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Assessment of groundwater quality of district Dir Lower Pakistan

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Abstract

The present study was aimed to assess the drinking water quality in District Dir Lower. During the study 33 water samples were collected from tube wells, dug wells and hand pumps and were analyzed for various physico-chemical parameters. The results of evaluated parameters were compared against the standard guideline values recommended by the World Health Organization for drinking water. The parameters studied were variable in different ranges: pH 6.5-8.5, conductivity 680-3250 µs/cm, total solids 880-1250 mg/L, total hardness 260-615 mg/L, calcium hardness 150-340 mg/L, magnesium hardness 75-220 mg/L, alkalinity 190-420 mg/L, total dissolved solids 720-2010 mg/L, total suspended solids 1-35 mg/L, sodium 100-250 mg/L, chlorides 60-220 mg/L, nitrites 0.5-2 mg/L, sulphate 60-312 mg/L and potassium 1.9-21.3 mg/L. The results showed that the water parameters of the areas distant from river Panjkora falls within the WHO suggested permissible limits. The water quality of the riverine areas was somewhat disturbed for some parameters. It is suggested to monitor the water regularly to avoid further deterioration. The agricultural run offs and domestic wastes should be treated properly before disposing off. The waste products should be dumped to proper disposal sites instead of river banks.

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Introduction

Due to the ever increasing demand for potable water and insufficiency of available surface water, the groundwater importance is increasing day by day. The study of hydro geochemical cycles is a handy tool for identifying the processes accountable for the chemistry of groundwater. Groundwater is an important natural resource, may be renewable or nonrenewable depending upon its use and consumption. Round about one third of the world's population use groundwater for drinking purpose (Nickson *et al.,* 2005). Groundwater is the principal source of water supply and presently it is the most plentifully consumed (more than 70 %) valuable natural resource for various human activities (Prasad and Narayana, 2004). Its use in such a huge amount is due to the scarcity of potable surface water. Due to the presence of protective soil cover, groundwater is considered purer and safer than surface water (Mishra *et al.,* 2005). The water quality is assessed by comparing its physico-chemical parameters against the suggested permissible limits (Burston *et al.,* 1993).

Water is the basic need of life but tragically its quality is continuously deteriorating due to anthropogenic activities (Agarwal, 2002). Surface and ground water quality degradation is the burning issue echoing on the horizon of environment research. The degree of human dependency on water and scarcity of usable water (0.002% of total water) renders its conservation on priority basis (Yousaf *et al.,* 2013). Water pollution, related health threats and aquatic biodiversity effects are clear like broad day light. According to "community health study" drinking of poor water quality is responsible for 50% of all reported cases of diseases. In Pakistan 40% mortalities are due to drinking of poor quality of water (Chhatwal, 1990).

More than 80% people in our province use clean drinking water (Yousaf *et al.,* 2013). However, some people are facing problem in getting clean drinking water such as southern districts are generally having brackish water or water is available in greater depth etc. In contrast some areas have potential of water resources. In northern parts of the province the systems are generally based on streams, springs and rivers. Due to lack of local treatment , regular assessment, poor condition of water supply system, contamination from drainage pipes and contaminated water sources in different parts of urban centers, the quality of drinking water is often low (Bangash and Khan, 2001).

Research about water quality has been carried out in different part of Khyber Pakhtunkhwa province and throughout Pakistan. Yousaf *et al.,* (2013) evaluated the potable water quality of District Nowshehra and concluded that more than 60% of water is not fit for human consumption. Ilyas *et al.,* (2008) evaluated the drinking water quality available to children at schools in Faisal Abad and concluded that the water is having less calcium content then the WHO permissible limits. Khan *et al.,* (2005) carried out research on the water quality of urban areas in Peshawar and concluded that magnesium content is higher than the WHO suggested permissible limits. Khan *et al.,* (1999) observed the water quality of Haripur and their study revealed its contamination due to the presence of nitrites. Hussain *et al.,* (1999) also studied the potable water quality of District Bannu and their study rendered its water unfit for drinking. Similarly research has also been carried out on various rivers of the province. The present study was undertaken to assess the groundwater quality of district Dir Lower for drinking purpose.

Materials and methods

Study Area

District Dir Lower is located with Latitudes and Longitudes of 71°, 31′ to 72°, 14′ East and 34°, 37′ to 35°, 07′ North respectively. It is approximately 2700 feet above mean sea level. An annual rain fall of 1468.8 mm and 253.7 mm during December and March respectively is common. District Dir is bounded by District Chitral (North), by Bajaur and Afghanistan (West), by District Malakand (South) and by District Swat (East). River Panjkora is the key river in District Dir that originates from Kohistan, District

Dir (Upper) and flow southward dividing District Dir Upper and Lower into two halves. River Panjkora joins River Swat at Sharbatti (behind Totakan, District Malakand). Fig. 1 shows sampling sites in the study area.

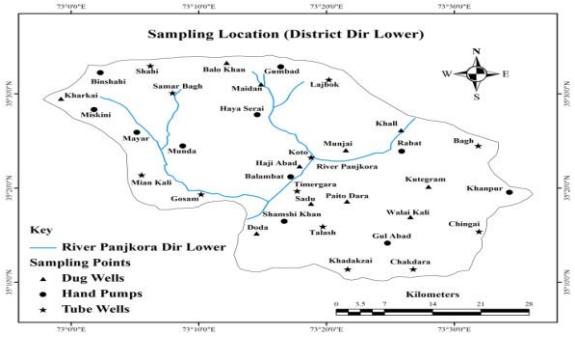

Fig. 1. Map showing District Lower Dir and the sampling sites.

Sampling and Analysis

A total of thirty three samples were collected from various sources including dug wells, tube wells and hand pumps within the study area. The samples were tested for pH and conductivity on the spot and were transported to the laboratory for further analysis.

The pH was measured with portable pH meter (Natner, UK made). The conventional methods referred by American public health association (APH/AWWA, 1998) were followed for determining total alkalinity, total suspended solids (TSS), total dissolved solids (TDS), total hardness, magnesium hardness, calcium hardness, chlorides, and sulphate contents. Potable conductivity meter (Jenway, England made) was used for finding conductivity. Sulphonilic method using UV Spectrophotometer (Hitachi-U-2000) was used for finding Nitrite contents. For finding out Sodium and Potassium contents Flame Photometer (Jenway-FPF-7) was used. The other parameters i.e., color; odor and taste were observed organolaptically.

Results

The results of the observed physico-chemical parameters showed variations. The description of Physical parameters for tube well, dug well and hand pump samples are given in table 1, 2 and 3 respectively. The results showed that 87% of collected water samples were colorless, odourless and tasteless while 20% water samples were turbid. The observed mean Electric Conductivity 1260 µs/cm for all locations, showing that it's higher than the suggested permissible limits (9). The observed mean pH was 7.3 for all locations, showing that pH of the study area has no alarming situation and fall within the permissible limits.

Table 1. Description of Physical parameters of tube wells' water samples.

S #	Location	Color	Odour	Taste	Turbidity	EC	pH
1	Koto	Colorless	Odorless	Tasteless	Clear	735	7.2
2	Timergara	Colorless	Odorless	Tasteless	Turbid	1820	7.8
3	Chakdara	Colorless	Odorless	Tasteless	Clear	1930	7.5
4	Samar Bagh	Colorless	Odorless	Tasteless	Clear	2250	7.7
5	Talash	Colorless	Odorless	Tasteless	Turbid	2070	7.1
6	Lajbok	Colorless	Odorless	Tasteless	Clear	680	7
7	Khadakzai	Colorless	Odorless	Tasteless	Clear	800	7.1
8	Shahi	Colorless	Odorless	Tasteless	Clear	700	7
9	Bagh	Colorless	Odorless	Tasteless	Clear	810	7.3
10	Mian Kali	Colorless	Odorless	Tasteless	Clear	725	6.9
11	Chingai	Colorless	Odorless	Tasteless	Clear	710	7.2

EC= Electrical Conductivity.

The results of Physico-chemical parameters for tube well, dug well and hand pump samples are given in Table 4, 5 and 6 respectively.

The observed mean Total Dissolved Solids was 976 mg/L, means the TDS fall within the suggested limits. The observed mean Total Suspended Solids was 5.636 for tube wells water, 14.82 for dug wells water and 7.182 mg/L for hand pumps water. The observed mean Total Hardness was 338 for tube wells water,

510 for dug wells water and 524 mg/L for hand pumps water. The observed mean Calcium Hardness was 271.364 for dug wells, 164.545 for tube wells and 285.909 mg/L for hand pumps water. The observed mean Magnesium Hardness was 160 for tube wells, 212.27 for dug wells and 155.36 mg/L for hand pumps water. The observed mean Alkalinity for tube wells was 283.182, for dug wells was 243.182 and hand pumps water was 292.727 mg/L.

Table 2. Description of Physical parameters of dug wells' water samples.

S #	Location	Color	Odour	Taste	Turbidity	EC	pH
1	Khall	Brownish	Smelly	Pungent	Turbid	3250	8.5
2	Munjai	Colorless	Odorless	Tasteless	Clear	2110	7.3
3	Sadu	Colorless	Odorless	Tasteless	Clear	825	7.2
4	Maidan	Colorless	Odorless	Tasteless	Clear	717	7.1
5	Haji Abad	Brownish	Smelly	Pungent	Turbid	3250	7.8
6	Paito Dara	Colorless	Odorless	Tasteless	Clear	871	7.2
7	Doda	Colorless	Odorless	Tasteless	Clear	1000	7.4
8	Kharkai	Colorless	Odorless	Tasteless	Clear	900	7.5
9	Kutegram	Brownish	Smelly	Pungent	Turbid	860	7.4
10	Walikali	Colorless	Odorless	Tasteless	Clear	835	7.1
11	Balo Khan	Colorless	Odorless	Tasteless	Clear	800	7.2

The observed mean Chloride for tube wells was 151.909, for dug wells' was 182.273 and for hand pumps water was 114.455 mg/L. The observed mean Nitrite was 0.827 for tube wells, 0.936 for dug wells and 0.736 mg/L for hand pumps water. The observed mean Sodium for tube wells was 182.727, for dug wells was 166.545 and for hand pumps water was 205.727 mg/L respectively. The observed mean Potassium was 7.718, 7.073 and 10.82 mg/L for tube wells, dug wells and hand pumps water respectively.

The observed ranges of the analyzed parameters are shown in Table 7, separately for tube wells, dug wells and hand pumps. It is also showing the WHO suggested limits as well as mean and standard deviation of the observed parameters.

Table 3. Description of Physical parameters of hand pumps' water samples.

S #	Location	Color	Odour	Taste	Turbidity	EC	pH
1	Munda	Colorless	Odorless	Tasteless	Clear	821	7.3
2	Balambat	Brownish	Smelly	Pungent	Turbid	3170	7.9
3	Rabat	Colorless	Odorless	Tasteless	Clear	1770	7.7
4	Haya Serai	Colorless	Odorless	Tasteless	Clear	811	7.2
5	Gul Abad	Colorless	Odorless	Tasteless	Clear	1170	7.5
6	Shamshi Khan	Colorless	Odorless	Tasteless	Clear	1260	7.4
7	Mayar	Colorless	Odorless	Tasteless	Clear	800	7
8	Binshahi	Colorless	Odorless	Tasteless	Clear	825	7.1
9	Khanpur	Colorless	Odorless	Tasteless	Clear	710	6.8
10	Miskini	Colorless	Odorless	Tasteless	Clear	825	6.7
11	Gumbad	Colorless	Odorless	Tasteless	Clear	770	7.2

Discussion

The water quality parameters were observed and the results showed its fitness for human consumption except those areas situated near river Panjkora such as Khall, Rabat, Munjai, Haji Abad and Balambat. The water of riverine areas is not fit for drinking purpose, after comparing their water parameters' values against the suggested ones. Most of water quality parameters of the areas distant from river Panjkora were within the permissible limits, suggested by World Health Organization, while some values were deviating from the suggested ranges (WHO, 2011).

Across all collected samples electrical conductivity ranged between 680 and 3250 µs/cm. The observed mean Electric Conductivity was showing that it's higher than the suggested permissible limits. The strongest correlations (r > 0.5, p = 0.001) with electrical conductivity included pH and TSS (r = 0.797), followed by Sodium (r = 0.723), TS (r = 0.692), total hardness (r = 0.644) and TDS (r = 0.577).

Table 4. Physico-chemical parameters of Tube Wells' water samples.

	TS	TDS	TSS	T.H	Ca	Mg	T.A	Cl_2	SO_4	NO_2	Na	K
Koto	910	875	13	360	230	170	305	162	305	1.1	222	5.5
Timergara	975	900	15	410	210	205	380	182	295	1.8	220	5.7
Chakdara	895	800	9	290	215	190	290	142	270	0.9	170	1.9
Talash	945	870	1	425	190	110	285	115	180	0.7	170	2.5
Samar Bagh	900	810	4	260	200	75	265	60	95	0.5	128	3.1
Lajbok	890	720	3	260	150	90	260	90	60	0.5	120	3.7
Khadakzai	900	800	3	270	150	150	200	150	290	0.4	170	8.3
Shahi	890	875	5	310	130	210	420	210	210	0.5	250	17.5
Bagh	825	790	4	360	100	200	270	200	110	0.8	200	5.7
Mian Kali	890	900	3	410	95	190	190	190	70	0.9	190	21.3
Chingai	910	800	2	370	140	170	250	170	250	1	170	9.7

TS= Total Solids, TDS= Total Dissolved Solids, TSS= Total Suspended Solids, T.H = Total hardness, Ca= Calcium, Mg= Magnesium, T.A= Total Alkalinity, Cl_2= Chloride, SO_4= Sulphate, NO_2= Nitrate, Na= Sodium and K= Potassium.

pH ranged from 6.5 to 8.5 across all sampling sites. The observed mean pH was showing that pH of the study area has no alarming situation and fall with in the suggested permissible limits by WHO in 2011 (11). The strongest correlations (r > 0.5, p = 0.001) with pH included Total Solids (r = 0.657), Nitrite (r = 0.627) and TSS (r = 0.578).

Table 5. Physico-chemical parameters of Dug Wells' water samples.

	TS	TDS	TSS	T.H	Ca	Mg	T.A	Cl_2	SO_4	NO_2	Na	K
Khall	1250	1900	35	600	305	260	250	185	290	1.5	190	4.7
Munjai	1110	2010	35	615	310	260	270	190	290	1.8	220	4.4
Sadu	1020	1000	15	475	270	190	215	180	250	1.1	190	4.1
Maidan	925	800	5	420	210	105	220	170	210	0.5	142	3.8
Haji Abad	1205	1575	20	525	310	260	230	180	280	1.7	210	4.9
Paito Dara	950	850	5	470	230	155	215	170	230	0.5	170	3.6
Doda	1010	900	1	470	270	205	270	170	200	0.9	140	12.1
Kharkai	900	1100	3	450	240	170	210	220	190	0.5	190	7.2
Kutegram	925	1000	12	500	230	200	245	190	170	0.7	100	9.3
Walikali	980	990	17	510	270	250	345	160	200	0.6	110	10
Balo Khan	990	1060	15	575	340	280	205	190	270	0.5	170	13.7

For all the collected samples TDS ranged from 720 to 2010 mg/L. The observed mean Total Dissolved Solids was 976 mg/L, means the TDS fall within the suggested limits of WHO (2007). The strongest correlations (r > 0.5, p = 0.001) with TDS included TSS (r = 0.829), TS (r = 0.81), Mg.H (r = 0.608), EC

(r = 0.577) and Nitrite (r = 0.546).

TSS, across all sampling sites, ranged from 1 to 35 mg/L. The observed mean Total Suspended Solids was 5.636 mg/L for tube wells water, 14.82 mg/L for dug wells water, and 7.182 mg/L for hand pumps water. The results showed that tube wells have got a bit better situations followed by hand pumps. Dug wells had quite higher mean value than the suggested one. The strongest correlations (r > 0.5, p = 0.001) with TSS across all sites and sampling depths was shown by Nitrite (r = 0.74), followed by Magnesium hardness (r = 0.697) and total hardness (r = 0.512).

Over all, Total hardness ranged from 260 to 615 mg/L. The observed mean Total Hardness was 338 mg/L for tube wells water, 510 mg/L for dug wells water and 524 mg/L for hand pumps water. The strongest correlation (r > 0.5, p = 0.001) with Total hardness across all sampling sites was shown by Nitrite (r = 0.825).

Table 6. Physico-chemical parameters of Hand Pumps' water samples.

	TS	TDS	TSS	T.H	Ca	Mg	T.A	Cl_2	SO_4	NO_2	Na	K
Munda	880	880	3	475	250	119	240	100	200	0.5	200	7.7
Balambat	1000	912	20	565	305	200	315	110	312	2	229	4.4
Rabat	1040	890	17	575	320	220	260	98	290	1.5	232	4.9
Haya Serai	910	880	3	490	300	115	210	88	250	0.5	210	6.3
Gul Abad	975	910	5	475	270	120	280	93	273	0.5	217	7.5
Shamshi Khan	950	890	8	510	270	135	210	90	250	0.5	205	5.7
Mayar	910	900	5	500	250	130	400	150	240	0.5	180	19.7
Binshahi	995	890	5	500	270	150	390	120	200	0.4	200	20.3
Khanpur	900	960	4	590	340	200	200	90	290	0.8	190	7.1
Miskini	910	900	5	500	250	150	415	170	210	0.5	190	18.3
Gumbad	1000	880	4	585	320	170	300	150	200	0.4	210	17.1

Across all sampling sites calcium ranged from 150 to 340 mg/L. The observed mean Calcium Hardness was 164.545, 271.364 and 285.909 mg/L for tube wells, dug wells and hand pumps water respectively. The strongest correlation (r > 0.5, p = 0.001) with calcium hardness across all sampling sites was shown by sulphate (r = 0.59).

For all sampling sites magnesium ranged from 75 to 220 mg/L. The observed mean Magnesium Hardness was 160, 212.27 and 155.36 mg/L for tube wells, dug wells and hand pumps water respectively. The strongest correlations (r > 0.5, p = 0.001) with Total hardness across all sampling sites included Chloride (r = 0.586), followed by Nitrite (r = 0.574).

Total alkalinity ranged from 190 to 420 mg/L across all sampling sites. The observed mean Alkalinity for tube wells, dug wells and hand pumps water were 283.182, 243.182 and 292.727 mg/L respectively. The highest correlation (p = 0.001) with Total alkalinity was shown by Potassium (r = 0.444).

Chloride ranged from 60 to 220 mg/L across all sampling sites. The observed mean Chloride for tube wells, dug wells and hand pumps water was 151.909, 182.273 and 114.455 mg/L respectively. The highest correlation (p = 0.001) with Chloride across all sampling sites included Potassium (r = 0.261).

Nitrite, across all sampling sites ranged from 0.5 to 2 mg/L. The observed mean Nitrite were 0.827, 0.936 and 0.736 mg/L for tube wells, dug wells and hand pumps water respectively. The strongest correlations (r > 0.5, p = 0.001) with Nitrite across all sampling sites included TSS (r = 0.74), followed by pH (r = 0.627), TS (r = 0.605) and TDS (r = 0.546).

Sodium ranged from 100 to 250 mg/L across all sampling sites. The observed mean Sodium for tube

wells, dug wells and hand pumps water were 182.727, 166.545 and 205.727 mg/L respectively. The strongest correlation (r > 0.5, p = 0.001) with Sodium across all sampling sites was shown by the electrical conductivity (r = 0.723).

Table 7. Physico-chemical parameters of water samples of District Dir (L).

Parameters	T. Wells	D. Wells	H. Pumps	WHO *
TS (mg/L)	890-975**	910-1250	880-1040	1000
	902.7***±37.04****	1024.1±116.19	951.8±52.83	
TDS (mg/L)	720-900	800-2010	880-960	1000
	830.9±56.78	1198.64±425.78	899.66±23.1	
TSS (mg/L)	1-15	5-35	3-20	5
	5.636±4.632	14.82±11.74	7.182±5.793	
T.H (mg/L)	260-425	420-615	475-590	500
	338.6±63.09	517.5±77.37	524.09±44.99	
Ca. H (mg/L)	150-240	210-340	250-340	250
	164.5±46.93	271.4±41.24	285.91±32.31	
Mg. H (mg/L)	75-205	105-280	115-220	150
	160±47.802	212.27±54.9	155.36±37.01	
T.A (mg/L)	190-420	205-345	200-415	500
	283.2±68.1	243.2±16.02	292.73±79.23	
Cl_2 (mg/L)	60-210	160-220	88-170	250
	151.91±47.13	182.27±16.02	114.45±29.15	
SO_4 (mg/L)	60-305	170-290	200-312	250
	194.1±95.5	234.54±43.44	246.82±40.82	
NO_2 (mg/L)	0.5-1.8	0.5-1.8	0.5-2.0	0.5
	0.827±0.398	0.936±0.51	0.736±0.524	
Na (mg/L)	120-250	100-220	180-232	200
	182.73±39.22	166.54±39.2	205.73±16.2	
K (mg/L)	1.9-21.3	3.6-13.7	4.6-20.3	75
	7.718±6.293	7.073±3.631	10.82±6.493	

* = * Limits suggested by World Health Organization, **= Range, *** = Mean, **** = Standard Deviation.

Potassium ranged from 1.9 to 21.3 mg/L across all sampling sites. The observed mean Potassium was 7.718, 7.073 and 10.82 mg/L for tube wells, dug wells and hand pumps water respectively. The highest correlations (p = 0.001) with Potassium across all sampling sites were comprised of total alkalinity (r = 0.444) and electrical conductivity (r = 0.221).

Conclusion

As for as the water parameters were concern, these were lying within the suggested limits except TSS, Nitrate, EC and Magnesium hardness by World Health Organization for ground water. Total hardness, calcium hardness and sulphates were also deviating from the standard limits in the riverine areas. The parameters values' of the samples, from areas near river Panjkora, were a bit higher than the suggested limits. This might be due to many factors, prominent being 2010 flooding, agricultural runoffs, domestic wastes, use of the riverine shores for recreational purpose and dumping of the waste materials into the river.

The water resources of the areas distant from river Panjkora were quite safer and there is no alarming change. On account of deep depth water of tube wells was safer as compare to hand pumps and dug wells. While comparing the sampled sites, no drastic changes have been recorded in the Physico-Chemical parameters except in electrical conductivity. To conserve and maintain the ground water quality, anthropogenic activities should be controlled. Regular assessment should be carried out in order to maintain water quality usable. Pretreatment of the wastes from houses and agricultural run offs should be carried out.

Disclosure

None of the authors have any conflict of interest. It is the combine effort of all the authors.

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