Quality Characteristics of Potable Water of Mardan City (Pakistan) and Surrounding Areas

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Summary: Quality characteristics of 31 potable water samples collected from 18 tube wells and 13 bore wells of Mardan city and adjoining areas were chemically investigated and compared with international standards. Most of the water samples were not fit for drinking due to the presence of higher oxygen demanding wastes and the possibility of biological activities. COD values in all samples were found to be above the permissible level of 4 mg O_2/l. Tube well waters were however, less polluted compared to bore well waters due to lower nitrite level. Calcium concentration in tube well and in bore well waters is below the permissible level except at Khat Koruna (350.96 mg/l). Magnesium concentration in both tube well and bore well waters is above the threshold limit of 150 mg/l except at Muqam Mandi and Shamsul Qamar Bagh. Results suggest that magnesium concentration compared to calcium in almost all samples were high. Results also show that a few samples were not potable because of the synergistic effect of magnesium and sulphate which imparts a laxative nature. Other parameters including Na^+ and K^+ were found well within the limits.

Introduction

Various physical and chemical characteristics for determining the water quality should not exceed the permissible limits of the international standards including WHO [1]. Studies have already been made in the past for ascertaining the suitability of water for human consumption in different areas of North West Frontier Province (NWFP). The water quality of District Abbottabad was studied by Hussain [2], who concluded that, due to bacteriological contamination, the water was injurious to human health. Previously, the potable waters of Peshawar, Kohat and D.I. Khan [3] were also evaluated. The waters of Peshawar and D. I. Khan were found contaminated due to the presence of bacteria. As such, waters of some areas of these districts were found to be unsafe for human consumption. Akhtar *et al.* [4] carried out chemical analysis of water samples from 15 plains, 9 hilly stations and 6 rivers/dams in NWFP and found that half of the drinking water samples showed high levels of Na^+, K^+ and TDS content, whereas those collected from hilly areas were found deficient in iodine, the main cause of *goiter*. The water quality characteristics of the Kabul River in Pakistan under high and low flow conditions were studied by Khan and Khan [5,6] who found that high concentrations of ammonia, nitrates, nitrites and sulfide over the 90 km stretch of the river made the water unsafe for human as well as aquatic life. Beside other quality criteria, the nitrate content of underground water in some areas of NWFP has been reported by Khwaja *et al.* [7], Bangash [8] and Wasim [9]. Nitrates and nitrite contamination of sub surface water of District Charsadda, Peshawar, Mardan and Nowshera of NWFP has been reported by Khan *et al.* [10] who found that the water samples collected from some areas of District Peshawar, Mardan and Nowshera showed very high levels of nitrite, whereas the water of Charsadda District has no indication of nitrites. The nitrate level in all the samples were within the permissible limits. Studies have also been made on the quality characteristics of the sub surface water of Haripur, Hazara [11] which showed that water of the area was potable. The main objection to the studies made by Khan *et al.* [3] is that they have based their findings on the analysis of a few samples from each district and presented them as representative of each district. This cannot be justified scientifically.

Very little data based on systematic study on potable quality of water of Mardan and its surrounding areas is available. This paper examines the potable water quality of this area and aims to

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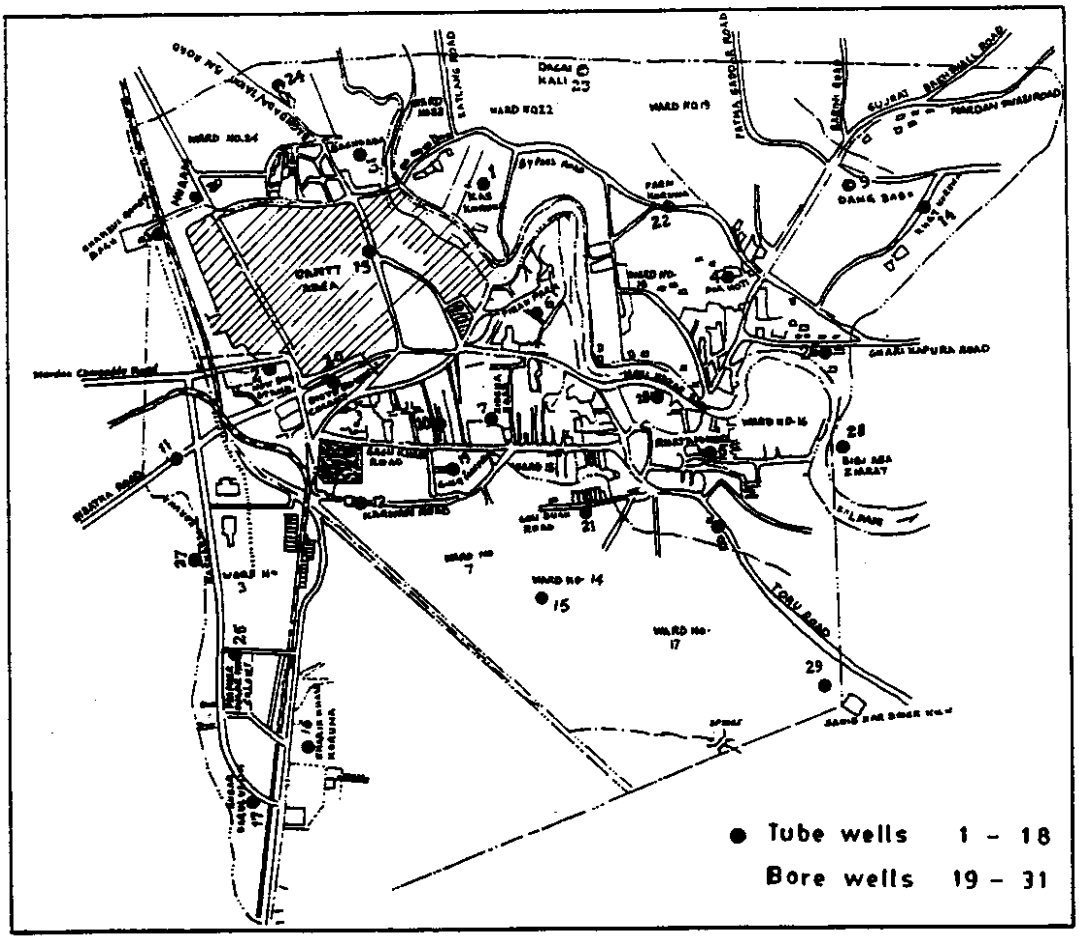

Fig. 1: Map of Mardan showing the sampling points.

give a guideline for determining the suitability of the water quality or otherwise of Mardan. The data would be useful for creating awareness amongst the inhabitants, the planners and decision makers for future potable water supply schemes.

Results and discussion

Figure 1 shows the locations of sampling points and Table 1 shows the generalized information about the depth of water sources, its state of surrounding and general public opinion about the quality of water. The depth of tube wells in Mardan varies between 160 and 410 feet, whereas bore wells are in the range 60-80 feet. General public opinion about the tube well waters at many places is that it creates stomach and gastrointestinal disorders, whereas most of the bore well waters are surprisingly rated as normal. This could be due to the fact that most of the tube wells are situated in Mardan city which is a congested and thickly populated area. As such, tube wells are more susceptible to pollution which might occur due to seepage of polluted water. On the other hand, the bore wells dug in almost every house in the surrounding villages are less contaminated. Due to low pollution in villages, compared to city areas, the seepage of less contaminated water does not cause the quality of subsurface water to deteriorate. Previously (unpublished data) no trend between depth of potable water sources of Bannu and COD was seen. Similarly no relationship has been observed in the present study between depth and COD level (Figure 2).

Physical properties

Table 2 shows the physical parameters of the water samples. Overall, the tube well waters are comparatively clearer than bore wells which could be

Table 1: Sampling points, state of surrounding and general complaints about waters

S. No.	Area/Location	*Depth* (Feet)	*State of surrounding*	*Public opinion*
Tube well				
1.	Kas Kor-na	410	Populated area	Normal, no complaints
2.	New bus stand	265	Congested area	Normal, no complaints
3.	Baghdada	280	Congested area	Stomach disorder
4.	Par Hoti	360	Scarcely populated	Normal, no complaints
5.	Rustam Khel	180	Densely populated	Normal, no complaints
6.	Piran park	345	Populated area	Gastro-intestinal problems
7.	Eidgah road	390	Congested area	Normal, no complaints
8.	Toru road	360	Very congested	Normal, no complaints
9.	Dang baba	280	Populated area	Normal, no complaints
10.	Gaju khan road	400	Congested area	Normal, no complaints
11.	Nisata road	200	Populated area	Stomach disorder & laxative
12.	Karwan road	160	Densely populated	Stomach disorder & laxative
13.	Cantt. area	185	Densely populated	Stomach disorder
14.	Khat Koruna	300	Scarcely populated	Stomach disorder & laxative
15.	Ward No. 14	250	Congested area	Stomach disorder & laxative
16.	Sharif Khan Koruna	200	Scarcely populated	Stomach disorder
17.	Akbar Darul ulum	175	Scarcely populated	Stomach disorder & laxative
18.	Hoti bazar road	190	Congested area	Normal, no complaints
Bore well				
19.	GHQ Hospital	75	Congested area	Normal, no complaints
20.	Distt. Council Colony	70	Densely populated	Normal, no complaints
21.	Gulli Gagh road	65	Populated area	Normal, no complaints
22.	Farm Koruna	45	Scarcely populated	Normal, no complaints
23.	Dagai Kali	45	Scarcely populated	Normal, no complaints
24.	Baghdada/Takht Bai road	60	Populated area	Normal, no complaints
25.	Premier Sugar Mills Colony	65	Populated area	Normal, no complaints
26.	Gari Kapura road	80	Congested area	Normal, no complaints
27.	Rashakai Koruna	70	Densely populated	Gastro-intestinal problems
28.	Bibi Aba Ziarat	65	Scarcely populated	Normal, no complaints
29.	Sahib Zar Brick Kiln	65	Populated area	Normal, no complaints
30.	Pipe Factory (Muqam)	60	Scarcely populated	Normal, no complaints
31.	Shamsul Qamer Bagh	60	Populated area	Normal, no complaints

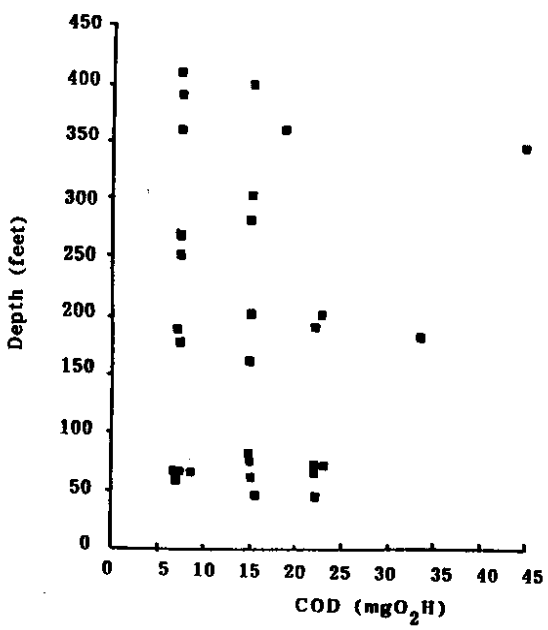

Fig. 2; Relationship between depth of wells and COD.

associated with the increased depth of the tube wells. All water samples were free of objectionable odour. At a few places the waters were found to be brackish in taste. The temperature of water in all samples was in the range 13.7-18.5 °C which is above the WHO permissible level of 12 °C [1]. DO concentrations which were in the range 6.1-9.5 in all water samples were quite good, being above the 3 mg O_2/l WHO standards. Higher DO levels are indication of purity [12]. Total suspended solids in all samples were in the range 12.2-79.4 mg/l and were above WHO permissible level, the threshold limit being 5 mg/l. The electrical conductivity values in all water samples were between 563 and 1367 µS/cm and were above the permissible level of 400 µS/cm. Total dissolved solids were in the range 309.7-751.9 mg/l in all samples. The WHO threshold limit for TDS is 500 mg/l. As such water from tube wells at Toru Road (751.97 mg/l) Nisata Road (551.1 mg/l.), Cantt area (590.2 mg/l), Khat Koruna (747.5 mg/l) and Sharif Khan Koruna (612.7 mg/l) were above the permissible level. Four water samples from bore

Table 2: Variation in physical characteristics of water samples of Mardan City and surrounding areas

Location	Appearance	Taste	Odour	Temp. °C	DO (mg O_2/l)	TDS (mg/l)	TSS (mg/l)	E. C. (µS/cm)
Tube well								
Kas Koruna	Sparkling clear	Tasteless	Odourless	14.4	7.8	442.2	16.0	804
New bus stand	Sparkling clear	Tasteless	Odourless	14.3	7.2	442.2	23.0	804
Baghdada	Slightly turbid	Tasteless	Odourless	14.4	7.3	376.2	34.1	684
Par Hoti	Sparkling clear	Tasteless	Odourless	14.5	6.6	421.9	19.2	767
Rustam Khel	Sparkling clear	Tasteless	Odourless	14.8	8.1	309.7	12.2	563
Piran park	Sparkling clear	Tasteless	Odourless	15.0	8.1	398.2	17.0	724
Eidgah road	Clear	Tasteless	Odourless	14.8	7.4	336.6	25.1	612
Toru road	Slightly turbid	Brackish	Odourless	15.0	6.5	751.9	29.4	1367
Dang baba	Slightly turbid	Tasteless	Odourless	14.5	7.8	370.7	41.2	674
Gaju khan road	Slightly turbid	Tasteless	Odourless	13.8	7.8	354.2	43.3	644
Nisata road	Slightly turbid	Brackish	Odourless	13.8	8.1	551.1	53.2	1002
Karwan road	Slightly turbid	Tasteless	Odourless	13.7	7.1	358.6	62.0	652
Cantt. area	Slightly turbid	Brackish	Odourless	13.9	8.8	590.2	59.4	1073
Khat Koruna	Slightly turbid	Brackish	Odourless	17.5	9.0	747.5	50.1	1359
Ward No. 14	Slightly turbid	Tasteless	Odourless	17.0	9.3	498.9	68.5	907
Sharif Khan Koruna	Slightly turbid	Brackish	Odourless	18.0	9.5	612.7	65.2	1114
Akbar Darul ulum	Clear	Tasteless	Odourless	18.1	9.3	492.8	36.1	896
Hoti bazar road	Slightly turbid	Tasteless	Odourless	18.0	8.7	379.1	64.0	722
Bore well								
GHQ Hospital	Slightly turbid	Tasteless	Odourless	14.8	6.9	372.9	27.4	678
Distt. Council Colony	Slightly turbid	Tasteless	Odourless	14.0	8.1	481.3	39.1	875
Guli Gagh road	Slightly turbid	Brackish	Odourless	13.8	8.7	543.4	47.2	988
Farm Koruna	Slightly turbid	Tasteless	Odourless	14.0	8.6	405.9	34.3	738
Dagai Kali	Slightly turbid	Tasteless	Odourless	13.9	8.1	435.6	30.4	792
Baghdada/Takht Bai road	Slightly turbid	Tasteless	Odourless	18.0	9.3	385.5	33.4	701
Premier Sugar Mills Colony	Sparkling clear	Tasteless	Odourless	18.5	8.7	426.8	17.5	776
Gari Kapura road	Sparkling clear	Brackish	Odourless	18.0	9.0	602.3	22.3	1095
Rashakai Koruna	Slightly turbid	Brackish	Odourless	15.0	9.0	737.6	67.4	1341
Bibi Aba Ziarat	Turbid	Tasteless	Odourless	15.1	8.0	438.4	79.4	797
Sahib Zar Brick Kiln	Turbid	Tasteless	Odourless	15.0	8.5	375.7	73.3	683
Pipe Factory (Muqam)	Slightly turbid	Tasteless	Odourless	15.5	8.0	382.3	68.2	695
Shamsul Qamar Bagh	Slightly turbid	Brackish	Odourless	15.0	8.6	620.4	61.2	1128

TDS = *Total dissolved solids* TSS = *Total suspended solids* D. O. = *Dissolved oxygen* E. C. = *Electrical conductivity*

wells of Guli Gagh Rd (543.4 mg/l), Garhi Kapura Road (602.3 mg/l), Rashakai Koruna (737.6 mg/l) and Shamsul Qamar Bagh (620.4 mg/l) were also above the permissible limit.

Chemical properties

The chemical characteristics of potable water of Mardan are given in Table 3. pH values of all water samples have been found to be within the WHO permissible limits; as presented in Table 5. Similarly, sodium, potassium and chloride concentrations in all water samples were within the WHO limits. In all water sample sodium varied in the range 44.2-169.7 mg/l, chloride 3.4-73.9 mg/l and potassium 3.1-73.9 mg/l. The threshold limits of sodium and chloride is 250 mg/l whereas the potassium concentration should not exceed 12 mg/l. Total hardness of all samples was within the permissible range except Khat Koruna where its concentration was 736.2 mg/l. Calcium values in all water samples except at Khat Koruna (351.0 mg/l) were found to be within the limits. COD ranged from 7.2 to 44.9 mg O_2/l, the WHO permissible limits being 10 mg O_2/l. A more stringent standard of 4 mg O_2/l has also been quoted [13]. With respect to the WHO standard, 7 of the 18 tube wells and 3 of the 13 bore wells have objectionable COD values. Higher value of 44.9 mg O_2/l has been observed at Piran Park. Nitrite was observed in 6 of the 18 tube wells, Khat Koruna showed the maximum concentration; Similarly 6 of the 13 bore well waters have indicated the presence of nitrite. Samples from District Council Colony, Rashakai Koruna, and Pipe factory at Muqam have higher concentration of nitrite. The presence of nitrite in waters shows bacterial activity, even traces of nitrites are objectionable [14] and renders the water unfit for drinking. A peculiar trend between calcium and magnesium concentrations was observed.

Table 3: Chemical characteristics of potable waters of Mardan City and surrounding areas

Location	pH	COD ($mg\ O_2/l$)	**Nitrite	*HCO_3^- (mg/l)	*T. H. (mg/l)	*Ca^{+2} (mg/l)	*Mg^{+2} (mg/l)	Na^+ (mg/l)	K^+ (mg/l)	Cl^- (mg/l)	SO_4^{-2} (mg/l)
Tube wells											
Kas Koruna	7.42	7.5	+	152.1	308.2	94.2	214.0	89.1	7.1	5.9	57.5
New bus stand	7.62	7.5	-	140.2	342.4	171.2	171.2	86.2	5.8	5.7	127.4
Baghdada	7.63	15.0	-	168.2	316.7	98.4	218.3	73.5	5.8	3.4	172.6
Par Hoti	7.66	18.8	-	184.7	338.1	184.0	154.1	77.2	8.5	5.9	127.4
Rustam Khel	7.97	33.7	+	156.2	286.8	94.2	192.6	57.2	6.3	3.4	123.3
Pirum park	8.07	44.9	++	164.3	252.5	85.6	166.9	97.5	5.2	9.2	135.6
Eidgah road	7.90	7.6	-	140.2	243.9	59.9	184.0	81.0	5.0	4.2	106.8
Toru road	7.50	7.6	-	312.2	453.7	158.4	295.3	169.6	9.9	18.5	86.3
Dang baba	7.75	15.2	-	152.0	316.7	94.2	222.6	76.4	5.9	57.5	143.8
Gaju Khan road	7.43	15.2	-	160.2	282.5	141.2	141.2	63.1	5.9	7.6	94.5
Nisata road	7.68	23.0	++	180.7	316.7	85.6	231.1	107.2	7.6	11.1	172.6
Karwan road	7.73	15.2	-	156.3	303.9	64.2	239.7	76.4	5.5	14.6	176.7
Cantt. area	8.09	7.6	-	208.4	440.8	154.1	286.8	87.2	6.4	19.2	201.3
Khat Koruna	7.46	15.2	+++	256.3	736.2	351.0	385.2	96.3	6.3	21.8	279.0
Ward No. 14	7.87	7.6	-	176.2	351.0	167.0	184.2	79.2	8.1	23.2	168.5
Sharif Khan Koruna	8.42	15.1	-	264.2	248.2	81.3	166.0	140.3	6.2	42.8	152.0
Akbar Darul ulum	8.17	7.4	++	228.0	205.4	42.8	162.6	142.6	4.5	31.1	160.2
Hoti bazar road	7.94	22.1	+	176.3	248.2	85.6	162.6	95.8	6.8	45.4	37.0
Bore wells											
GHQ Hospital	7.78	15.2	-	176.2	300.0	94.2	205.0	72.4	5.9	5.0	123.3
Distt. Council Colony	7.58	22.8	+++	224.3	346.7	145.5	201.2	94.1	8.6	10.0	135.6
Gali Gagh road	7.93	7.2	-	240.6	303.9	128.4	175.5	112.3	6.2	8.4	131.5
Farm Koruna	7.75	15.7	-	212.5	389.5	166.9	222.6	44.2	4.9	6.7	28.8
Dagai Kali	7.79	22.2	-	208.4	201.2	85.6	115.6	111.4	3.1	8.4	86.3
Baghdada/Takht Bai road	7.88	15.1	-	168.2	308.2	94.2	214.0	66.0	5.9	23.2	53.4
Premier Sugar Mills Colony	7.86	22.1	-	168.0	252.5	102.7	149.9	103.5	6.0	47.9	74.0
Gari Kapura road	7.74	15.1	+	260.1	209.7	64.2	145.5	114.6	11.5	51.2	65.5
Rashakai Koruna	7.75	22.2	+++	292.3	476.0	124.0	352.0	134.8	4.5	73.9	307.2
Bibi Aba Ziarat	8.03	7.6	+	176.2	300.0	120.0	180.0	111.6	7.3	42.0	49.9
Sahib Zar Brick Kiln	8.04	8.5	-	180.4	332.0	160.0	172.0	54.0	3.9	21.0	92.2
Pipe Factory (Muqam)	8.15	17.6	+++	192.4	364.0	120.0	144.0	144.1	4.5	31.9	130.6
Shamsul Qamer Bagh	8.26	15.2	+	240.3	228.0	84.0	144.0	169.7	6.0	50.4	84.5

*as $CaCO_3$ OH^- and CO_3^{-2} alkalinities as $CaCO_3$ is *Nil.* T. H.= Total Hardness

**-: Nil + : ≤0.1 mg/l ++ : ≤0.5 mg/l +++: ≥ 1 mg/l

Magnesium had a higher concentration in most of the samples compared to calcium (Table 2). The usual regular trend observed previously in the Indus River at Tarbella Dam [15], Indus River at Kalabagh Dam [16] and in US rivers [17], is that calcium concentrations were higher than magnesium. Most of the tube well waters in Mardan have higher concentration of magnesium, the permissible limit being 150 mg/l, except at Gaju Khan Road where it is 141.2 mg/l. Similarly only 4 of the 13 samples of bore wells had magnesium level within the limits

Magnesium level becomes vital when it is supplemented with sulphate. Higher concentration of both magnesium and sulphate in potable waters make it unfit as it imparts a laxative nature to it. Generally all water samples except Khat Koruna (279.0 mg/l) and Rashakai Koruna (307.2 mg/l) have sulphate concentration within the limits. Table 4 shows the synergetic effect of magnesium and sulphate. Three standards have so far been reported. It has been reported that magnesium Mg^{+2} should not exceed 30 mg/l when the sulphate concentration is 250 mg/l or 50 mg Mg^{+2}/l with 200 mg/l sulphate [18]. WHO standards (Table 5) show 150 mg/l magnesium as $CaCO_3$ which comes to about 36.45 mg Mg^{+2}/l [1]. With respect to WHO standards all tube well waters except the sample from Gaju Khan Road are above permissible level. 4 of the 13 samples of bore wells are within the permissible limits. However, the sulphate concentration in 29 samples of both tube wells and bore wells are less than 250 mg/l. Khat Koruna and Rashakai Koruna show higher values of both magnesium and sulphate concentration which make these waters laxative in nature. Probably this is the reason why the public opinion about these waters is not good. The people of these areas (Table 1) have been complaining about

Table 4: Synergetic effect of magnesium and sulphate in potable waters of Mardan City and surrounding areas

Location	Magnesium as Mg^{+2}	Sulphate as SO_4^{-2}
Tube wells		
Kas Koruna	52.0	57.5
New Bus Stand	41.6	127.4
Baghdada	53.0	172.6
Par Hotl	37.5	127.4
Rustam Khel	46.8	123.3
Piran Park	40.6	135.6
Eidgah Road	44.7	106.8
Toru Road	71.8	86.3
Dang Baba	54.1	143.8
Gaju Khan Road	34.3	94.5
Nisata Road	56.2	172.6
Karwan Road	58.2	176.7
Cantt. Area	69.7	201.3
Khat Koruna	93.6	279.0
Ward No. 14	44.8	168.5
Sharif Khan Koruna	40.3	152.0
Akbar Darul ulum	39.5	160.2
Hotl Bazar Road	39.5	37.0
Bore wells		
GHQ Hospital	49.8	123.3
Distt. Council Colony	48.9	135.6
Guli Gagh Road	42.6	131.5
Farm Koruna	54.1	28.8
Dagai Kali	28.1	86.3
Baghdada/Takht Bai road	52.0	53.4
Premier Sugar Mills Colony	36.4	74.0
Gari Kapura Road	53.4	65.5
Rashakai Koruna	85.5	307.2
Bibi Aba Ziarat	43.7	49.9
Sahib Zar Brick Kiln	41.8	92.2
Pipe Factory (Muqam)	35.0	130.6
Shamsul Qamer Bagh	35.0	84.5

Table 5:Potable water quality standards [1]

Analytes	WHO Standards
Colour	Colourless
Odour	Odourless
Taste	Tasteless
Temperature	12 °C
pH	6.5-9.2
Dissolved oxygen	≥ 3 (mg O_2/l)
Total dissolved solids	500 (mg/l)
Total suspended solids	5 (mg/l)
Total solids	505 (mg/l)
Chlorides as Cl^-	250 (mg/l)
Nitrates as NO_3^-	45 (mg/l)
Nitrites as NO_2^-	0.1 (mg/l)
Total hardness as $CaCO_3$	500 (mg/l)
Calcium as $CaCO_3$	250 (mg/l)
Magnesium as $CaCO_3$	150 (mg/l)
Biochemical oxygen demand (COD)	10 (mg O_2/l)
Sulphates as SO_4^{-2}	250 (mg/l)
Sodium as Na^+	250 (mg/l)
Potassium K^+	12 (mg/l)
Electrical conductivity	400 (µS/cm)

the stomach/gastrointestinal problems. Employing 30 mg Mg^{+2}/l and 150 mg SO_4^{-2}/l as standards, 8 of the 18 tube wells and one of the 13 bore wells fell in the non-potable category. The quality of bore well samples is better than tube wells due to the reason that most of the tube wells are situated in the thickly populated urban areas and therefore seepage of waste waters of the city make the water unhygienic. On the other hand bore wells are mostly situated in rural areas which are less susceptible to pollution caused by any seepage despite low depth of bore wells.

Experimental

Thirty one sampling sites were randomly selected for sampling. These included the samples collected from tube wells and bore wells. Approximately 2 litres sample was collected in properly washed plastic bottles, Before collection, each bottle was rinsed with the same water thrice and then filled with the sample. The color and odour of the samples were observed on the spot whereas taste was checked organoleptically. The temperature was measured by an ordinary centigrade thermometer on the spot. General public opinion was also recorded during the sample collection. Conductivity was also measured on the spot with a potable conductivity meter (Jenway) while dissolved oxygen (DO) was measured with a DO meter (model OXI-57 WTW) Weilheim, Germany. The standard open reflux method was used for the determination of COD [19]. Sodium and potassium were measured using a flame photometer (Corning). UV Spectrophotometer (U-2000 Hitachi Japan) was used for the semiquantitative determination of nitrites whereas the rest of the chemical analyses were made employing standard methods [19].

Conclusion

On the basis of chemical characterization of 31 potable water samples from tube wells and bore wells of Mardan City and surrounding areas it was found that the presence of higher level of COD, higher conductivity, higher level of magnesium and sulphate make the water unfit for human consumption. Results also suggest that magnesium concentration compared to calcium in almost all samples were high. The bore well waters seem comparatively less polluted than the tube well

waters. The conclusion drawn in this study is supported by the statements of the inhabitants that gastrointestinal problems are common in those areas.

It is suggested that water should be boiled before drinking to kill most of the bacteria and remove some of calcium and magnesium by converting their soluble bicarbonates into insoluble carbonates.

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