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Chemical Investigation of the Drinking Water Sources from Mardan, Khyber Pakhtunkhwa, Pakistan

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Abstract: In Pakistan, the quality of drinking water is not properly managed and various studies provide evidence that most of the drinking-water sources are contaminated. In this study, 39 water samples were collected from open wells, hand pumps and public water supply schemes of the highly populated 13 union councils from the urban area of district Mardan, to find out their suitability for drinking purposes. These were investigated for various chemical parameters including sulfate (SO_4), fluoride (F), chloride (Cl),), nitrate (NO_3), sodium (Na), potassium (K), iron (Fe) and arsenic (As), using standard methods of analysis recommended by American Public Health Association (APHA). The results of various parameters showed variations from the WHO and Pakistan recommended standard values for drinking water. The Na of 15%, SO_4^{2-} of 13% and Cl^- of 2% samples were found high than the WHO/Pakistan recommended values for drinking water. Geological strata of the area, surrounding pollution sources, age, poor construction and maintenance were found to be the key factors responsible for water quality deterioration of the various water sources. The usage of house hold sand filter and innovative bio-sand filter may be successfully applied as low cost techniques to get clean and safe drinking water.

Key words: Drinking water · Mardan · Chemical investigation · APHA

INTRODUCTION

Drinking water is the basic need of humans and it also has a great influence on the all aspects of life [1]. It has been estimated that a man can live for around 20 days without food but very difficult to survive just after one day if water is not available for drinking [2]. Water is the most drinking fluid and is the universal solvent, therefore often a potential source of causing infections. The primary concern of the people living in most of the developing countries, throughout the world is that of obtaining clean and safe drinking water. In some parts of the world, this problem is much serious by the fact that the available water sources are non potable directly, without some forms of treatment [3].

Drinking water quality has been debated throughout the world [4-5]. Generally discharge of direct domestic and industrial effluent wastes, leakage from improperly maintained septic water tanks and poor management of farm wastes are considered as the major sources of water pollution and ultimately of waterborne diseases [6-7].

The sources of fresh water in Pakistan are glaciers, rivers and lakes but due to the shortage of rains and snowfall and also because of pollution, Pakistan is suffering from water shortage. To overcome this situation, presently ground water is the most abundantly (>70 %) consumed natural resource for various human activities [8-9].

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Table 1: Guidelines and standards for quality of drinking water (mg/L)

Properties/Parameters	Guideline/Standard Values for Pakistan HDL*	MPL**	WHO Standards
Chloride as Cl^-	200	600	250
Fluoride as F^-	1.00	1.50	1.50
Sulfate as SO_4^{-2}	200	400	250
Nitrate as NO_3^{-1}	45.0	45.0	45.0
Sodium (Na)	150	200	200
Potassium (K)	50.0	75.0	75.0
Iron (Fe)	0.10	0.30	0.30
Arsenic (As)	0.01	0.05	0.01

* Highest Desirable Level ** Maximum Permissible Level

Poor water quality is responsible for the deaths of an estimated five billion children annually. According to World Health Organization (WHO) survey 80% of all human diseases in developing countries are water borne [10]. The past research studies have shown that various quality parameters of Pakistan drinking water are not in accordance to the WHO/Pakistan standards [7, 9, 11-18].

Drinking water quality standards have been established by agencies such as WHO and UNICEF. In Pakistan, the Pakistan Standards and Quality Control Authority have specified the criterion for drinking-water quality. Some of the chemical parameters along with their standards specified are given in Table 1[19-23].

The main drinking water sources of urban Mardan are open wells (OW), hand pumps (HP) and domestic tube wells (DTW). Their microbiological study for bacterial contamination and physiochemical evaluations for turbidity, color, odor, pH, total dissolved solids (TDS), electrical conductance (EC), total hardness, calcium hardness, magnesium hardness, bicarbonate and alkalinity have shown that various sources are polluted and cannot be used for drinking purposes without treatment [16, 18].

The present research work was designed as a continuation of our previous work to evaluate the various ground water sources for important chemical parameters of the urban areas of district Mardan, to further confirm and strengthen our previous research findings and get a clear picture of the contamination sources which may lead to solve the problem and reduce the dangers of any possible health risks.

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 by Khan et al., 2012b [7]. 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 [24].

Determination of Chloride, Fluoride, Sulfate and Nitrate: Argentometric titration method was used to measure the concentration of chloride in water samples. Potassium chromate was used to indicate the end point of the silver nitrate titration of chloride at neutral or slightly alkaline condition. Silver chloride is precipitated quantitatively before red silver chromate is produced [24].

The SPANDS colorimetric method used for fluoride was based on the reaction of fluoride and zirconium-dye lake, dissociating a portion into a colorless complex anion and the dye. The increase of fluoride concentration causes lighter the color of the dye lake. Absorbance was taken at 580 nm and standard calibration curve was used for concentration determination [24].

Turbidimetric method was used for sulfate determination in which sulfate ion was precipitated as barium sulfate crystals by reaction with barium chloride in the presence of acetic acid. Light absorbance of the barium sulfate suspension was measured by UV-spectrophotometer at 420 nm and the sulfate concentration was determined by comparison with standard curve [24].

Nitrate was determined as nitrogen by UV-Spectrophotometric screening method at 220 nm enabling automatic measurement by the instrument using the calibration curve. Because the dissolved organic matter may also absorb at 220 nm and a second measurement at 275 nm was used for empirical correction of the nitrate value. Acidification with 1 N HCl was used to prevent the interferences from hydroxide or carbonate concentrations [24].

Determination of Sodium, Potassium, Iron and Arsenic: Sodium was determined by flame emission photometry at 589 nm. The sodium resonant spectral line at 589 nm was separated by interferences filters or light-dispersing devices such as prism or gratings. Emission light intensity measured by phototube, photomultiplier or photodiode was approximately proportional to the sodium concentrations in water samples. Potassium was also determined through flame photometer at 766.5 nm, having the same general principle as that of sodium [24].

Phenanthroline method was used for determination of iron using spectrophotometer. Iron was reduced to the ferrous by boiling with acid and hydroxylamine and then treating with 1,10-phenanthroline at pH 3.2-3.3. The molecules of phenanthroline chelated ferrous iron to form an orange-red complex. Absorbance was determined with spectrophotometer at 510 nm. The iron concentration in the sample was automatically determined from the calibration curve [24].

Arsenic concentration was determined with Atomic absorption spectrometer (AAS, Vario 6 Analytik Jena AG) using Hydride Generation mode, after properly calibrating the instrument with standards for precised results. This method was based on conversion of arsenic to its volatile hydride by sodium borohydride in acid solution. The hydrides were purged continuously by argon into a quartz cell heated by flame of atomic absorption spectrometer and converted to the gas-phase atoms. The reducing agent sodium borohydride, by rapid generation of the elemental hydrides in an appropriate reaction cell, minimize the dilution of the hydrides by the carrier gas and provide rapid, sensitive determinations of arsenic [24].

Statistical Analysis: Data were reported as mean ± standard deviation of triplicate measurements. Significant differences ($p < 0.05$) within means were analyzed by analysis of variance (ANOVA) and Tukey's honestly significant difference (HSD) test in the SPSS Statistics Software Version 20 (IBM, New York, USA).

RESULTS AND DISCUSSION

The contents of chloride, fluoride, sulfate and nitrate are given in Table 2 and that of sodium, potassium, iron and arsenic are mentioned in Table 3. The important results are discussed in context of causes, health impacts and published literature in the following sub-headings.

Chloride, Fluoride, Sulfate and Nitrate: Chloride is an essential anion of water, which occurs at high concentrations in surface water as compared to ground water. Table salt is the main source of chloride in water, in addition to potassium chloride and magnesium chloride which also make appreciable contribution. According to WHO the maximum permissible limit for chlorides in drinking water is 250 mg/L, whereas PCRWR reports that the highest desirable level for chloride should be 200 mg/L. Table 2, shows that level of chloride in ground water sources of the selected urban areas of district Mardan, ranged from 21.3-193 mg/L. Only one sample (A-20) of open well having 100 ft depth was found to have 250 mg/L chloride level but was within the MPL of WHO. The age of the well and surrounding contamination source was about 60 years. There was 45 ft horizontal and 100 ft vertical distance between the water source and surrounding contamination source, with bricks/cements lining. The concentration of calcium ion and the value of hardness were also found high in same source [18]. Local community complains about the kidney stones disease in the area. Thus it can be concluded that high value of chloride and other stated parameter may be due to the underground geological strata.

Generally in study area, the examination of chloride in drinking water revealed that the distribution of chloride in the ground water of UC Mardan Khas was high (A-19 193 mg/L, A-20 250 mg/L and A-21 120.9 mg/L), followed by Baricham and Gulibagh (21-160 mg/L), Bagh-e-Iram (64-127 mg/L) and Bicket Gunj (80-125 mg/l). The areas having relatively lower chloride concentration include UC Skandari Koroona (63.9-106.5 mg/L), followed by Baghdada and Kas Koroona (39-94.4 mg/L), Dargai (21.3-92.3 mg/L), Muslimabad (53-88.5 mg/l), Bijlighar (35-70 mg/L) and UC Hoti and Par Hoti (24.85-58.8 mg/L) Table2, Figure 1.

Water is the only significant source of dietary intake of fluoride, which is essential for protection of teeth against dental caries. WHO has recommended 1.5 mg/L as the maximum permissible limit for fluoride in drinking water. The level of fluoride in the water samples of the selected areas ranged from 0.14-1.15 mg/l (Table 2), none of the sample has level exceeding the maximum permissible limits (Figure 2). Generally, the level of fluoride in the ground water of the entire region occurs relatively smaller than the highest desirable value set by PCRWR (1.0 mg/l) with the exception of two samples, A-1 and A-2 of UC Bagh-e-Iram. Among the different areas, the ground

Table 2: Concentration (mg/L) of Chloride, fluoride, sulfate and nitrate in water sources

S.#	Code	Location	Source	Chloride	Fluoride	Sulfate	Nitrate
1.	A-1	Bagh-e-Irum, Janabad	DTW	127	1.10	230	7.6
2.	A-2	Janabad, Moh. Tanki	HP	64	1.15	104	5.4
3.	A-3	Janabad, Moh. Tanki	DTW	88	0.71	128	3.4
4.	A-4	Baghdada, Bar Kanday	DTW	99	0.37	261	7.3
5.	A-5	Baghdada, Gadbano	DTW	36	0.37	115	5.2
6.	A-6	Baghdada, Pohan Colony	DTW	39	0.69	126	2.0
7.	A-7	Gulshan Colony, Kanal Road	DTW	35	0.53	99	1.2
8.	A-8	Gulshan colony, Railway Patak	DTW	70	0.50	88	3.3
9.	A-9	Kanal Road, Khyber Street	DTW	67	0.49	175	7.5
10.	A-10	Kanal Bank, Shamsi Road	DTW	21	0.14	61	0.5
11.	A-11	Chakaro pull, Fazalabad	OW	42	0.49	152	3.8
12.	A-12	Chakaro pull, Itifaq colony	OW	160	0.80	250	1.6
13.	A-13	Bari Cham, Moh. Sari	DTW	92	0.44	174	7.7
14.	A-14	Bari Cham, Samarabad	WSS	42	0.44	89	2.0
15.	A-15	Bari Cham, Moh Mesriabad	DTW	160	0.49	380	8.0
16.	A-16	Cannal Road, Agr. Office	DTW	71	0.62	400	6.7
17.	A-17	Cannal Road, Bilal Town	DTW	88	0.87	175	6.6
18.	A-18	Cannal Road, Bilal Town	DTW	53	0.61	140	2.0
19.	A-19	Moh. Bara Khankhel	DTW	193	0.36	160	6.7
20.	A-20	Moh Bara Khankhel	OW	250	0.44	430	6.7
21.	A-21	Mosque Bara Khankhel	DTW	121	0.64	495	10.6
22.	A-22	Bicket Gunj, Moh., Dr. Latif	DTW	80	0.62	59	0.9
23.	A-23	Bicket Gunj, Moh., Dr.Latif	DTW	110	0.45	131	7.2
24.	A-24	Bicket Gunj, Husanain Street	OW	126	0.41	117	7.1
25.	A-25	Kas Koroona, Moh. tekadaran	DTW	99	0.51	236	10.4
26.	A-26	Kas Koroona, Moh. Abdullah	DTW	78	0.41	115	5.1
27.	A-27	Kas Koroona, G.H.School	DTW	46	0.31	135	6.3
28.	A-28	Dargai, Qutab Palao	DTW	21	0.71	32	6.2
29.	A-29	Dargai, Qutab Palao	DTW	25	0.91	27	5.5
30.	A-30	Akhon Baba, Khanmia mosque	OW	92	0.89	207	7.5
31.	A-31	Allahdad khel, Nali Par	DTW	25	0.69	95	1.4
32.	A-32	Allahdad khel, Sherabad	DTW	25	0.38	210	1.5
33.	A-33	Allahdad khel, Sherabad	DTW	57	0.33	125	6.1
34.	A-34	Skandari, Moh. Bachagano	HP	64	0.33	98	3.6
35.	A-35	Skandari, Moh.Bachagano	HP	53	0.46	64	7.1
36.	A-36	Skandari, Moh.Sultan Mehmod	DTW	106	0.38	146	4.0
37.	A-37	Par Hoti, Moh.Norman khel	DTW	57	0.31	195	1.6
38.	A-38	Anwar Paki Degi, Mohib Road	DTW	50	0.30	126	1.6
39.	A-39	Par Hoti, Moh. Habib Gul	HP	57	0.37	146	1.7

DTW = Domestic tube well, HP= Hand pump, OW= Open well

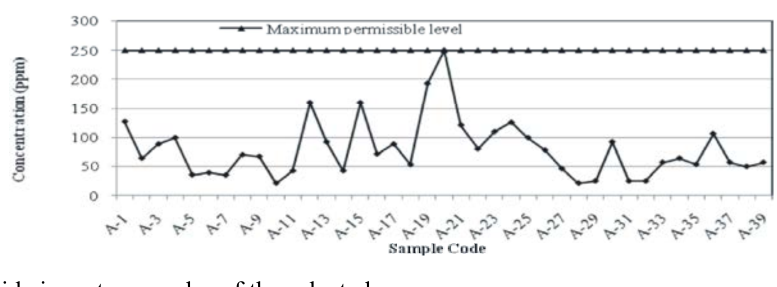

Fig. 1: Level of Chloride in water samples of the selected areas

Table 3: Concentration (mg/L) of sodium, potassium, iron and arsenic in water sources

S.#	Code	Location	Source	Sodium	Potassium	Iron	Arsenic
1.	A-1	Bagh-e-Irum, Janabad	DTW	232	8	0.02	0.58
2.	A-2	Janabad, Moh. Tanki	HP	150	3	0.06	0.69
3.	A-3	Janabad, Moh. Tanki	DTW	127	4	0.07	1.06
4.	A-4	Baghdada, Bar Kanday	DTW	165	7	0.03	0.64
5.	A-5	Baghdada, Gadbano	DTW	99	5	0.17	0.76
6.	A-6	Baghdada, Pohan Colony	DTW	109	5	0.05	0.44
7.	A-7	Gulshan Colony, Kanal Road	DTW	92	5	0.01	1.42
8.	A-8	Gulshan colony, Railway Patak	DTW	100	7	0.02	0.43
9.	A-9	Kanal Road, Khyber Street	DTW	201	8	0.05	0.93
10.	A-10	Kanal Bank, Shamsi Road	DTW	63	4	0.07	0.75
11.	A-11	Chakaro pull, Fazalabad	OW	325	2	0.04	2.59
12.	A-12	Chakaro pull, Itifaq colony	OW	341	1	0.02	3.74
13.	A-13	Bari Cham, Moh. Sari	DTW	136	7	0.02	3.68
14.	A-14	Bari Cham, Samarabad	WSS	90	4	0.01	0.85
15.	A-15	Bari Cham, Moh Mesriabad	DTW	127	5	0.07	0.83
16.	A-16	Cannal Road, Agr. Office	DTW	120	5	0.20	0.75
17.	A-17	Cannal Road, Bilal Town	DTW	169	5	0.25	1.03
18.	A-18	Cannal Road, Bilal Town	DTW	92	5	0.25	1.04
19.	A-19	Moh. Bara Khankhel	DTW	197	5	0.22	0.92
20.	A-20	Moh Bara Khankhel	OW	170	6	0.23	1.30
21.	A-21	Mosque Bara Khankhel	DTW	220	8	0.29	0.66
22.	A-22	Bicket Gunj, Moh., Dr. Latif	DTW	69	4	0.19	0.55
23.	A-23	Bicket Gunj, Moh., Dr.Latif	DTW	170	9	0.20	7.66
24.	A-24	Bicket Gunj, Husanain Street	OW	130	5	0.18	9.36
25.	A-25	Kas Koroona, Moh. tekadaran	DTW	108	4	0.22	12.6
26.	A-26	Kas Koroona, Moh. Abdullah	DTW	60	2	0.29	1.45
27.	A-27	Kas Koroona, G.H.School	DTW	109	4	0.18	5.07
28.	A-28	Dargai, Qutab Palao	DTW	141	3	0.25	0.85
29.	A-29	Dargai, Qutab Palao	DTW	131	2	0.19	0.39
30.	A-30	Akhon Baba, Khanmia mosque	OW	202	5	0.25	0.52
31.	A-31	Allahdad khel, Nali Par	DTW	172	5	0.01	0.99
32.	A-32	Allahdad khel, Sherabad	DTW	134	2	0.06	2.42
33.	A-33	Allahdad khel, Sherabad	DTW	150	2	0.00	1.65
34.	A-34	Skandari, Moh. Bachagano	HP	90	3	0.03	0.49
35.	A-35	Skandari, Moh.Bachagano	HP	13	2	0.05	0.37
36.	A-36	Skandari, Moh.Sultan Mehmod	DTW	146	5	0.01	0.45
37.	A-37	Par Hoti, Moh.Norman khel	DTW	70	3	0.03	0.77
38.	A-38	Anwar Paki Degi, Mohib Road	DTW	95	1	0.07	0.30
39.	A-39	Par Hoti, Moh. Habib Gul	HP	115	2	0.02	0.32

DTW = Domestic tube well, HP= Hand pump, OW= Open well

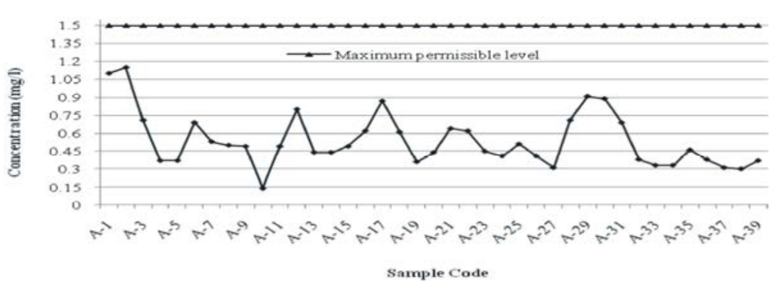

Fig. 2: Level of Fluoride in water samples of the selected areas

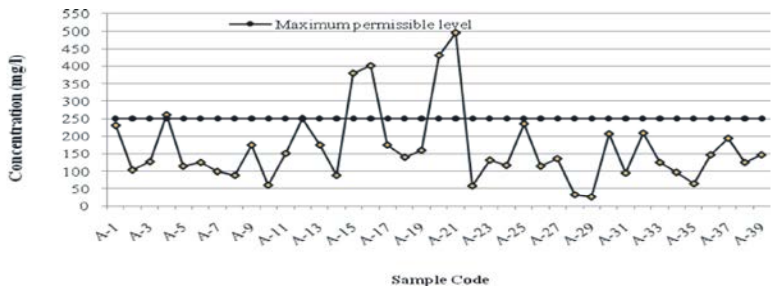

Fig. 3: Level of sulfate in water samples of the selected areas

water of Dargai showed the highest level of F, ranging from 0.71-0.91 mg/L, followed by that of Muslimabad 0.61-0.87 mg/L and Gulibagh from 0.14 to 0.80 mg/L.

The only sources of the fluoride in ground water is the deposits of fluoride mineral in the deep soils like flourapatite, from where it is washed down to the ground water sources. It means that level of fluoride in the ground water depends upon the nature of geological strata, rather than any of the sewage channels, gutters, garbage places, waste bins etc in the vicinity of the water sources. It may be therefore concluded from the results in Table 2, that the ground of the rural areas of Mardan was deficient in deposits of fluoride minerals. The people of this area may be informed and instructed to use dental creams in order to avoid dentals caries.

Sulfate is a common anion of water, which comes from its naturally occurring minerals in some soil and rock formations that contains ground water [25]. According to WHO the maximum permissible limit for sulfate in drinking water is 250 mg/L (Table 1). Excess of sulfate impart unacceptable taste and may be laxative, cathartic and corrosive especially when combined with sodium and magnesium.

The concentration of sulfate in the ground water sources of the selected areas ranged from 27 mg/L to 495 mg/L (Table 2). Out of the total 39 samples, five samples were found to have sulfate level exceeding the maximum permissible level recommended by WHO (Figure 3). Out of these five samples, one was collected from open well while other four were from domestic tube wells. Area wise distribution of sulfate showed that, two samples (A-20 and A-21), open well and domestic tube well, of UC Mardan Khas have the highest value of sulfate, 430 mg/L and 495 mg/L, respectively. The open well water source was 60 years old, 100 ft depth and 60 ft ground water table, completely covered and surrounding contamination sources located around 45 ft away. The domestic tube well A-21 of the same area was 5 years old with 180 ft depth and 160 ft water table and also located in hygienic surrounding. In respect of high level of sulfate, it seems that both water sources were likely to be not contaminated by poor sanitation practices. It was also evident from other parameters of these samples like magnesium, hardness and TDS exceeding the permissible levels [18]. The third sample (A-16) of Muslimabad collected from 14 years old domestic tube well, with 100 ft depth and 50 ft water table. The surrounding sewage line and gutter with adequate lining are located at 15 ft distance. The same sample also has hardness and TDS above permissible level [18]. Fourth sample bearing code A-15 of Baricham was having excessive value of sulfate (380 mg/L). The source of water was domestic tube well, constructed 29 years ago. The depth of well was 70 ft and water table of 50 ft, having latrine and municipal sewage line at 15 ft distance. Last sample A-4 collected from Baghdada have sulfate level 261 mg/L slightly higher than the permissible limits. Water source of the sample was 19 years old domestic tube well having 100 ft depth. The surrounding sewage line latrine was well lined with bricks/cement and located at 16 ft distance from water source. Other parameters like hardness and TDS of the sample are also above permissible level. So it may be suggested that composition of underground geological strata was likely to be responsible for high quantity of sulfate in the samples.

The major cause of nitrate in the water is industrial and domestic effluents, fertilizers, decayed animals and plants materials, farm leachates and atmospheric washout [26]. The maximum permissible limit for nitrate recommended by WHO and PSQCA is 45 mg/L. Table 2, shows that the level of nitrate in water samples of the selected areas ranged 0.5-10.6 mg/L and none of the sample has concentration beyond the MPL. Area wise distribution of nitrates showed that the ground water of UC Mardan Khas has the highest level of nitrate (6.7-10.6 mg/L), followed by Kas Koroona (5.1-10.4 mg/L), Baricham (2.0-8.0 mg/L), Dargai (5.5-7.5 mg/L), Bagh-e-Iram (3.4-7.6 mg/L), Bicket Gunj (0.9-7.2 mg/L), Muslimabad (2.0-6.7

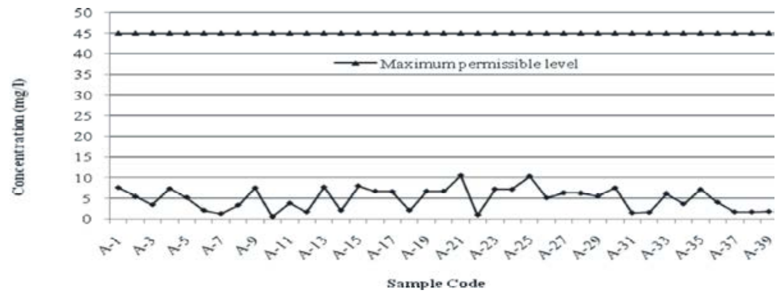

Fig. 4: Level of Nitrate in water samples of the selected areas

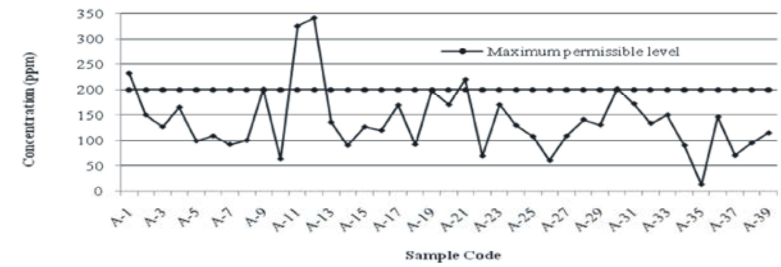

Fig. 5: Level of Sodium in water samples of the selected areas

mg/L), Skandari Koroona (3.6-7.1 mg/L), Baghdada (2.0-7.3 mg/L), Bijlighar (1.2-7.5 mg/L), Hoti (1.4-6.1 mg/L) and Par Hoti (1.6-1.7 mg/L) (Figure 4).

From Table 2, 3.9 two samples (A-21 and A-25) have concentration of nitrates above 10 mg/L, which were collected from domestic tube wells. As nitrate level in the ground water depends upon the surrounding water sources, rather than geological nature of the soil, therefore those water sources were liable to receive seepage from contamination sources like animal farms, garbage place, municipal sewage channel and gutters. On other hand sources with well protection of the linings, larger depths and larger distance from the contamination showed smaller concentrations of nitrates.

Sodium, Potassium, Iron and Arsenic in Water Sources: Sodium salts are highly soluble in water and found abundance in mineral deposits. Underground deposits of sodium salts are the main sources of sodium in ground water. WHO has recommended 200 mg/L as maximum permissible limit for sodium in drinking water. Levels of sodium in the study area are indicated in the Table 3 and Figure 5, which show that six samples have concentration of sodium exceeding MPL recommended by WHO. In all other samples the concentration of sodium ranged, 13-192 mg/L.

In UC Gulibagh, 325 mg/L and 341 mg/L of sodium was found in open well source (A-11 and A-12). Water table in the area was between 7-10 ft and the depths of both the wells were in the range of 8-12 ft. The surrounding contamination sources were animal farms and water logged area having distance of 3-12 ft. Thus it can be suggested that water table is shallow and the area is water logged due which sodium concentration was found exceeding the MPL. It was also noted that consumers of these water sources complain about the objectionable salty taste. The third sample having sodium level of 232 mgL (A-1) was of Bagh-e-Iram, a 25 years old domestic tube well, having total depth of 30 ft and water table of 25 ft. The surrounding contamination source was garbage place with 15ft distance. Other two sample from the same UC has sodium concentration in the acceptable range and one has smaller depth of well (28 ft). Fourth sample A-21 having sodium concentration beyond MPL was of domestic tube well. The well was 180 ft deep with water table 160 ft, having quite hygienic surrounding area. The other two samples of the same area (A-19 and 20) also have comparatively high sodium level 197 and 170 mg/L respectively (Figure 6). It was suggested that underground strata of the area is rich in sodium compounds.

Concentration of sodium in samples A-9 and A-30, domestic tube well and open well sources respectively, were slightly above the MPL. Water source of sample A-9 has 55 ft depth with water table of 45 ft and 26 years age. The surrounding contamination sources were well protected and 14 ft away from water source. Again we can suggest that the underground geological strata of the sources have sodium compounds in excess quantity. Sample A-30 was open well source with shallow water

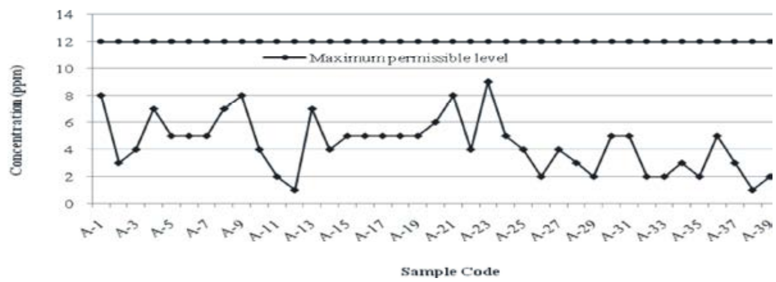

Fig. 6: Level of Potassium in water samples of the selected areas

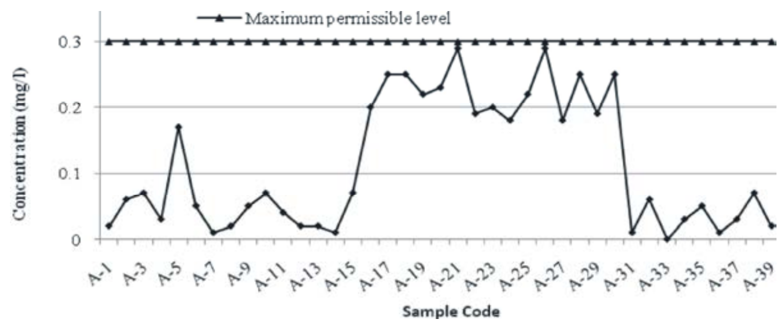

Fig. 7: Level of Iron in water samples of the selected areas

table of 8 ft and 39 years age. Agricultural fields and animal farms surround the well. It may be predicted that seepage from agricultural fields to shallow water was the cause of high level of sodium. Interpretation of sodium concentration in the ground water of the selected areas showed that the level of sodium changes with the depth of source and water table. From the above discussion it can be suggested that level of sodium in deep underground water was related to the underground geological strata, however in case of shallow water sources the seepage from animal farms and agricultural fields may cause high concentration of sodium.

Potassium is amongst the major cations of water which occur largely in sea water and mineral water than the ground water. According to WHO the maximum permissible limit of K in drinking water is 12 mg/L (Table 1). The levels of K in the ground water of selected areas as mentioned in Table 3, show that K level in all the samples were in the WHO permissible limits. Ground water urban areas of district Mardan have an average 4.4 mg/L of potassium. Viewing the results area wise average value of potassium in water samples was comparatively high in UC Bijlighar 6.7 mg/L, followed by Mardan Khas 6.3 mg/L, Bicket Gunj 6 mg/L, Baghdada 5.7 mg/L, Baricham 5.3 mg/L, Muslimabad and Bagh-e-Iram were 5mg/L, Skandari, Kas Koroona and Dargai was 3.3 mg/L. UC Hoti was 3 mg/L, followed by Gulibagh and Par Hoti having average potassium level 2.2 mg/L (Table 3, Figure 6).

From the data on potassium concentration in the ground water sources of the selected urban areas of district Mardan showed that the level of potassium remained comparable in the same area due to uniform distribution of potassium in the ground water table of an area.

Iron is among the most abundant element by weight in the earth crust. Iron finds its way to the water sources with the rain water, the low pH infiltrates of the soil and underlying geological formations dissolve iron and seeps to the ground water sources. Besides this municipal and industrial sewages also raise the iron level in the ground water. The maximum permissible limit recommended by WHO for drinking water is 0.3 mg/l. The concentration of iron in the ground water of the selected areas ranged from 0 to 0.29 mg/L (Table 3). From the table it was evident that the all samples were found having iron concentration within the WHO permissible limits. Distribution of iron among the different areas show that ground water of Mardan Khas has the highest concentration of iron (0.22-0.29 mg/L), followed by Kas Koroona (0.18-0.29 mg/L), Dargai (0.19-0.25 mg/L), Muslimabad (0.22-0.25 mg/L), Bicket Gunj (0.18-0.20 mg/L) and Baghdada (0.05-0.17 mg/L) (Table 3, Figure 7).

Correlating the nature of the sources and concentration of the iron in high range of 0.24-0.29 mg/L in the water samples (A-17, A-18, A-21, A-26, A-28 and A-30), it was found that those sources located closely

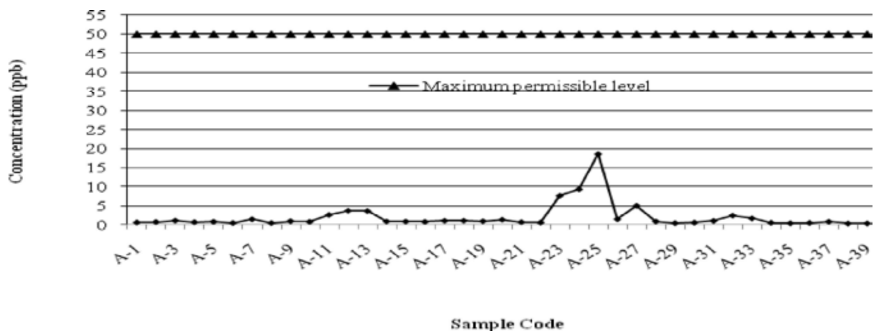

Fig. 8: Level of Arsenic in water samples of the selected areas

to the municipal sewage channel of a garbage place (less than 12 ft away), or then the sources were aged more than 14 years after which the protection measures were weakened enough to allow the seepage of nearby contamination sources. This assumption was further supported by the fact that all deep water sources like tube wells which have depth more than average of 200 ft, where the contamination from adjacent contamination sources cannot approach to water aquifer, showed negligible level of iron. However the iron contamination in ground water due to underground iron deposits cannot be overlooked as well.

Arsenic is a very important for drinking water analysis from health impact point of view. Arsenic finds its way into water sources from its minerals (arsenates) in deep soils especially in areas of high hydrothermal activities. Besides it is also used in pesticides on large scales, therefore agriculture run off may also lead to raise the arsenic level of the water. The WHO recommended level for arsenic in drinking water is 10 ppb, however the MPL set by Pakistan National Standards for Drinking Water Quality is 50 ppb. The table 3, indicates the levels of arsenic in the ground water of urban areas of Mardan which remained within the MPL set by National Standards for Drinking Water Quality. The data showed that the level of As in the samples ranges from 0.3 to 9.36 ppb, except only one sample A-25 which was having As level of 18.62 ppb.

As occurrence of As is often of geological origin in water, therefore area wise distribution was also viewed, showing that the highest level of As in ground water of Kas Koroona (1.45-12.62 ppb), followed by Bicket Gunj (0.55-9.36 ppb), Gulibagh (0.75-3.74 ppb), Baricham (0.83 to 3.68 ppb) and Hoti (0.99-2.42 ppb). The level of As in ground water of each area was a direct indication of the level of As minerals present in the soil of each area. These results showed that soils of Kas Koroona and Bicket Gunj were rich in As minerals, the shallow water table of the area assisted the transportation of As from the its deep reservoirs to the ground level and thereby to shallow sources.

The domestic tube well in UC Kas Koroona showed excessive level of arsenic, but within the MPL. The arsenic level of mentioned source was immensely higher than the other sources in the same area, which may be attributed to the seepage from the nearby farms directly through farm leachate or indirectly through irrigation canal. Canal water contains municipal sewage and agriculture runoff as well, therefore it was believed that the same canal receive the pesticides residue contained in the agriculture runoff from the farms closely located to the source, where the sources was nearly 30 feet deep and the water was at depth of 80 ft, whereas the irrigation canal was flowing at the distance of 60 ft from the source. Thus the sources easily receive the pesticides contamination released by the nearest farms, which cause to raise the arsenic level more than the other sources in the same area. On other hand the rest of the areas showing relatively smaller levels of As, may be attributed to the geological strata of the respective areas. It may be assumed that the soil contents of these areas are poor in As minerals, due to which they appear less in the ground water.

CONCLUSIONS

Several ground water sources of open wells, hand pumps and domestic tube wells were not fulfilling the WHO/Pakistan guidelines set for drinking water levels of chloride, sulfate and sodium metal. 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 usage of house hold sand filter and innovative biosand filter may be successfully applied as low cost techniques to get clean and safe drinking water. 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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