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Physico-chemical quality of drinking water and human health: a study of salt range Pakistan

Abstract

The Salt Range a hill system located in the Punjab province of Pakistan is affected by heavy salinity and condition is deteriorating overtime with the use of brackish underground water. Common health problems are hypertension, viral hepatitis due to virus A and E, many types of urinary problems and gastrointestinal tract problems like diarrhea and other abdominal ailments. Present study was designed to evaluate the physico-chemical parameters of drinking water of the Salt Range by taking water samples from different locations of Pind Dadan Khan and Khewra. Each parameter was compared with the standard desirable limit prescribed by WHO. Eight percent water samples showed pH level above the permissible limit while EC and TDS values also crossed the permissible guideline values in 48 and 24 percent samples respectively. The results revealed that 16% sulfates 10% iron content and 30% chlorides were higher than the WHO standards. In 54 percent samples chromium values also crossed the WHO guideline limit. The higher values of certain parameters (when compared with acceptable standard limits for drinking purposes) point towards the salt water intrusion and pollution level in drinking water. Suitable suggestions were made to improve the water quality of salt range.

Keywords: drinking water quality, health problems, pollution, salt range, salinity

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Introduction

Quality of drinking water is just as important as its quantity. The quality of ground water is consequence of all the reactions and processes that act on the water from the time of condensation in atmosphere to the release by a well or spring. Thus quality differs from point to point and when moving towards the water table.[1] Hard rocky areas make the water more susceptible to low quality causing serious health problems.[2] All ground waters contain salts in the form of solution coming from different locations.[3] Many natural and anthropogenic factors are responsible for the extent of salt water imposition into ground water. Some important natural factors are kind of aquifer and its natural recharge rates. While anthropogenic factors consist of too much ground water extractions and carelessness in sealing of dumped boreholes and oil wells.[4] Hydro-geochemical assessments have been carried out to determine groundwater suitability for different uses. It is evaluated by comparing the hydro chemical parameters of groundwater with the requirement of World Health Organization.[5]

A study was conducted by Shah et al.[6] in close proximity of Khewra salt mines in the foothills of the salt range in village Kaslian. It is situated in the salt affected area of Tehsil Pind Dadan Khan, District Jhelum. This area is under strong influence of heavy salinity and condition is deteriorating overtime with the use of salty underground water. Water-borne diseases contribute about 70-80% of health problems specifically in case of developing countries and among these diarrheal diseases are the most common leading cause of illness and even death.[7] Other than diarrhea, constant reports of cholera, hepatitis and typhoid have also been recorded in different areas of Punjab.[8] Presence of sodium (in the form of chlorides) along with sulphates in high concentrations results in saline water thus making it non potable[9] and may become cause of high BP and hypertension.[10] The sources of drinking water in salt range localities are ground as well as surface water. Drinking water supplies in salt range have been found to be unhygienic posing severe health threats for consumers. Feedback from locals included too much salty taste and many health problems. But due to unawareness of the locals, many problems are still unidentified. It was very much important to carry out physico-chemical assessment of water from different locations of salt range. To ensure safe drinking water supplies, there was need to suggest an effective management strategy to generate a comprehensive base line data on the physic-chemical status of drinking water from different residential areas of salt range and to explore the health problems originating from consumption of contaminated water.

Material and methods

Site description

The salt range extends from Jhelum River to Indus across the northern portion of the Punjab province of Pakistan covering an area of 10,529 square kilometers. Area is divided into two zones Tehsil Pind Dadan Khan and Khewra and is well known as Khewra Salt Mines. On the south-east Khewra Salt Mines (about 160 kilometers from Islamabad) are bounded by the river Jhelum and traversed by the Salt Range in northern portion. Pind Dadan Khan Tehsil of Jhelum District and is a beautiful place. Khewra is a town of Pind Dadan Khan surrounded with hills. In Khewra there are two main sources of water, pattan headwork PMDC supply (Pakistan Mineral Development Corporation) which is supplied through pipelines, and Tehsil Municipal Administration (TMA). But some people are unable to get it due to limited quantity. Due to these problems at some places borings are introduced. Other sources are water supplied by ICI (industrial commercial and institutional) through a tap at a central place from where residents fill their pots and small water spring in Chingli upside Khewra. Water samples were taken randomly from all these sources. Figure 1 &Figure 2 shows the percentage distribution of water supplies in accordance with samples.

Figure 1 Map of the study area (courtesy google maps).

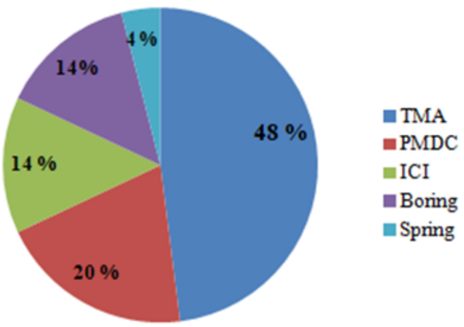

Figure 2 Percentage distributions of water supplies in study area.

Sampling and preservation

Water samples were collected from different locations of tehsil Pind Dadan Khan and Khewra during day time. Sampling was done from tap water, water coolers and springs at sampling points in Pind Dadan Khan and Khewra in plastic bottles of one-liter capacity. The well stopper PET bottles were pre-soaked and rinsed with 10% nitric acid and distilled water and sampling water respectively. Water was collected in bottles after allowing it to run for at least five minutes. Fifty (50) samples were randomly collected from Pind Dadan Khan and Khewra. Samples were subjected to analyses as soon as possible after being brought to the laboratory and were stored at 4°C until analysis. Parameters of immediate nature e.g., pH, electrical conductivity (EC), dissolved oxygen (DO) and free chlorine were tested on the spot.

Determination of water quality parameters

Statistical analysis

All data was analyzed by applying statistical procedure that was ANOVA. It provided significant comparison between values of each parameter (obtained for collected samples) with the standard values of World Health Organization (WHO, 2008) Table 1 & Table 2.

Table 1 Distribution of water samples in accordance with supplies

Water sources	No. of samples
TMA	24
PMDC	10
ICI	07
Boring	07
Spring	02

Results and discussion

The results obtained from the analyses of drinking water samples are described as under

pH

pH value indicates the acidic or alkaline nature of water. The pH values were found in the range of 6.15 to 7.94. Highest pH (7.94) was recorded at sampling point S36 of TMA supply followed by S47 (7.33) and S48 (7.35) respectively. Lowest pH of 6.15 was found in S32. The permissible range for pH (WHO, 2008) of drinking water is 6.5 – 8.5. Ten percent samples showed pH values below 6.5 (Table 3). Statistical analysis by ANOVA showed the highly si.gnificant

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results for pH as probability value for this factor was equal to 0.03. Figure 3 shows the mean values of pH for all the supplies. Two spring water samples in Khewra and two samples from TMA supply in PDK showed pH value below acidic limit. In Pind Dadan Khan people store water in the storage tanks at home. The water supply pipes are out dated and not in good condition. It may lower the pH below acidic limit. In drinking water, acidic pH may cause corrosion of metal pipes in the distribution system.[7] If pH is below 6, acid water is likely to be corrosive to pipes and faucets.[11] Acidic nature of water at some sampling points of PDK and Khewra can also be strongly related to mining activities and geological location of salt range.[12] Fifty eight percent water samples of all supplies indicated slight alkaline values. Slightly alkaline pH could assure the protection of water pipes and metallic fittings from corrosion.[13] pH doesn't affect human health directly but can effect indirectly by altering some other parameters like solubility of metals and pathogens survival.[14]

Table 2 Parameters, their measuring units and methods of analyses

	Physicochemical parameter	Unit	Method	Reference
1	pH	-	at the spot by digital pH meter (make BMS, model pH-200L)	APHA, 2005
2	Color	-	By vision	-
3	Odor	-	By smell	-
4	Temperature	°C	Celsius thermometer	APHA, 2005
5	Total Dissolved Solids	mgL^{-1}	portable TDS meter make Hanna model HI 98301	APHA, 2005
6	Total Suspended Solids	mgL^{-1}	difference of weights of filter paper	APHA, 2005
7	Turbidity	NTU	turbidity meter, make Hanna model HI 93203	APHA, 2005
8	Electrical conductivity	mS/cm	digital EC meter, make Hanna model HI 98303	APHA, 2005
9	Dissolved oxygen	mgL^{-1}	Hanna instruments water proof DO Meter	APHA, 2005
10	Alkalinity	mgL^{-1}	Acid base titration method using phenolphthalein and methyl orange indicators	APHA, 2005
11	Hardness	mgL^{-1}	EDTA-titrimetric method	APHA, 2005
12	Chlorides	mgL^{-1}	Argentometric titration method	APHA, 2005
13	Suphates	mgL^{-1}	nephelometeric method	APHA, 2005
14	Nitrates	mgL^{-1}	ultraviolet spectrophotometer screening method	APHA, 2005
15	Nitrites	mgL^{-1}	ultraviolet spectrophotometer screening method	APHA, 2005
16	Sodium	mgL^{-1}	flame emission photometric method make Jenway PFPS, model 8515	APHA, 2005
17	Potassium	mgL^{-1}	flame emission photometric method	APHA, 2005
18	Heavy metals (Fe, Cr, Cd, Mn, Zn and Pb)	mgL^{-1}	Atomic Absorption Spectrophotometer make GBC model 932 plus	APHA, 2005

Table 3 Distribution of measured parameters in the samples. The mean, minimum and maximum values are given along with the WHO guideline values and the percentage of samples which exceeded the guideline value. (N=No of samples)

Parameter	N	Unit	Mean	Min.	Max.	WHO guideline	% exceeding guideline
pH	50	-	6.98	6.15	7.94	6.5-8.5	8
C	50	µS/cm	1170.24	338	3330	1400	48
TDS	50	mgL^{-1}	706.7	174	1781	1000	24
DO	50	mgL^{-1}	67	67.0	56	4-7	-
Hardness	50	mgL^{-1}	174.29	41.6	393.6	500	-
Chlorides	50	mgL^{-1}	196.81	28.4	639	250	30
Turbidity	50	mgL^{-1}	0.45	0	7.81	5	2
Sulfates	50	mgL^{-1}	154.76	3.84	888.96	250	16
Sodium	50	mgL^{-1}	30.38	6.0	94	200	-
Potassium	50	mgL^{-1}	1.21	0.5	3.5	12	-
Carbonates		mgL^{-1}	0	0	0	120	-
Bicarbonates	50	mgL^{-1}	534.84	219.6	1049.2	500	52
Nitrates	50	mgL^{-1}	5.62	2.109	14.162	50	-
Nitrites	50	mgL^{-1}	0.001	0	0.001	3	-
Iron	50	mgL^{-1}	0.169	0.022	0.406	0.3	10
Cadmium	50	mgL^{-1}	0.005	0.001	0.012	0.003	4
Copper	50	mgL^{-1}	0.027	0.002	0.279	2	-
Lead	50	mgL^{-1}	0.067	0.00	0.067	0.01	2
Nickel	50	mgL^{-1}	0.20	0.003	0.483	0.02	54
Chromium	50	mgL^{-1}	0.139	0.002	0.494	0.05	50

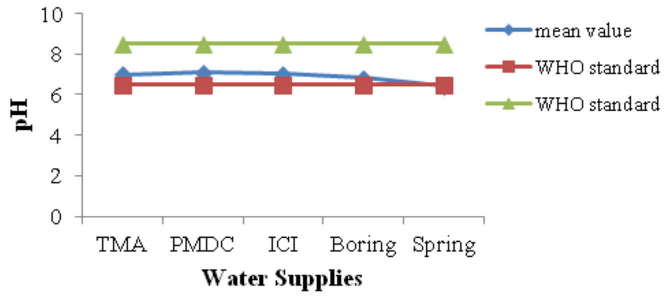

Figure 3 Comparison of mean, maximum and minimum pH values observed in water supplies.

Electrical conductivity (EC)

Values of Electrical conductivity ranged from 324µS/cm to 3330µS/cm with the lowest value in sample S36 and the highest value in S30. WHO maximum allowable EC level is between 1400µS/cm for drinking water. Mean EC values of PMDC and boring water samples were above WHO limit while ICI, TMA and spring water had their mean values within range (Figure 4). Statistical analysis by ANOVA showed the significant results for EC as probability value for this factor was equal to 0.04. Electrical Conductivity is an indicator of the taste or salinity of the water. Significant fluctuations in electrical conductivity were observed in water samples of the PDK and Khewra. Forty percent samples were having EC values higher than the WHO permissible limits (Table 3). All these exceeded values were in more than one source like municipal supply, PMDC water supply, ICI supply, boring water and TMA supply. Values exceeding the limits are indicative of the presence of millions of tons of salt in salt range as well as saline water mixing into the groundwater.[7] Fluctuations in EC values are due to many factors like the variations in the mineral content of the area due to its geological settings, due to differences in the mineral and chemical properties of the water body leading to excessive scaling in water pipes, heaters, boilers and household appliances.[6,14] There is little direct health risk associated with this parameter, but high EC values are related with poor taste and high percentage of total dissolved solid.[15]

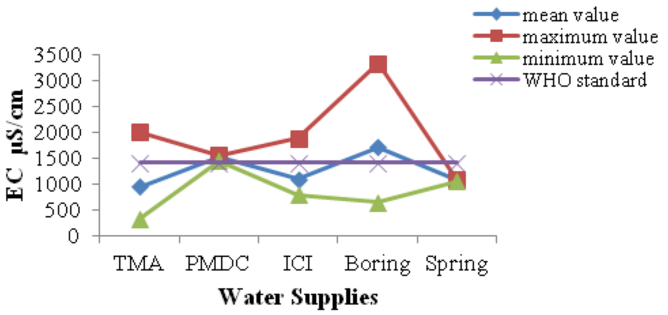

Figure 4 Comparison of mean, maximum and minimum EC values observed in water supplies.

Total dissolved solids(TDS)

The highest amount of total dissolved solids in the drinking water of salt range area of PDK and Khewra was recorded at S30 (1781mgL^{-1}) whereas the lowest value of 174mgL^{-1} was found in sample S36. According to WHO (2008) permissible limit of TDS is 1000 mgL^{-1}. Twenty four (24) percent water samples analyzed for TDS showed higher TDS values than the prescribed limit given by WHO (Table 3). Lowest mean value (610mgL^{-1}) was calculated in spring water while highest mean value was found to be 1167mgL^{-1} in boring water (Figure 5). Statistical analysis by ANOVA showed the highly significant results for TDS as probability value for this factor was equal to 0.00. Total dissolved solids indicate the salinity behavior of groundwater. Highest amount of TDS content was observed in water samples of boring water. The intrusion of saline water into the fresh water zone as a result of over pumping has also caused the deterioration of drinking water quality in bore water of salt range. Water samples of PMDC supply were found to be within permissible WHO limits. Samples having high value of TDS were also having high EC values and pH below 7. Obiefuna & Sheriff[11] showed the same trend of TDS and EC in acidic conditions (pH 6.65). Total Dissolved Solids (TDS) generally reflect the amount of mineral contents dissolved in the water. High values of TDS in almost all water sources of the salt range may be due to run-off from the sedimentary rocks, mainly limestone and gypsum, into the ground water. Total suspended solids occurred mainly in the form of carbonates and bi-carbonates and may have been released from the host sedimentary rocks, mainly limestone and dolomite, into the water aquifer. Such type of dissolved solids were mainly found coarser in size and caused suspension but no turbidity.[16]

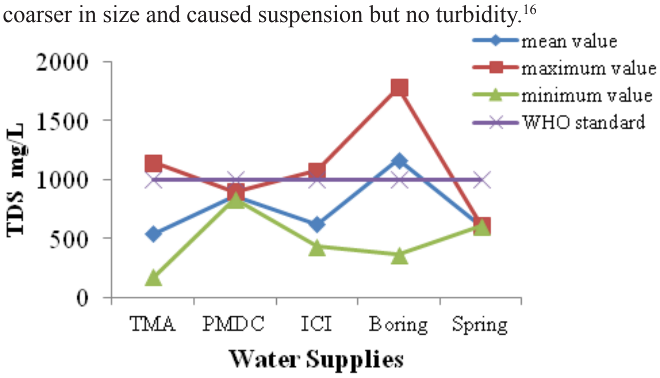

Figure 5 Comparison of mean, maximum and minimum TDS values observed in water supplies.

Turbidity

The data obtained for turbidity measurements ranged from 0 to 7.81 NTU. Lowest value (0 NTU) was calculated at five sampling points S25, S36, S37, S39 and S47. Turbidity of most water samples (98%) was found within the acceptable limit of WHO (5NTU). Statistical analysis by ANOVA showed the significant results for turbidity as probability value for this factor was equal to 0.00. No sample exceeded the standard limit for drinking water established by WHO. Turbidity is a major water-quality problem for a significant proportion of the water supplies in the country. It has no health effects. Only one sampling site (S49) had turbidity value greater than 5 NTU which is the WHO (2008) maximum desirable limit in drinking water. This water was of TMA supply. As iron level is related to turbidity content of water so this sampling site also has maximum iron content with muddy appearance which shows that it is highly contaminated and not fit for drinking purposes. Usually, water with high turbidity has unpleasant appearance, color, taste and odor. It is caused by the presence of suspended and colloidal matter.

People in the P.D Khan store the water of TMA supply in the storage tanks at home. Utilization of ground water is inappropriate due to sanitations problems. The water supply pipes are not in good condition and are harmful for human health. This might be the major cause of high turbidity content in TMA supply. Tamiru et al.[17] supported the same condition by evaluating that high turbidity value found in many water supplies and the poor sanitary conditions of water supplies are inter dependent in Ethiopia. According to Shafqat et al.[18] cases of viral hepatitis due to virus A&E, diarrhea and dysentery are very common in salt mine hospitals of PDK and Khewra. High turbidity may show the presence of disease causing organisms including bacteria, viruses, and parasites that can cause symptoms such as nausea, cramps, diarrhea, and associated headaches.[19]

Hardness

Statistical analysis by ANOVA showed the highly significant results for hardness as probability value for this factor was equal to 0.00. Values of hardness ranged from 41.6mgL^{-1} at sampling point S35 to 393.6mgL^{-1} in S3. None of the drinking water samples analyzed for hardness exceeded the limit permitted by WHO (500mgL^{-1}). Mean values of all supplies were also within desirable limits. Hardness levels were high at 16 locations in drinking water of Cambodia. High hardness levels lead to scale deposits in cooking pots and also related to complaints of bitter-tasting water. In many parts of the world water hardness and kidney stones have been linked, but such linkage is considered doubtful.[20] As insufficient hydration is often a contributing factor in the formation of kidney stones regardless of water hardness.[21]

Carbonates and bicarbonates

The carbonate content was not found in all water samples of all supplies. The bicarbonate content of salt range drinking water ranged from a minimum of 219.6mgL^{-1} to a maximum of 1049.2mgL^{-1} in S2 and S16 respectively. The maximum permissible level is 500mgL^{-1}. Bicarbonate values observed in 52 percent samples were above the detection limit (Table 3). Only 48 percent samples showed values below the permitted level. Statistical analysis by ANOVA pointed out the highly significant results for bicarbonates as probability value for this factor was equal to 0.00. Figure 6 illustrates the mean values of all the supplies above the desirable limit of WHO (2008). The total alkalinity is mostly due to the presence of bicarbonate. More than half of the sampling sites (26) having all water sources showed high bicarbonate level. Salt range area is rich in mineral resources, including salt, coal, gypsum and lime stone. These bicarbonate values indicate the weathering effects of rock compounds in Khewra. Carbonate rocks and carbonate species present in the area are major sources of bicarbonate ions in ground water. The existing carbonate alkalinity in some stations can be as a result of the suspension of rock minerals.[22] The carbonate (CO_3) alkalinity was absent in every water supply at all the sampling points. Carbonates and pH are directly related with each other. No sampling point showed pH value greater than 8.3. **Khanfar**[23] also supported the situation that carbonates can only be present in the water if the pH of the water goes beyond 8.3 and it hardly occurs in natural waters.

Chlorides

The permissible limit of chloride in drinking water is 250mg/L. The value of chloride observed at sampling points S8 and S33 (28.4mgL^{-1}) was well below the permissible limit given by WHO. Maximum value of chloride (639mgL^{-1}) was found at S26. The chloride content was above the WHO guideline level in 30 percent samples (Table 3). Statistical analysis by ANOVA showed the significant results for chlorides as probability value for this factor was equal to 0.02. Figure 7 shows the mean value (326.6mgL^{-1}) in boring water above desirable limit while mean values of other sources did not exceeded the desirable limit. Chloride in natural water results from agricultural activities, industries and chloride rich rocks. High concentration of chloride gives a salty taste to water. High ranges of chloride concentration were observed in water samples of TMA supply line, ICI and boring water. All the values of PMDC supply were found to be within the limits of WHO. Maximum chloride concentration was observed in boring water. Its reason can be that due to limited quantity, people use their own sources of water (boring water) without treatment. The presence of chloride in salt range may also be due to processes such as the passage of water through natural salt formations in the earth. Another major reason is geological settings of salt range, huge deposits of rock salt and deposits of crystalline and non crystalline gypsum which affect the drinking water quality from place to place.[24] Boring water also contain high chloride contents. In Islam Ganj, Khewra, borings were introduced due to water scarcity in that area but due to sanitation problems, water was not found satisfactory because of inappropriate system for sewerage and unprotected drainages. Chloride in drinking water mainly originates from natural sources but sewage and industrial effluents, urban runoff containing de-ionizing salts and saline intrusions also increase the level of chloride in drinking water.[7] Chloride are not health related but set in order to avoid unpleasant taste and corrosion effect in pipes.[25] According to MS. THQ hospital PDK, the most abundant problem in PDK and Khewra are water born diseases like diarrhea, dysentery, typhoid, viral hepatitis and worm infections.[18] Although these diseases are not directly related to chloride contamination but are due to poor quality of water in study area. Cases of cholera, typhoid, hepatitis and dysentery are consistently reported in urban and rural areas. In Punjab, amongst 15 infectious diseases in children under 5 years of age diarrhoea ranks second.[26]

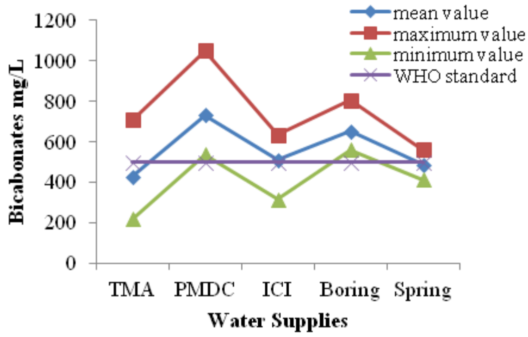

Figure 6 Comparison of mean, maximum and minimum bicarbonate values observed in water supplies.

Sulfates

The level of sulfates in drinking water samples varied between 3.84mgL^{-1} in S50 and 888.96mgL^{-1}in S23. Sixteen percent water samples showed higher sulfate values above the standard desirable limit of WHO i-e 250 mgL^{-1} (Table 3). Statistical analysis by ANOVA showed the non significant results for sulfates as probability value for this factor was equal to 0.00. Mean value calculated in boring water showed highest range (888.96 mgL^{-1}) above WHO limit. Other supplies like PMDC, ICI, TMA and spring water had mean values within range showing very little difference between each other (Figure 8). Sulfate occurs in water as the inorganic sulfate salts and occurs naturally in water as a result of leaching from gypsum and other common minerals. High sulfate level was observed in all the water supplies present in Pind Dadan Khan and Khewra but maximum concentration was found to be observed in boring water. It was house hold water in Khewra. As the high sulfate concentration is prevailing in all the supplies of the region so major reason can be geological settings of salt range having huge deposits of gypsum rocks and other rock compounds. High sulfate level indicates the weathering effects of these rocks. Sulfate ion concentrations are mostly originated from weathering of sulfate and gypsum-bearing sedimentary rocks.[27,28]

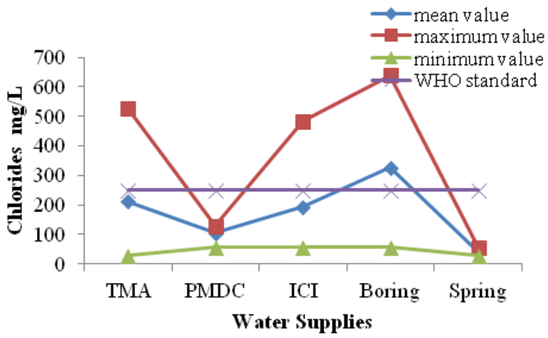

Figure 7 Comparison of mean, maximum and minimum chloride values observed in water supplies.

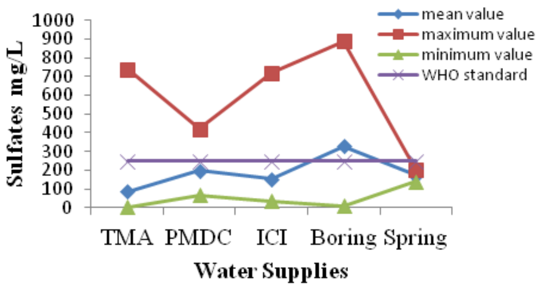

Figure 8 Comparison of mean, maximum and minimum sulfate values observed in water supplies.

Second highest sulfate concentration was present in ICI water supply. ICI water is treated water so increase in sulfate content may be due to this treatment process.[29] Dehydration from diarrhea as a common problem due to intake of large amounts of magnesium or sodium sulfate in drinking water.[30] Sulfate content was found maximum in boring water and this water was not found satisfactory due to poor sewerage and sanitation problems causing these gastro intestinal diseases in Khewra and P.D Khan.

Sodium (Na)

The levels of Sodium in the samples were in the range of 6mgL^{-1} in S33 to 94mgL^{-1} in S26. All the values were within WHO prescribed limit of 200mgL^{-1}. Statistical analysis by ANOVA illustrated the highly significant results for sodium as probability value for this factor was equal to 0.00. Excess sodium consumption in drinking water results in a greater availability of sodium ions in the blood stream leading to greater than normal heart activity, enlargement of the heart, increased risk of hypertension and stroke. Heart disease is currently the leading cause of death in the United States and stroke is third.[31]

Potassium (K)

Statistical analysis by ANOVA showed the highly significant results for potassium as probability value for this factor was equal to 0.00. The potassium content of all the samples was very low. Highest value was calculated at sampling point S26 and minimum concentration (0.5mgL^{-1}) was recorded in 26 percent water samples. All the values were below the WHO maximum permissible level (12mgL^{-1}). The major sources of both the cations (Na and K) possibly are weathering of rocks along with sewage and industrial effluents.[32] Sodium and potassium are the most important minerals occurring naturally. All water samples have Sodium and potassium values within limits of WHO.

Nitrite

Nitrite content of most of water samples (98 %) were found below the detection limit. Only one sample (S23) contained nitrite content up to 0.00195mgL^{-1}. It was within the acceptable limit proposed by WHO (3mgL^{-1}). Statistical analysis by ANOVA showed the significant results for nitrite as probability value for this factor was equal to 0.00. High concentration of nitrite was identified in a small number of drinking water samples in Cambodia. Nitrites have known human health impacts, primarily in newborn babies taking baby formula made with the affected water source. Nitrate and nitrite affect haemoglobin in the blood and cause blue baby syndrome. There is also a link between exposure to nitrites and cancer in humans.[33]

Nitrate

The nitrate concentration observed in all the 50 samples were within the desirable limit of 50mgL^{-1} with a minimum of 2.109mgL^{-1} in 8 percent samples to a maximum of 14.862mgL^{-1} in S48. Drinking water from different supplies varied significantly when statistically analyzed by ANOVA as probability value for this factor was equal to 0.00. Nitrate and nitrites were not detected at all sampling points in PDK and Khewra. Generally ground water had low concentrations of nitrates but can reach high values as a result of run off or leaching from agricultural lands.[34] Nitrates signify the final product of the biochemical oxidation of ammonia. Because of health effects of nitrates on humans and animals, monitoring of nitrates in drinking water supply is very much important.[35]

Dissolved Oxygen (DO)

Statistical analysis by ANOVA showed the highly significant results for potassium as probability value for this factor was equal to 0.00. Highest value was calculated at sampling point S49 (6.49mgL^{-1}) and minimum concentration (4.04mgL^{-1}) was recorded in S6. All the values were below the WHO maximum permissible level (4-7mgL^{-1}).

Cadmium

Cadmium concentration ranged between 0.001mgL^{-1} (S21) to 0.012mgL^{-1} (S2) with the mean value of 0.0054mgL^{-1}, which is higher than the maximum allowable concentration 0.003mgL^{-1}based on WHO 2008 standards. Only 4 percent water samples showed high concentration of cadmium above limit set by WHO (Table 3). Statistical analysis by ANOVA at 0.05level of significance showed the highly significant results for cadmium as probability value for this factor was equal to 0.00. Mean values calculated for the samples showed that TMA supply and boring water had the maximum value for cadmium (0.006mgL^{-1}) and (0.008mgL^{-1}) respectively while lowest mean values were observed in PMDC, ICI and spring water (Figure 9). Cadmium is an element of great concern from a toxicity point of view causing both acute and chronic toxicity in humans. Cadmium content was detected only in five water samples. Maximum concentration was found to be observed in THQ hospital having TMA supply PDK and house hold boring water in Khewra. Groundwater of Khyber Pakhtoonkhwa and Sindh provinces also had relatively high contamination of Cd as compared to Punjab.[34] It can be due to water supply pipes which were installed many years back. In boring water it can be due to sanitation problem and improper system for sewerage causing gastrointestinal problems. In our study area only few houses have their own septic tanks otherwise small pit latrines are present in every house. Highest cadmium content was observed in hospital water which can be dangerous for patients. A child specialist in THQ, PDK added a lot in our information by telling that monthly 25% OPD cases were of diarrhea and gastrointestinal problems. Intake of cadmium can cause acute gastrointestinal problems, such as vomiting and diarrhea while cadmium exposure for a long time can be the source of kidney damage.[36,37]

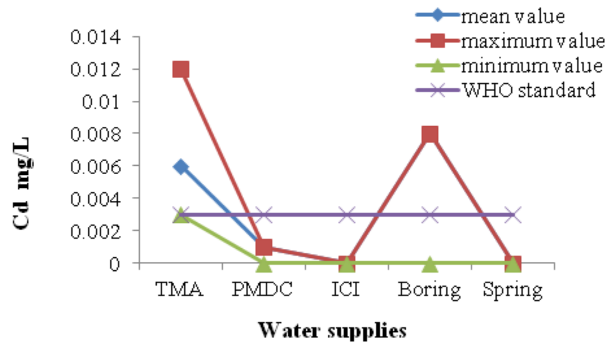

Figure 9 Comparison of mean, maximum and minimum Cd values observed in water supplies.

Iron

Regarding iron fluctuating trends in its value were observed in all the five supplies. The highest iron concentration of 0.406mgL^{-1}was recorded in water sample S49 (TMA supply) and the lowest amount of 0.022mgL^{-1} was measured at S8 (spring water). Ten percent water samples analyzed had iron concentration greater than 0.3mgL^{-1}, which is the WHO standard for iron in drinking water (Table 3). Statistical analysis by ANOVA at 0.05 level of significance showed the highly significant results for iron as probability value for this factor was equal to 0.00. Among the supplies maximum mean value for iron was observed in TMA supply and minimum mean value for iron was found in spring water followed by the PMDC, ICI water supplies and boring water (Figure 10). Iron in drinking water is more significant in its aesthetic and taste value rather than in health aspects. About 90 percent of the samples fulfill the desirable concentration of iron in drinking water (0.3mgL^{-1}) set by WHO (2008). Iron concentration was found to be prominent in TMA supply and this water is supplied through pipelines so it can be due to the water supply pipes which were placed almost two decades back and have lived longer than their actual life. These high concentrations of iron can be a possible risk for human health in Khewra and P.D. Khan. Although not much scientific data regarding water quality and related health problems is available in Khewra and P.D. Khan but feedback from locals and annual record of THQ hospital P.D khan.[18] included many health problems like diabetes, skin diseases and hyper tension. In comparison to its deficiency, excess of iron or overexposure is not as much common but it can lead to several serious health problems like diabetes[38] liver and heart diseases.[39,40] Iron content is strongly related to low pH and turbidity. It can be due to enhanced mining activity in this area because this area is famous for its geology and huge deposits of rock salts. House hold water of TMA supply line having maximum iron content has highest turbidity value as well. High concentration of iron gives an unwanted taste and increases turbidity.[30] Increased mining activity may lowers the pH of water and helps in dissolving iron in water.[41]

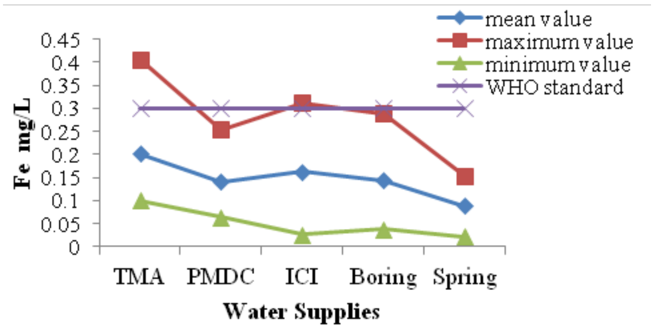

Figure 10 Comparison of mean, maximum and minimum Fe values observed in water supplies.

Chromium

The range of chromium content of water samples collected from different areas of salt range was 0.002mgL^{-1} to 0.494mgL^{-1}. S35 (TMA supply) and S15 (boring) water samples had the minimum and maximum values of chromium respectively. Fifty percent water samples showed chromium concentration greater than 0.05mgL^{-1}, the WHO standard limit for chromium in drinking water (Table 3). Statistical analysis by ANOVA at 0.05level of significance showed the significant results for chromium as probability value for this factor was equal to 0.03. Figure 11 illustrates the mean values of chromium of all the supplies above the desirable limit of WHO (2008). Chromium is an essential micronutrient for animals and plants, as well as is considered as pollution significant element. Salt range Area is rich in mineral resources like coal, gypsum, lime stone and chromites. Leaching from rocks and coal mines in the area are most important natural sources of chromium entry into water. It can be due to that the main centre of mining is at Khewra where rock-salt deposits are found. Asthma and skin allergy problems are common in Dandot area due to cement factory which can also be attributed to high chromium content in drinking water of salt range. Skin diseases like scabies and dermatitis which are most abundant in salt range area and are commonly registered in hospital. It can be due to skin contact with chromium contaminated water. Some of chromium compounds especially in its hexavalent form cause skin diseases, cancer, and diseases related to the digestive, excretory, respiratory and reproductive system.[34] Urinary tract diseases are also frequently reported in THQ hospital PDK which can also be related to high chromium content. Cases of dermatitis and ulceration of the skin and kidney problem are common in long-term exposure of chromium.[42,43]

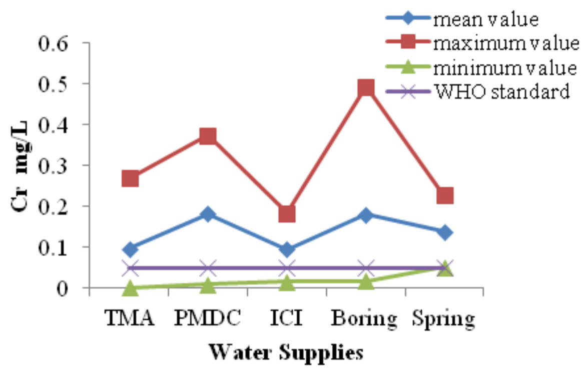

Figure 11 Comparison of mean, maximum and minimum Cr values observed in water supplies.

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Nickel

Statistical analysis by ANOVA at 0.05level of significance showed the significant results for chromium as probability value for this factor was equal to 0.00. The nickel content of water samples ranged from 0.003mgL^{-1} to 0.483mgL^{-1} in TMA supply (S2) and boring water (S31) respectively. Nickel content in 27 out of 50 (54%) water samples were above the 0.02mgL^{-1} (WHO desirable limit for chromium in drinking water) (Table 3). Boring water had highest mean nickel content followed by PMDC, TMA and spring water. Mean values of all the supplies were above the permissible limit (Figure 12). Nickel is a widely distributed element in the environment, and can be found in air, water and soil. Other than geographical settings of salt range area, high nickel content can be attributed to water supply pipes through which water is distributed to PD Khan and Khewra. Maximum concentration was found in house hold boring water in Khewra. Here in this area boring water is not satisfactory due to sewer or other potential source of pollution nearer to the water source. The geographical distribution also affects the maximum concentrations of nickel but its presence in groundwater may also be due to release from metallic coatings on modern taps and other plumbing fittings.[44] Nickel compounds can cause a variety of adverse effects, like nickel allergy in the form of contact dermatitis, cardiovascular diseases, lung fibrosis, kidney and respiratory problems.[45]

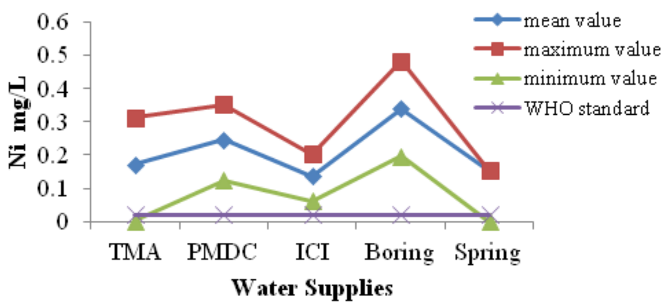

Figure 12 Comparison of mean, maximum and minimum Ni values observed in water supplies.

Lead

Lead content of most of water samples (98%) was found within the acceptable limit proposed by WHO guideline i-e 0.01mgL^{-1}. Only one sample of boring water (S14) contained lead content above the WHO guideline value and was found to be 0.067mgL^{-1}. Statistical analysis by ANOVA showed the highly significant results for lead as probability value for this factor was equal to 0.00. Lead is the most significant of all the heavy metals. Lead was the only metal that was not detected in all water samples except one which was of boring water of mines labour welfare school, Pidh, Khewra. This value was above the prescribed limit of WHO. It can be due to unhygienic conditions around the source and unacceptable condition of water pipes. In old homes lead water pipes can contaminate drinking water. This high concentration of lead in the body can cause death or permanent damage to the central nervous system, brain, and kidneys.[42]

Copper

Statistical analysis by ANOVA at 0.05 level of significance showed the highly significant results for copper as probability value for this factor was equal to 0.00. The maximum acceptable limit of copper for drinking water is 2mgL^{-1} (WHO, 2008). The copper concentrations observed at all sampling points were within limits with a minimum value of 0.001mgL^{-1} in S41 to a maximum value of 0.279mgL^{-1} in S16. Mean values of all supplies were also within range. Copper is the only metal that was far below the detection limit of WHO (2008) in all the sampling sites. There was no health related risk due to the presence of copper in drinking water of the salt range. Contamination of drinking water with high level of copper may cause chronic anemia.[46] Drinking water of salt range area is though fit for drinking purpose but some parameters (sulfates, chlorides, TDS, EC, Iron, cadmium, nickel and chromium) exceeded the permissible limits which showed that treatment is needed to minimize the contamination especially salinity.[47–50]

Conclusion

Quality of drinking water is just as important as its quantity. Quality varies from place to place because geological settings affect the drinking water quality of the area. Various health problems are originated due to lack of availability of good quality water. Drinking water quality of salt range has not been monitored on a routine basis and no reliable data are available in this respect. The sanitary system in many locations is not well established, also playing prime role in causing contaminations of water. The water supply pipes were installed almost two decades back and may be harmful for human health. The intrusion of saline water into fresh water zone as a result of over pumping has also caused the deterioration of ground water quality. Drinking water supplies in salt range are largely contaminated posing serious health risks to the consumers. It needs treatments to minimize the contamination.

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Conflict of interest

The authors declare that there is no conflict of interest.

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