Quality Parameters and Its Impact on the Drinking Water of Peshawar Division, Pakistan

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Summary: Drinking Water samples collected from different localities of Peshawar division were examined for different physico-chemical parameters such as pH, conductance, anions like Cl^{-1}, SO_4^{-2}, F^{-1}, NO_3^{-1}, cations such as Na^+, K^+, Cu^{+2} and the total Iron. The values were compared with the standards of W.H.O and encyclopedia of environmental sciences and were found to be within the permissible limit except nitrite. The toxic effects of these parameters have also been discussed.

Introduction

Water pollution is a worldwide issue. This problem is quite different in numerous respects in the economically stable and unstable countries. Heat, poisonous metals, acids, sediments, animal and human wastes and synthetic organic compounds foul the waterways of developed countries. Human and animal wastes, sediment and pathogenic organisms head the list in the non-industrialized countries. In these countries, unsanitary water and malnutrition account for most of illness and death [1].

Water pollutants arise from many natural sources like natural runoff, soluble chemicals in water that diffuse through the soil and anthropogenic activities such as farming, mining, building, manufacturing, homes and businesses. The pollution sources may be point sources or non-point sources. Point sources involve the release of waste from particular point including sewage treatment plants, storm water runoff from joint storm and sanitary sewer lines in city areas, manufacturing plants and animal feedlots. While the nonpoint sources involve the diffuse discharge of wastes from land runoff, atmospheric precipitation and sources of that which are difficult to recognize and control for example, runoff of residue from natural and human caused forest fires, building, logging and farming, effluents of chemical fertilizers, pesticides and saline irrigation water from croplands, urban storm water runoff, drainage of acids, minerals and sediments from active and dumped mines. Nonpoint source pollution is a big problem and is not recognize as a major problem because the sources are extensively spread out, hard to identify and tough to control [1].

Water pollutants can be categorized as degradable or nondegradable. High degradable (non persistent) pollutants can be broken down quite rapidly by natural chemical cycling processes as long as the pollutants don't over load the system, together with domestic sewage, other oxygen demanding wastes, plant nutrients and some synthetic organic chemicals. These pollutants can be degraded in to harmless or dangerous forms, for instance acidic waters can change moderately harmful mercury metal and inorganic mercury compounds into very poisonous organic methyl mercury. Non-degradable pollutants are not be broken down by natural purifying processes such as mercury, lead and arsenic, some salts of metals, sediments, some man-made organic compounds like plastics and some bacteria and viruses. These contaminants can be controlled by removing them through waste treatment or by preventing them from entering the environment [1].

The survival of human being itself is a source of water pollution. In prehistoric era, the purifying capability of nature was much superior than the rate of water pollution caused by human living. But with the way of time, men began to settle close to water areas for the ease of living, and then they developed a variety of industries, which give them with the establishment of sophisticated life. Frequently, with the increase in the number of these industries the quality of water was contaminated, discharging a variety of wastes in to water bodies. On the other hand, the increase in inhabitants has also invited the concentration of contamination sources. As a

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consequence, the rate of ecological pollution has improved the rate of natural decontamination [1].

Previous research workers have investigated various anions and cations in the drinking water as well as in industrial effluents and have also discussed their acute and chronic effects.

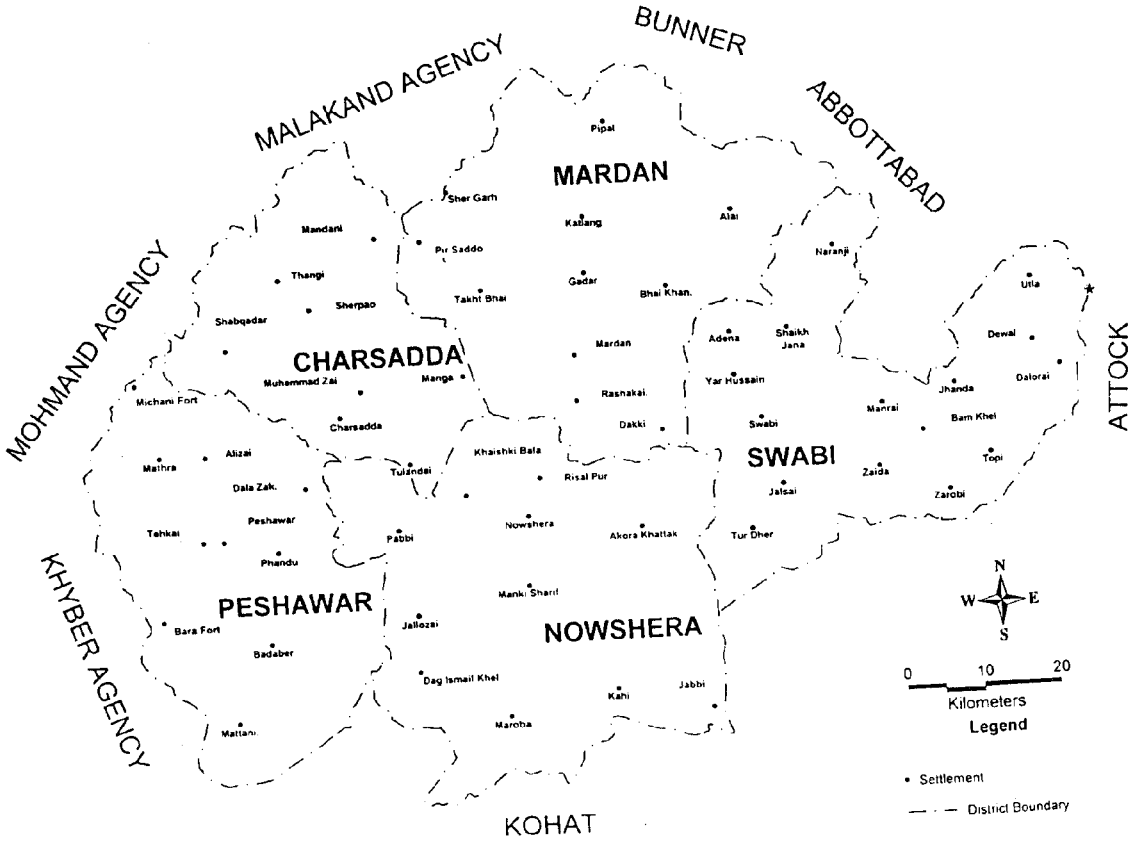
pH of waters of different sources has been investigated previously by different workers [2-5]. Vengosh monitored chlorides and fluorides in the domestic wastewater [6]. Nitrate in different sources of water was determined by different research workers [7-10]. Sulfate in water has also been investigated by Darie [11]. Mumtaz and Khuhawar determined Sodium in the wastewater [3,12]; Gutekunst *et al* studied the heavy metal in various media [13], Potassium in water of different sources have also been investigated [3, 12].

The purpose of this research work was to study quality parameters and its impact on the drinking water of Peshawar division. The Physical geography of the division includes the districts of Peshawar, Nowshera, Charsada, Mardan and Swabi. The region is located from 33° and 42′ to 34° and 32′ North latitudes and 71° and 22′ to 72° and 46′ East longitudes over the globe. The area is bounded by Kohat district in the south, Attock in the east, Mohammad and Khyber agencies in the west, Malakand Agency, Bunner and Abbottabad district in the North and North East (Map -1)

Results and Discussion

Drinking water samples collected from different localities of Peshawar division, PAKISTAN (Map-1), were examined for various parameters like pH, conductivity, alkalinity, total hardness, NO_3^{-1}, Cl^{-1}, SO_4^{-2}, F^{-1}, Cu^{+2}, Na^{+1}, K^{+1} and total iron.

Table-1 shows the pH of drinking water of Peshawar division, which is in the range of 7.14-7.80.



Map-1: THE DRINKING WATER SAMPLING AREAS OF PESHAWAR DIVISION

Table-1: Determination of pH, Conductance, Hardness and Alkalinity in the Drinking Water Samples Collected at Different Locations of Peshawar Division.

	pH			Conductance μS/Cm			Hardness (mg/L)			Alkalinity (mg/L)		
Sample Areas	1	2	M	1	2	M	1	2	M	1	2	M
Rashaki Banda	7.43	7.43	7.43	438	434	436	362	358	360	444	436	440
Shabqadar	7.39	7.39	7.39	370	366	368	384	376	680	555	545	550
Mechni R. House	7.16	7.12	7.14	1206	1202	1204	623	617	620	601	599	600
Ghalani	7.75	7.71	7.73	479	475	477	344	336	340	520	500	510
Ekka Ghund	7.80	7.76	7.78	493	488	490	324	316	320	460	420	440
Pandu	7.36	7.32	7.34	512	508	510	442	438	440	490	450	470
Bazarkhel	7.67	7.63	7.65	522	518	520	502	498	500	383	377	380
Dalazak Road	7.17	7.13	7.15	414	410	412	504	496	500	476	474	475
Kohat Road	7.18	7.12	7.15	577	573	575	472	468	470	402	398	400
Warsak Road	7.82	7.78	7.80	552	548	550	462	458	460	426	424	425
Hayat Abad	7.47	7.43	7.45	602	598	600	514	506	510	450	410	430
Nishtar Abad	7.8	7.2	7.5	502	498	500	532	528	530	440	430	435
Gul Bahar	7.35	7.27	7.31	403	397	400	601	599	600	510	510	510
Charsadda	7.56	7.52	7.54	422	418	420	403	397	400	377	375	376
Tehkal	7.32	7.28	7.3	412	408	410	377	373	375	300	300	300
Nowshera	7.46	7.42	7.44	335	331	333	371	369	370	303	301	302
Risalpur	7.58	7.52	7.55	658	654	656	482	478	480	398	398	398

Generally acidity in pure water is due to the presence of dissolved carbonic acid. Whereas the presence of free mineral acids in the industrial effluents make the pH of water below 3.7. Acidic water also increases the rate of solubility of heavy metals like copper, zinc and lead. The WHO recommended rang of pH for drinking water is 7.0 - 8.5 [14].

Conductivity is dependent upon the presence of ions in solution. The water samples of Peshawar division show conductivity from 333-1204 μ S/cm (table-1). The variations are due to the difference in the concentration of free ions like Cu^{++}, K^{+}, Cl^{-1}. Similar results have also been reported by earlier workers [2]

Alkalinity in water is mostly due the presence of bicarbonates, carbonates, hydroxides and the basic radicals like calcium, magnesium, sodium and potassium. The samples collected from different localities of Peshawar division show alkalinity in the range of 300-600 mg/L, which is above than the recommended standard for drinking waters *i.e.* 500mg/L. Beyond this limit, problems like hardness, gastrointestinal irritation, kidney stone and explosion of metallic pipes due the accumulation of scales inside, are resulted [15].

Total hardness is mainly due to the presence of carbonates of calcium and magnesium. Total hardness determined in the samples was in the range of 320-680 mg/L, and is shown in table-1. The hardness values of some samples is above the maximum limit (500mg/L), recommended by W.H.O. Beyond this limit, hardness may cause gastric problems, dehydration, gas trouble, kidney stone and heart problem [15].

Chlorides in water bodies are mostly present in combination with sodium, calcium and magnesium. Its concentration varies with the physiological and biological actions. Chlorides make its routes through natural mineral rocks, seawater, irrigation discharge, or from industrial effluents. Mostly, all types of water reservoirs contain chlorides less than 50 mg/L (variations occur according to the weather. Table-2 shows the chloride concentrations in the drinking water of Peshawar division and is in the range of 100-600 mg/L, whereas the permissible level for drinking purpose is 250 mg/L. Thus same samples have chloride concentrations above the permissible range. The high chloride concentration i.e. above 250 mg/L can cause toxic effects [14,15].

The fluorides in water come from fluoride-bearing rocks or from the water treatment processes (fluoridation). The optimum concentration for fluoride in the drinking water according to W.H.O is 1.5 mg/L. The drinking water of Peshawar division has fluoride concentrations of 0.001-0.009 mg/L, as can be seen from table-2, which is less than the optimum limit and is thus safe for health. Although beyond the optimum concentration it may generate problems like deformation of knee joints and other parts of the body, mottling of teeth, forward bending of vertebral column, skeletal fluorosis and paralysis [15].

Table-2: Determination of Nitrite, Chloride, Sulphate and Flouride in the Drinking Water Samples Collected at Different Locations of Peshawar Division.

Sample Areas	Nitrate (mg/L)			Chloride (mg/L)			Sulphate (mg/L)			Fluoride (mg/L)		
	1	2	M	1	2	M	1	2	M	1	2	M
Rashaki Banda	15	05	10	150	50	100	200	200	200	0.001	0.001	0.001
Shabqadar	16	14	15	202	198	200	400	200	300	0.005	0.001	0.003
Mechni Rest House	10	10	10	375	175	275	350	150	250	0.0017	0.0013	0.0015
Ghalani	7.0	3.0	5.0	237	233	235	352	348	350	0.009	0.005	0.007
Ekka Ghund	8.2	7.8	8.0	335	331	333	279	275	277	0.004	0.004	0.004
Pandu	6.5	5.5	6.0	548	538	543	270	70	170	0.008	0.008	0.008
Bazarkhel	15	05	10	343	143	243	200	120	160	0.001	0.001	0.001
Dalazak Road	40	20	30	557	553	555	317	297	307	0.004	0.004	0.004
Kohat Road	25	21	23	432	432	432	304	104	204	0.007	0.003	0.005
Warsak Road	32	12	22	220	424	222	205	205	205	0.007	0.005	0.006
Hayat Abad	29	09	19	299	299	299	200	200	200	0.004	0.002	0.003
Nishtar Abad	20	16	18	402	398	400	350	150	250	0.004	0.004	0.004
Gul Bahar	18	24	26	505	495	500	303	299	301	0.008	0.004	0.006
Charsadda	27	23	25	610	590	600	405	395	400	0.003	0.001	0.002
Tehkal	35	15	25	555	535	545	355	345	350	0.008	0.008	0.008
Nowshera	27	23	24	446	442	444	150	150	150	0.009	0.009	0.009
Risalpur	41	21	31	555	555	555	262	258	260	0.008	0.006	0.007

Nitrate found in natural waters is in the oxidized form produced by nitrifying bacteria. The extensive uses of synthetic nitrogenous fertilizers for the high yield of crops have increased the nitrate concentration in surface as well as in ground water. The concentration of nitrates in surface water is changeable and depends upon the seasonal fluctuations, which are related to the activity of microbes, as nitrates concentration is greater in winter season as compared to summer. Water containing high quantity of nitrates is extremely toxic to infants because the bacteria in the digestive system convert the nitrates to nitrites, which then diffuse in the blood stream and change the oxygen transporter haemoglobin into methaemoglobin. Also the ingested nitrites react with the secondary and tertiary amines from certain foods, form nitrosamines that are potentially carcinogenic. In our study the nitrate level found was 5-31mg/L (table-2), while the maximum permissible level for drinking water is 20 mg/L. The high concentration of nitrates may be dangerous and can cause the above-mentioned lethal effects [15].

Sulphate in surface and ground water comes from the dissolution of mineral deposits containing sulphides, thiosulphates and sulphates like pyrites.

$$2\ FeS_2 + 2\ H_2O + 7O_2 \rightarrow 2\ FeSO_4 + 2\ H_2SO_4$$

$$2\ FeSO_4 + O_2 + 2\ H_2SO_4 \rightarrow 2\ Fe\ (SO_4)_3 + 2\ H_2O$$

Sulphates in domestic wastewater contribute to permanent hardness. Table-2 shows the quantity of sulphate in the selected area, which are in the limits 150-400 mg/L, whereas its maximum concentration limit with regard to health is 400 mg/L. The determined concentration is thus below the optimum concentration. When the sulphate concentration exceed that of the recommended level, then laxative and corrosive mode of action results [14].

Sodium is present in all natural water in abundance. The presence of sodium in water depends upon the anions present in that system and the temperature. The threshold taste concentration of sodium varies from compound to compound for example, for sodium chloride it is about 350 mg/L (138 mg/L as Na^{23}), whereas for sodium sulphate is 1000 mg/L (as 348 mg/L sodium). The leaching of sodium from their respective rocks is less as compared to other metal. As can be seen from the table-3, the sodium concentrations are 19-66 mg/L, which is below the maximum threshold. The high concentrations of sodium impart taste to the water and make it unfit for every day use [14].

Potassium is an important micronutrient for plants and human beings, playing an important role in the metabolism processes of animals. The highest permissible concentration of potassium in drinking water with respect to health is 20-mg/L [14] above which it creating problems linked to sodium. The drinking water of Peshawar division shows the concentration of potassium as, 10-29 mg/L. The samples collected from certain locations such as Kohat road (22 mg/L), Warsak road (23 mg/L),

Table-3: Determination of Sodium, Potassium, Iron (Total) and Copper in the Drinking Water Collected at Different Locations of Peshawar Division.

Sample Areas	Sodium (mg/L)			Potassium (mg/L)			Iron (Total) (mg/L)			Copper (mg/L)		
	1	2	M	1	2	M	1	2	M	1	2	M
Rashaki Banda	21	17	19	10	10	10	0.1	0.1	0.1	1.0	1.0	1.0
Shabqadar	20	20	20	15	15	15	0.3	0.1	0.2	3.0	1.0	2.0
Mechni R. House	45	35	40	27	11	19	0.09	0.09	0.09	2.1	1.7	1.9
Ghalani	55	45	50	30	10	20	1.0	0.06	0.08	2.0	1.6	1.8
Ekka Ghund	30	30	30	31	11	21	0.09	0.05	0.07	1.9	1.5	1.7
Pandu	37	33	35	15	11	13	0.06	0.02	0.04	2.2	1.8	2.0
Bazarkhel	46	44	45	17	15	16	0.1	0.1	0.1	1.9	2.3	2.1
Dalazak Road	48	28	38	20	20	20	0.4	0.4	0.4	3.0	3.0	3.0
Kohat Road	56	36	46	27	17	22	1.1	0.07	0.09	3.1	3.1	3.1
Warsak Road	56	56	56	23	23	23	0.08	0.08	0.08	1.2	.08	1.0
Hayat Abad	48	28	38	25	25	25	0.05	0.05	0.05	2.0	2.0	2.0
Nishtar Abad	43	39	41	31	27	29	0.1	0.1	0.1	1.0	1.0	1.0
Gul Bahar	45	45	45	17	27	22	0.3	0.1	0.2	2.2	1.8	2.0
Charsadda	57	53	55	21	10	11	0.2	0.2	0.2	1.3	1.3	1.3
Tehkal	69	61	66	25	25	25	0.35	0.35	0.35	2.5	2.1	2.3
Nowshera	39	37	38	26	22	24	0.09	0.05	0.07	2.1	1.7	1.9
Risalpur	61	59	60	22	22	22	1.1	0.07	0.09	2.3	2.3	2.3

Table-4: Variance and Standard Deviation for Quality Parameters in the Drinking Water of Peshawar Division.

Sample Areas	pH		Conductance		Hardness		Alkalinity	
	S	S^2	S	S^2	S	S^2	S	S^2
Rashaki Banda	0.00	0.00	0.10	0.02	0.10	0.02	0.14	0.04
Shabqadar	0.00	0.00	0.10	0.02	0.14	0.04	0.158	0.05
Mechni R. House	0.10	0.02	0.10	0.02	0.12	0.03	0.07	0.01
Ghalani	0.10	0.02	0.12	0.03	0.14	0.04	2.23	10
Ekka Ghund	0.10	0.02	0.12	0.03	0.14	0.04	3.16	20
Pandu	0.10	0.02	0.10	0.02	0.10	0.02	3.16	20
Bazarkhel	0.10	0.02	0.10	0.02	0.10	0.02	0.12	0.03
Dalazak Road	0.10	0.02	0.10	0.02	0.14	0.04	0.07	0.01
Kohat Road	0.12	0.03	0.10	0.02	0.10	0.02	0.10	0.02
Warsak Road	0.10	0.02	0.10	0.02	0.10	0.02	0.07	0.01
Hayat Abad	0.10	0.02	0.10	0.02	0.014	0.04	3.16	20
Nishtar Abad	0.10	0.02	0.10	0.02	0.012	0.03	1.58	05
Gul Bahar	0.14	0.04	0.12	0.03	0.07	0.01	0.00	0.00
Charsadda	0.10	0.02	0.10	0.02	0.12	0.03	0.07	0.01
Tehkal	0.10	0.02	0.10	0.02	0.10	0.02	0.00	0.00
Nowshera	0.10	0.02	0.10	0.02	0.07	0.01	0.07	0.01
Risalpur	0.12	0.03	0.10	0.02	0.1	0.02	0.00	0.00

Table-5: Variance and Standard Deviation for Quality Parameters in the Drinking Water of Peshawar Division.

Samples Area	Sodium		Potassium		Iron (Total)		Copper	
	S	S^2	S	S^2	S	S^2	S	S^2
Rashaki Banda	1.28	05	000	00	0.000	0.00	0.00	0.00
Shabqadar	0.71	01	000	00	0.223	0.1	0.223	0.1
Mechani R. House	0.00	0.0	002	08	0.000	0.00	0.316	0.2
Ghalani	001	02	2.23	10	0.100	0.02	0.316	0.2
Ekka Ghund	0.316	0.2	2.23	10	0.122	0.03	0.316	0.2
Pandu	0.50	0.5	001	02	0.100	0.02	0.316	0.2
Bazarkhel	1.28	05	0.07	01	0.000	0.00	0.316	0.2
Dalazak Road	2.23	10	000	00	0.000	0.00	0.000	0.0
Kohat Road	001	02	1.28	05	0.100	0.02	0.000	0.0
Warsak Road	2.23	10	000	00	0.000	0.00	0.316	0.2
Hayat Abad	2.23	10	000	00	0.000	0.00	0.000	0.0
Nishtar Abad	001	02	001	02	0.000	0.00	0.000	0.0
Gul Bahar	1.41	04	1.28	05	0.070	0.01	0.316	0.2
Charsadda	001	02	2.23	10	0.000	0.00	0.000	0.0
Tehkal	2.23	10	000	00	0.000	0.00	0.316	0.2
Nowshera	1.22	03	001	02	0.100	0.02	0.316	0.2
Risalpur	2.23	10	000	00	0.100	0.02	0.000	0.0

Table-6: Variance and Standard Deviation for Quality Parameters in the Drinking Water of Peshawar Division.

Samples Area	Nitrite		Chloride		Sulphate		Fluoride	
	S	S^2	S	S^2	S	S^2	S	S^2
Rashaki Banda	1.580	05	5.00	50	0.00	00	0.000	0.000
Shabqadar	0.707	01	001	02	7.07	100	0.0316	0.002
Mechani R. House	0.00	00	7.07	100	7.07	100	0.0316	0.002
Ghalani	001	02	001	02	001	02	0.0316	0.002
Ekka Ghund	0.316	0.2	001	02	001	02	0.000	0.000
Pandu	0.500	0.5	1.58	05	7.07	100	0.000	0.000
Bazarkhel	1.580	05	7.07	100	4.47	40	0.000	0.000
Dalazak Road	2.23	10	001	02	2.23	10	0.000	0.000
Kohat Road	001	02	000	00	7.07	100	0.0316	0.002
Warsak Road	2.23	10	001	02	000	00	0.022	0.001
Hayat Abad	2.23	10	000	00	000	00	0.022	0.001
Nishtar Abad	001	02	001	02	7.07	100	0.000	0.000
Gul Bahar	2.00	08	1.58	05	001	02	0.0316	0.002
Charsadda	001	02	2.23	10	1.58	05	0.022	0.001
Tehkal	2.23	10	2.23	10	1.58	05	0.000	0.000
Nowshera	1.22	03	001	02	000	00	0.000	0.000
Risalpur	2.23	10	0.00	00	001	02	0.022	0.001

Table-7: Standards for Drinking Water [14]

S. No.	Pollutants	Permissive	Excessive
	Physical		
1	Turbidity (Units or Silica)	5 Units	25Units
2	Colour (Units On Platinum Cobalt Scale)	5 Units	25 Units
3	Taste And Odour	Nothing	Disagreeable
	Chemical:		
4	PH	7.0-8.5	< 6.5 or > 9.2
5	Total Solids	500 mg/L	1500 mg/L
6	Total Hardness (as $CaCO_3$)	300 mg/L	600 mg/L
7	Calcium (as Ca^{+2})	75 mg/L	200 mg/L
8	Magnesium (as Mg^{+2})	50 mg/L	150 mg/L
9	Iron (as Fe^{+3})	0.3 mg/L	1.0 mg/L
10	Manganese (as Mn^{+2})	0.1 mg/L	0.5 mg/L
11	Copper (as Cu^{+2})	1.0 mg/L	3.0 mg/L
12	Zinc (as Zn^{+2})	5.0 mg/L	15 mg/L
13	Chlorides (as Cl^{-1})	250 mg/L	1000 mg/L
14	Sulphate (as SO_4^{-2})	250 mg/L	400 mg/L
15	Phenolics Substances (as Phenol)	0.0001 mg/L	1.0 mg/L
16	Fluorides (as F^{-1})	1.0 mg/L	2.0 mg/L
17	Nitrates (NO_2^{-1})	20 mg/L	50 mg/L
	Toxic substance:		
18	Arsenic (as As^{+3})	0.2 mg/L	0.2 mg/L
19	Chromium (as Hexavalent)		0.05 mg/L
20	Cyanides (as CN^{-1})		0.01 mg/L
21	Lead (as Pb^{+2})		0.1 mg/L
22	Selenium (as Se^{+4})		0.05 mg/L
	Radio Activity:		
23	Alpha Emitter (μc/ml)		10^{-7}
24	Beta Emitter (μc/ml)		10^{-6}

Hayatabad (25 mg/L), Nishtarabad (29 mg/L), Gulbahar (27 mg/L), Tehkal (25 mg/L), Nowshera (24 mg/L) and Risalpur (22 mg/L), indicate high potassium contents as compared to the permissible limits for drinking water. Therefore the drinking water of these sites may be tasty, leading to polluted water. These areas are actually over populated and thus result in the greater consumption and disposal of water (municipal sewage), thus adding greater pollutants to the surface and ground waters.

Copper is not often found in pure water (both surface and ground), although the trace quantity is found in soft and acidic water. In domestic water supplies copper arise from the corrosion of copper containing materials like pipes, fittings etc. The W.H.O (1970) highest desirable level for copper in drinking water is 1.5 mg/L, whereas according to the encyclopedia of environmental science it is 3.0 mg/L. The samples collected from Dalazak road and Kohat road (Table-3) show highest level of copper, which is

above the permissible limits. Acute poisoning resulting from ingestion of excessive amount of copper salts may result in death. The symptoms are vomiting, hematemesis, hypotesion, melena and coma etc [16].

Iron is generally present in trace amount in the drinking water in colloidal complex with other minerals or organic substances. The table-3 shows the total iron in the samples in the range of 0.04-0.35 mg/L. whereas the maximum limit according to W.H.O standards is 1.0 mg/L. Thus, Iron concentration, in all the samples is below the maximum permissible limit, hence cause no toxic effects. The exposure above the limit (1 mg/L) may cause coldness, restlessness, backache and rapid respiration and haemochromatosis [17].

Experimental

Drinking water samples were collected from both the source and consumption points at different localities of Peshawar division, in clean polyethylene bottles. Before taking the samples, bottles were first rinsed with the sample water. During sampling no air bubbles were left in the samples. pH and conductance were noted at the spot. The bottles were then carried to the laboratory and stored in refrigerator. Physical and chemical parameters such as pH, conductivity, total hardness, nitrates, fluoride, sulphate, chloride and the cations were then investigated.

pH was measured using pH meter and conductivity by conductometer. Measurements of total hardness and alkalinity were carried out by titration with standard EDTA [18, 19]. Chloride [20] was determined by volumetric method. NO_3^{-1}, SO_4^{-2} and F^{-1} were found spectrophotometrically [21,22]. Copper and Iron were determined by atomic absorption spectrophotometer. Sodium and Potassium in the samples were determined by flame photometry.

Variance and Standard Deviation

The variance and standard deviation for the sample data were calculated using the following formula [23].

Variance:

$$S^2 = \Sigma (xi - \bar{x})^2/n$$

Standard Deviation:

$$S = \sqrt{\Sigma (xi - \bar{x})^2/n}$$

Nomenclature

S^2	= Variance
S	= Standard deviation.
mg/L	= Milligram per liter
μ	= Micro
WHO	= World Health Organization.
μc/ml	= Micro curie per milliliter
xi	= Individual Number
$\bar{x}$	= Mean
n	= Total number

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