DTW	1987	GI pipe	100	50	S.waste /Latrine	1990	Cement	7
A-7	DTW	1983	GI pipe	100	50	S.waste/Latrine/ Sewerage/Gutter	1980	Bricks/cement	4
A-8	DTW	1981	GI pipe	90	60	S.waste/Latrine/Sewage/Gutter	1960	Bricks/cement	3
A-9	DTW	1983	GI pipe	55	45	S.waste /Gutter	2001	Bricks/cement	14
A-10	DTW	2009	GI pipe	120	40	S.waste /Effluent stream	1920	Mud	33
A-11	OW	1984	Cement	8	7	Animals Farm/Water logged area	1930	Mud	3
A-12	OW	1999	Mud	12	10	S.waste/Animals Farm/Water logged area	1984	Mud	12
A-13	DTW	2004	GI pipe	75	70	Latrine/Gutter	1989	Bricks/mud	33
A-14	WSS	1991	PVC pipe	280	120	Sewerage line/ Rusted pipes	1991	Bricks/cement	10
A-15	DTW	1980	GI pipe	70	50	Latrine/Sewage	1950	Bricks/cement	8
A-16	DTW	1995	GI pipe	100	50	Sewage/Latrine/Gutter	1985	Bricks/cement	15
A-17	DTW	2000	GI pipe	75	60	S.waste /Gutter	1994	Bricks/cement	12
A-18	DTW	1998	GI pipe	110	55	Municipal Sewage	1985	Rocks/cement	10
A-19	DTW	2007	GI pipe	60	50	S.waste /Latrine/Gutter	1987	Bricks/cement	13
A-20	OW	1949	Rocks/mud	100	60	S.waste /Gutter	1949	Bricks/cement	45
A-21	DTW	2007	GI pipe	180	160	Latrine	2007	Bricks/cement	48
A-22	DTW	2002	GI pipe	120	100	S.waste/Latrine/Sewage	1980	concrete	10
A-23	DTW	1994	GI pipe	120	110	S.waste /Latrine	1948	Bricks/cement	6
A-24	OW	1960	Bricks/cement	50	40	Sewage/Latrine	1965	Bricks/cement	20
A-25	DTW	1995	GI pipe	80	40	Sewage	1990	Bricks/cement	1
A-26	DTW	2003	GI pipe	70	40	Gutter/Latrine/Sewage	1996	Bricks/cement	2
A-27	DTW	1994	GI pipe	80	70	S.waste /Latrine/Gutter	1994	Bricks/cement	15
A-28	DTW	2003	GI pipe	120	70	Latrine/Sewage/Agri. Field/Animals Farm	1992	Bricks/cement	10
A-29	DTW	1998	GI pipe	105	50	S.waste/Latrine/Sewage/Gutter	1998	Concrete	5
A-30	OW	1970	Bricks/cement	12	8	Latrine/Sewage/Agri. Field/Animals Farm	1960	Mud	20
A-31	DTW	1999	GI pipe	180	50	S.waste / Sewage	1997	Bricks/cement	20
A-32	DTW	2009	PVC pipe	120	80	S.waste /Latrine	2009	Bricks/cement	17
A-33	DTW	2009	PVC pipe	100	70	Sewage/Latrine	2007	Concrete	6
A-34	HP	2002	GI pipe	65	45	Garbage/Sewage/Gutter	1999	Bricks/cement	10
A-35	HP	2004	GI pipe	50	40	Effluent stream/Animals Farm	2000	Bricks/cement	5
A-36	DTW	2008	GI pipe	70	45	S.waste /Animals Farm/ Sewage	2000	Concrete	30
A-37	DTW	1997	GI pipe	50	45	Latrine	2000	Concrete	60
A-38	DTW	1994	PVC pipe	45	40	S.waste /Latrine	1990	Bricks/cement	45
A-39	HP	1992	GI pipe	70	60	S.waste /Sewage	1980	Bricks/cement	3

open well of Chakaro pull, Fazalabad, was found to have turbidity value (6.9), beyond permissible limits (Table 3, Figure 1). These results were supported by published literature (Baig et al., 2012b). The water table and depth of the polluted source was 7 and 8 ft respectively. The well was internally lined with cement; however, the lower portion was unpaved. The age of the well was 25 years. It was located in the vicinity of animal farms and water

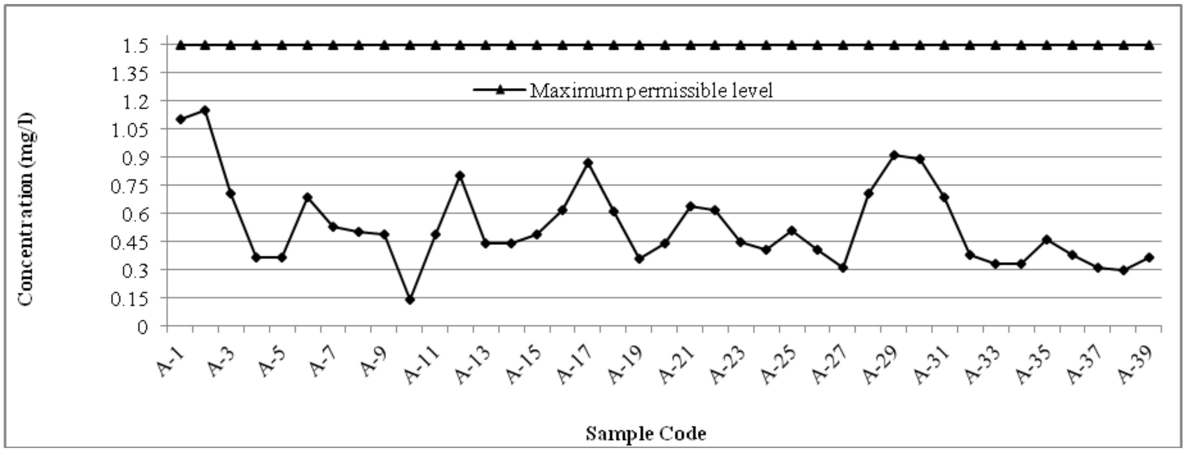

Figure 1. Levels turbidity in selected water sources analyzed.

Table 2. Guidelines and standard values for drinking water quality.

S/N	Guideline/standard values for Pakistan				WHO standards
	Parameter	**Unit**	**HDL***	**MPL****	
1	Color	TCU	15	15	15
2	Odor	---	Non obj/Accep	Non obj/Accep	Non obj/Accep
3	Taste	---	Non obj/Accep	Non obj/Accep	Non obj/Accep
4	TDS	ppm	1000	1500	1000
5	pH	---	7.0-8.5	6.5-9.2	6.5-9.2
6	EC	$\mu S/cm^3$	1000.00	1200.00	1200.00
7	Turbidity	NTU	05.00	05.00	05.00
8	Total hardness	ppm	200.00	500.00	500.00
9	Ca hardness	ppm	75.00	200.00	250.00
10	Mg hardness	ppm	30.00	150.00	150.00
11	Total alkalinity	ppm	400.00	500.00	500.00

*Highest desirable level; **maximum permissible level; Non obj/Accep, Non objectionable/Acceptable.

logged area (Table 1). Hence the clay texture at the bottom of the wells may be responsible for the high turbidity of the water sample.

Power of hydrogen ion concentration (pH) is of utmost importance in drinking water quality. Other contaminations like microbial activities and solubility and stability of metal salts etc, primarily depends on pH level of water. According to WHO standards for drinking water, pH value must be in the range of 6.5-8.5. It is clear from the Table 3, that for all samples, the values of pH were within the permissible limits, and none of the sample has pH exceeding 8.5 or below 6.5.

Electrical conductivity (EC) is the measure of ions concentration in water. Its value is the direct indication of the presence of mineral salts present in the water. The guideline value of electrical conductance for drinking, water set by WHO is 1200 $\mu S/cm^3$ (Table 2). According to the results, 15 samples (38%) were those having electrical conductance values more than the permissible limits (Table 3). The same results were shown for drinking water of district water (Khan et al., 2012; Khan et al., 2013). In case of high value of EC, there will be high concentration of electrolytes, whereas in case of low EC, either the water will be contaminated with organic materials or low electrolytes concentration.

The high values of EC may be attributed to the low water table and the geological strata of the area. It may be assumed that soil contents of these areas are rich in variety of salts, whereby shallow water tables carry these salts in dissolved states from the lower strata to the easily accessible water sources. The EC of samples collected from same area is matching, except those sources which have sewage and irrigation channel in their premises. These eventually increase further more the salts contents of the water as they collect excessive chemical contaminations as municipal effluents during their course

Table 1. Physical and aesthetic parameters of selected urban drinking water sources.

S/N	Code	Location	Source	Color	Taste	Odor	Turb. (NTU)	Temp. (ºC)	pH	EC (µS/cm^3)	TDS (ppm)
1.	A-1	Bagh-e-Irum, Janabad	DTW	C.less	T.less	O.less	1.1	32.3	6.9	1595	992
2.	A-2	Janabad, Moh. Tanki	HP	C.less	Obj.	O.less	0.3	26.1	6.9	1005	595
3.	A-3	Janabad, Moh. Tanki	DTW	C.less	T.less	O.less	2.0	25.9	7.1	950	577
4.	A-4	Baghdada, Bar Kanday	DTW	C.less	T.less	O.less	0.5	24.6	7.2	1428	929
5.	A-5	Baghdada, Gadbano	DTW	C.less	T.less	O.less	1.7	24.9	7.6	1100	606
6.	A-6	Baghdada, Pohan Colony	DTW	C.less	T.less	O.less	1.0	24.4	6.8	852	527
7.	A-7	Gulshan Colony, Kanal Road	DTW	C.less	Obj.	O.less	2.9	24.7	7.2	766	450
8.	A-8	Gulshan colony, Railway Patak	DTW	C.less	T.less	O.less	0.0	28.6	6.9	890	535
9.	A-9	Kanal Road, Khyber Street	DTW	C.less	T.less	O.less	2.0	26.8	7.0	375	864
10.	A-10	Kanal Bank, Shamsi Road	DTW	C.less	T.less	O.less	0.5	25.0	6.9	715	423
11.	A-11	Chakaro pull, Fazalabad	OW	Muddy	Obj.	O.less	6.9	24.0	7.1	1660	1012
12.	A-12	Chakaro pull, Itifaq colony	OW	C.less	Obj.	O.less	2.4	24.4	6.9	1835	1170
13.	A-13	Bari Cham, Moh. Sari	DTW	C.less	T.less	O.less	2.0	24.8	7.7	1225	788
14.	A-14	Bari Cham, Samarabad	WSS	C.less	Obj.	O.less	0.2	29.6	7.3	790	482
15.	A-15	Bari Cham, Moh Mesriabad	DTW	C.less	Obj.	O.less	0.7	25.4	7.2	1605	1109
16.	A-16	Cannal Road, Agr. Office	DTW	C.less	T.less	O.less	2.8	24.0	7.1	1545	1079
17.	A-17	Cannal Road, Bilal Town	DTW	C.less	T.less	O.less	1.1	25.5	6.9	1280	704
18.	A-18	Cannal Road, Bilal Town	DTW	C.less	T.less	O.less	2.2	29.1	7.1	990	563
19.	A-19	Moh. Bara Khankhel	DTW	C.less	T.less	O.less	0.0	26.9	6.9	1763	977
20.	A-20	Moh Bara Khankhel	OW	Yellow	Obj.	O.less	3.9	29.4	7.7	2450	1379
21.	A-21	Mosque Bara Khankhel	DTW	C.less	Obj.	O.less	1.3	25.5	6.9	2536	1398
22.	A-22	Bicket Gunj, Moh., Dr. Latif	DTW	C.less	T.less	O.less	1.0	28.1	7.2	720	500
23.	A-23	Bicket Gunj, Moh., Dr.Latif	DTW	C.less	T.less	O.less	2.1	25.1	7.0	1500	828
24.	A-24	Bicket Gunj, Husanain Street	OW	C.less	T.less	O.less	0.6	28.6	7.0	1500	826
25.	A-25	Kas Koroona, Moh. tekadaran	DTW	C.less	T.less	O.less	0.1	27.8	7.1	1445	800
26.	A-26	Kas Koroona, Moh. Abdullah	DTW	C.less	T.less	O.less	0.2	28.0	7.2	1032	584
27.	A-27	Kas Koroona, G.H.School	DTW	C.less	T.less	O.less	2.0	27.4	7.5	1110	658
28.	A-28	Dargai, Qutab Palao	DTW	C.less	T.less	O.less	1.2	28.1	7.9	1085	612
29.	A-29	Dargai, Qutab Palao	DTW	C.less	T.less	O.less	0.9	28.1	7.3	1015	566
30.	A-30	Akhon Baba, Khanmia mosque	OW	C.less	T.less	O.less	1.0	24.0	8.1	1745	999
31.	A-31	Allahdad khel, Nali Par	DTW	C.less	T.less	O.less	2.6	29.1	7.1	1360	754
32.	A-32	Allahdad khel, Sherabad	DTW	C.less	T.less	O.less	1.9	26.1	7.8	1502	854
33.	A-33	Allahdad khel, Sherabad	DTW	C.less	T.less	O.less	0.5	26.4	7.7	1494	826
34.	A-34	Skandari, Moh. Bachagano	HP	C.less	Obj.	O.less	0.7	28.7	7.6	1140	631
35.	A-35	Skandari, Moh.Bachagano	HP	C.less	T.less	O.less	0.9	25.0	7.8	1070	603
36.	A-36	Skandari, Moh.Sultan Mehmod	DTW	C.less	T.less	O.less	3.8	25.2	7.4	1715	946
37.	A-37	Par Hoti, Moh.Norman khel	DTW	C.less	T.less	O.less	0.0	26.6	8.0	1205	707
38.	A-38	Anwar Paki Degi, Mohib Road	DTW	C.less	T.less	O.less	0.8	24.9	8.1	1260	699
39.	A-39	Par Hoti, Moh. Habib Gul	HP	C.less	T.less	O.less	1.9	24.2	7.9	1360	753

DTW, domestic tube well; OW, open well; HP, hand pump; C.less, colorless; O.less, odorless; T.less, tasteless; Obj., objectionable.

of running. On the other hand in case of deep sources like domestic tube well, the salty sap of the water table cannot access the deeper aquifer due to which they show slightly low value of EC.

Total dissolved solids give an estimation of the soluble organic and inorganic salts in water. The maximum permissible level for TDS in drinking water set by WHO is 1000 ppm. The TDS values of the water sources analyzed show that out of 39 samples only six have TDS values beyond MPL set by WHO (Table 3, Figure 2). These sources must be treated before using for drinking purposes (Mahmood et al., 2011; Baig et al., 2011). Of these six samples, three samples (A-11, A-12 and A-20) were those collected from open wells while the rest (A-

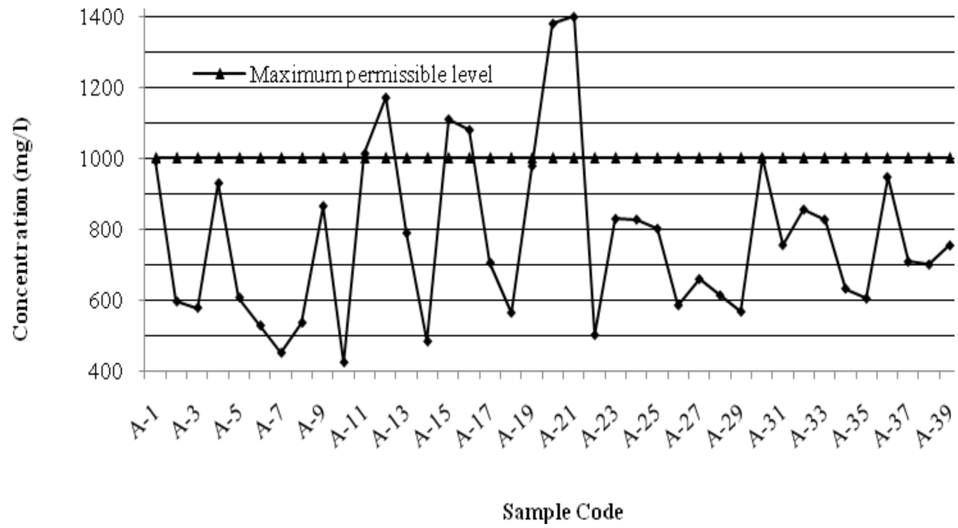

Figure 2. Level of TDS in water samples of the selected areas.

15, A-16, A-21) were from domestic tube wells. The details about these sources in Table 1, showed that in water table of sample A-11 and A-12 lies in range of 7-10 ft, whereas depth of well was 8-12 ft. It was noted that both the wells are located in water logged area which always have high salts concentration. As both the wells were shallow, so it may be therefore concluded that high salinity in the surrounding caused high TDS value. The third open well A-20 was about 60 years old, having 100 ft depth with water table at 60 ft. The surrounding contamination sources were found gutter and garbage places located at sufficient distance of 45 ft. Sample A-21 collected from domestic tube well was located in the same area of UC Mardan Khas. It has well depth of 180 ft and water table at 160 ft and located 48 ft away from nearest contaminated source of latrine. It seems that the underground strata contain high concentration of easily soluble salts, which may be the main cause of high TDS value.

Sample A-15 and A-16 were collected from domestic tube wells, having age of 25-30 years and water table of 50 ft. The surrounding sewage line, gutter and latrine were located at about 8-15 ft away. The domestic tube wells and surrounding contamination sources were well lined and properly protected. Viewing other chemical profile of these samples, it was suggested that areas of these samples were rich in various water soluble minerals causing high TDS values. Out of 39 samples, 36 show TDS value relatively higher (> 500 ppm), therefore it may be concluded that the areas which showed high TDS values at water sources were rich in minerals. On overall basis, it was evident that most of the urban areas of Mardan have ground water rich in minerals and even in some cases many parameters of the same sample were beyond the permissible limits.

Chemical parameters

Bicarbonate is an important anion present in all ground and surface waters, normally ranging from 25 to 400 ppm. Bicarbonate salts pass to water sources from weathering of carbonaceous rocks. In the studied samples, the concentration ranged from 250 to 690 ppm (Table 4). Viewing the results area wise, it was found that more than 500 ppm of bicarbonates prevail in three sources of Hoti, two sources of Gulibagh, and in one source of Mardan Khas, Dargai, Skandari Koroona and Par Hoti union councils (Figure 3). In all water sources of Muslimabad, Bicket Gunj and Par Hoti and two water sources of UC Bagh-e-Iram, Baghdada, Bijlighar, Baricham, Mardan Khas, Kas Koroona, Dargai and Skandari Koroona, carbonate level ranged from 300-500 ppm, followed by one water source in Bagh-e-Iram, Baghdada, Bijlighar, Baricham and Kas Koroona, where it was between 250-300 ppm. As bicarbonate level in the ground water sources is of geological origin, therefore its concentration depends on location. The main sources of bicarbonates in the ground water are of carbonaceous rocks, which dissolve in water to give bicarbonate. The common rocks of carbonates include calcite and dolomite and calcites (Kahlown et al., 2006). It was therefore assumed that areas showing high level of bicarbonates in ground water have deep soil rich in carbonaceous minerals.

Calcium is an important mineral, essential for carrying out numerous functions in the body like blood clotting and transmission of nerve impulses. According to WHO and Pakistan standards (WHO, 1996), the maximum permissible amount of calcium in drinking water is 75 ppm. The calcium levels in the ground water of selected areas ranged from 16 to 68 ppm, indicating that all samples contains adequate quantities of calcium, lying

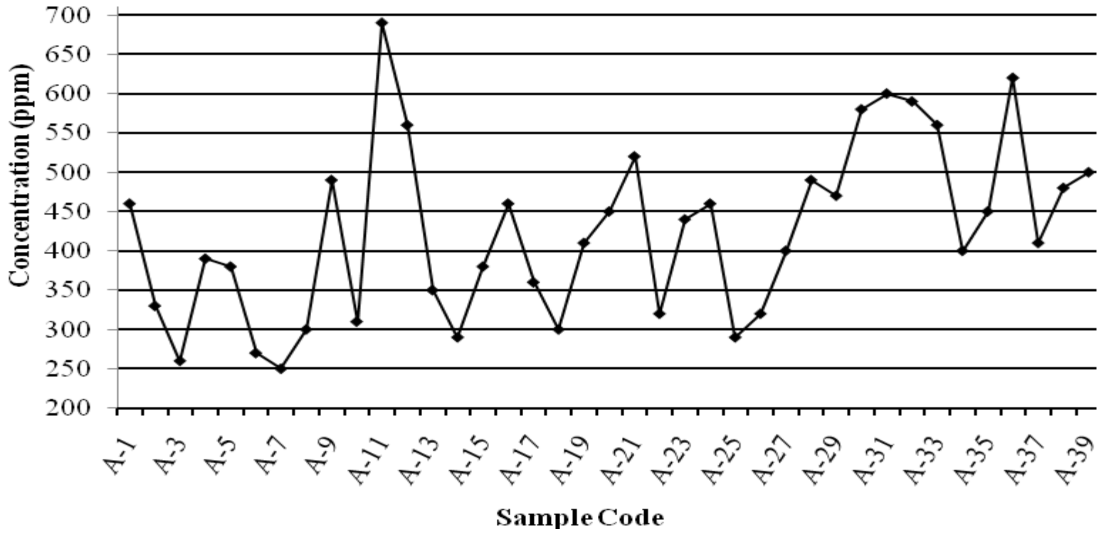

Figure 3. Level of bicarbonate in water samples of the selected area.

Table 4. Chemical parameters of selected urban drinking water sources.

S/N	Code	Location	Water source	Hardness (ppm)	Ca (ppm)	Mg (ppm)	Alkalinity (mmol/L)	HCO_3^- (ppm)
1	A-1	Bagh-e-Irum, Janabad	DTW	320	20	65.61	9.2	460
2	A-2	Janabad, Moh. Tanki	HP	170	28	24.3	6.6	330
3	A-3	Janabad, Moh. Tanki	DTW	200	24	34.02	5.2	260
4	A-4	Baghdada, Bar Kanday	DTW	510	16	114.21	7.8	390
5	A-5	Baghdada, Gadbano	DTW	380	20	80.19	7.6	380
6	A-6	Baghdada, Pohan Colony	DTW	240	48	29.16	5.4	270
7	A-7	Gulshan Colony, Kanal Road	DTW	210	32	31.59	5.0	250
8	A-8	Gulshan colony, Railway Patak	DTW	270	24	51.03	6.0	300
9	A-9	Kanal Road, Khyber Street	DTW	290	40	46.17	9.8	490
10	A-10	Kanal Bank, Shamsi Road	DTW	280	48	38.88	6.2	310
11	A-11	Chakaro pull, Fazalabad	OW	170	48	12.15	13.8	690
12	A-12	Chakaro pull, Itifaq colony	OW	240	44	31.59	11.2	560
13	A-13	Bari Cham, Moh. Sari	DTW	450	64	70.47	7.0	350
14	A-14	Bari Cham, Samarabad	WSS	250	32	41.31	5.8	290
15	A-15	Bari Cham, Moh Mesriabad	DTW	650	40	133.65	7.6	380
16	A-16	Cannal Road, Agr. Office	DTW	640	56	121.5	9.2	460
17	A-17	Cannal Road, Bilal Town	DTW	250	28	43.74	7.2	360
18	A-18	Cannal Road, Bilal Town	DTW	290	36	48.60	6.0	300
19	A-19	Moh. Bara Khankhel	DTW	510	56	89.91	8.2	410
20	A-20	Moh Bara Khankhel	OW	810	68	155.52	9.0	450
21	A-21	Mosque Bara Khankhel	DTW	750	32	162.81	10.4	520
22	A-22	Bicket Gunj, Moh., Dr. Latif	DTW	340	24	68.04	6.4	320
23	A-23	Bicket Gunj, Moh., Dr.Latif	DTW	410	32	80.19	8.8	440
24	A-24	Bicket Gunj, Husanain Street	OW	533	32	109.35	9.2	460
25	A-25	Kas Koroona, Moh. tekadaran	DTW	480	40	92.34	5.8	290
26	A-26	Kas Koroona, Moh.Abdullah	DTW	400	44	70.47	6.4	320
27	A-27	Kas Koroona, G.H.School	DTW	350	28	68.04	8.0	400
28	A-28	Dargai, Qutab Palao	DTW	320	40	53.46	9.8	490
29	A-29	Dargai, Qutab Palao	DTW	260	28	46.17	9.4	470

Table 4. Contd.

30	A-30	Akhon Baba, Khanmian mosque	OW	420	24	87.48	11.6	580
31	A-31	Allahdad khel, Nali Par	DTW	350	16	75.33	12.0	600
32	A-32	Allahdad khel, Sherabad	DTW	480	16	106.92	11.8	590
33	A-33	Allahdad khel, Sherabad	DTW	480	32	97.20	11.2	560
34	A-34	Skandari, Moh. Bachagano	HP	450	28	92.34	8.0	400
35	A-35	Skandari, Moh.Bachagano	HP	650	28	140.94	9.0	450
36	A-36	Skandari, Moh.Sultan Mehmood	DTW	590	24	128.79	12.4	620
37	A-37	Par Hoti, Moh.Noorman khel	DTW	480	32	97.20	12.2	410
38	A-38	Anwar Paki Degi, Mohib Road	DTW	500	28	104.49	9.6	480
39	A-39	Par Hoti, Moh. Habib Gul	HP	480	24	102.06	10.0	500

DTW, domestic tube well; OW, open well; HP, hand pump.

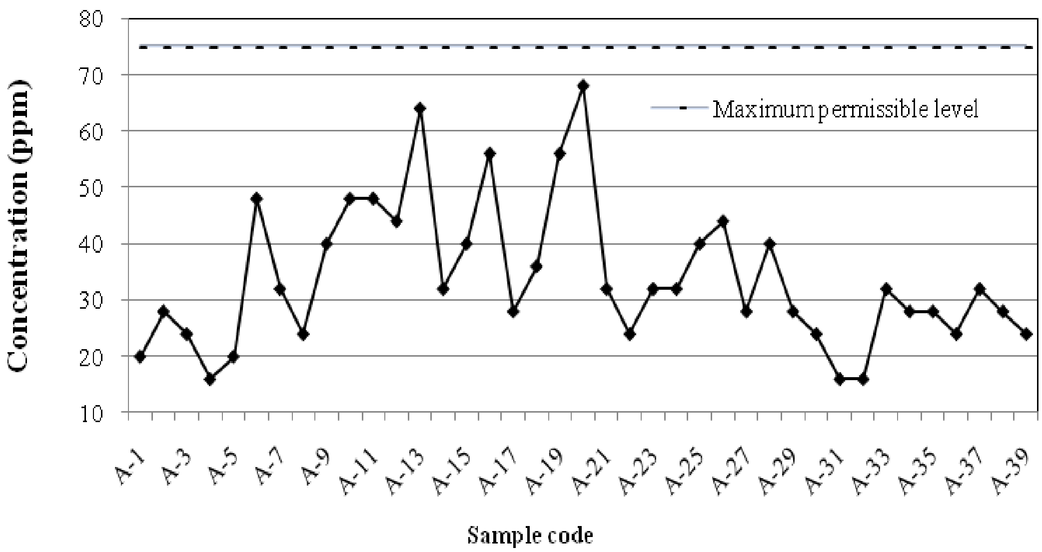

Figure 4. Level of calcium in water samples of the selected area.

within the maximum permissible limits (Table 4, Figure 4). Calcium in water is of geological origin as it comes from its deposits like gypsum, limestone, calcite and dolomite. Area wise all the three samples of UC Gulibagh and two samples of Mardan Khas, one sample each of Baghdada, Baricham and Kas Koroona shows calcium valve within range of 40-68 ppm, high when compared to others.

Hardness in water is mainly due to the presence of carbonates, bicarbonates, chlorides and sulfates, of calcium and magnesium. According to WHO and PCRWR, the maximum permissible level of hardness in drinking water is 500 ppm. Excessive hardness of water causes scaling, corrosion and choking of the pipes and utensils, thus mostly contributes in economic damages. It is also reported that excessive hardness may cause diarrhea, gas trouble, kidney stones and heart problems (Rubenowitz et al., 1998, Shakirulla et al., 2005).

Out of total 39 samples, 8 samples were found to have hardness higher than the permissible limits, ranging from 510 to 810 ppm. Out of these eight sources one is open well and hand pump while the rests are all domestic tube wells (Table 4, Figure 5). House hold sand filters (HSF), (Mahmood et al., 2011), and innovative biosand filter (BSF) (Baig et al., 2011), as successfully applied in the past may be applied to get safe drinking water. The location of the samples having hardness levels exceeding MPL, were found to be as one sample each in Baghdada, Baricham, Muslimabad and Bicket Gunj followed by two samples in Skandari Koroona and all the three samples of UC Mardan Khas. It means that the land of urban areas of Mardan particularly that of Baghdada, Baricham, Muslimabad, Bicket Gunj, Skandari Koroona and UC Mardan Khas is rich in calcareous and carbonaceous minerals and that is why the ground water show high levels of hardness than others. During the survey, the

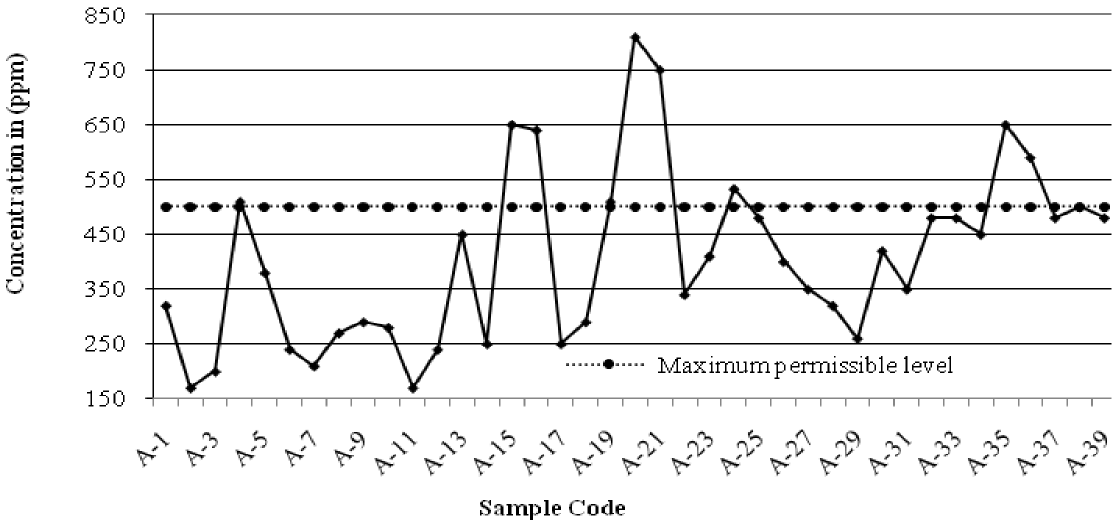

Figure 5. Level of hardness in water samples of the selected urban areas.

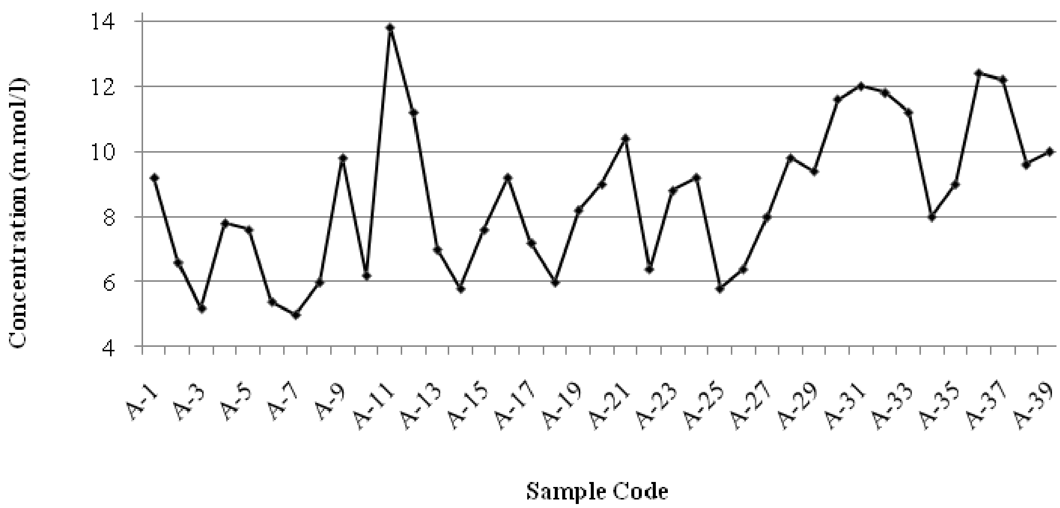

Figure 6. Level of alkalinity in water samples of the selected areas.

consumers of water having hardness value beyond permissible level complaint about scale formation and salty taste. Generally scales formation in water of these areas was a very common phenomenon, a direct indicative of high hardness of the water.

Alkalinity is the acid neutralizing capacity of water. The ions mostly contributing to alkalinity are chlorides, bicarbonate and sulfate. The values of alkalinity ranged from 5.0 to 13.8 mmol/L. The ground water of Dargai, Hoti, Skandari Koroona, Par Hoti showed high alkalinity, ranging from 8.0 to 12.4 m.mol/L, whereas for other areas, it was from 5.0 to 8.0 mmol/L (Table 4, Figure 6).

As alkalinity depends upon the geological strata of the area, therefore its values varied from area to areas, and remain comparable within the same areas. On the other hand, alkalinity is less affected by the ground water contamination from the sewage effluents as its level do not vary much with the contamination sources or sources of water supply rather than the nature of the locality as seen from the experimental data. Hence the areas showing high alkalinity in ground water have minerals of chloride, sulfates and carbonates and due to shallow water bed these minerals are easily available to the ground water. The results of electrical conductivity also show matching results supporting the evidence of minerals distribution which is more in the areas showing high alkalinity values in ground water.

Magnesium is among the most common elements of earth crust that is present in ground water, as salts of magnesium are highly soluble in water. It contributes in

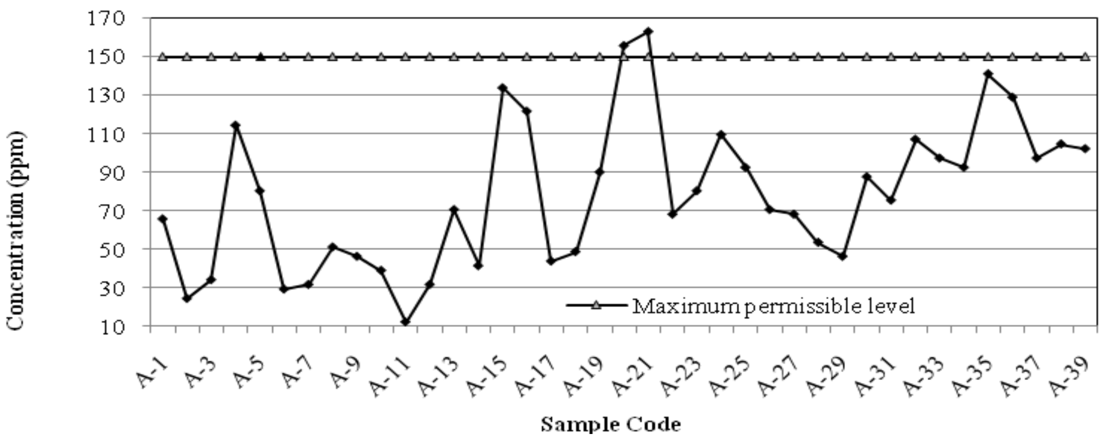

Figure 7. Level of Magnesium in water samples of the selected areas.

hardness of water together with calcium. According to PCRWR, the highest desirable level of magnesium in drinking water is 30 ppm whereas the maximum permissible limit is 150 ppm (Kahlown et al., 2006). Out of 39 samples, only two samples (A-20 and A-21) were found to have high magnesium concentration 155.5 and 162.8 ppm, respectively (Table 4, Figure 7). These results are supported by published research studies in the past (Khan et al., 2012a).

The samples having high Mg level were collected from open well and domestic tube well of UC Mardan Khas. The Mg concentration shows same pattern as like hardness, which evidences the geological nature of the respective areas. As Mg finds its way from mineral rocks in the ground through water bed to the water sources, regardless of the nature of the sources (hand pump, open well and domestic tube well), thus it is assumed that ground of areas showing high concentrations of Mg are rich in magnesium deposits like magnetite, gypsum, epsom.

Conclusions

Several ground water sources of open wells, hand pumps and public water supply schemes were not fulfilling the WHO/Pakistan guidelines set for drinking water. Geological strata of the area, surrounding pollution sources, age, poor construction and maintenance of drinking water sources were found to be the key factors responsible for water quality deterioration. Water from the polluted sources cannot be recommended for human consumption without proper treatment. The concepts of house hold sand filter and innovative biosand filter may be successfully applied as low cost techniques to get clean safe drinking water. Also the concerend authorities should take all necessary measures to overcome water pollution and eliminate any possible risks to the inhabitants of the local area.

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