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Research Article

Concentrations of Lead in Groundwater and Human Blood in the Population of Palosai, a Rural Area in Pakistan: Human Exposure and Risk Assessment

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Lead (Pb) is a toxic environmental contaminant, which enters water bodies from natural and anthropogenic activities. The present study investigates the Pb concentration in groundwater sources and evaluates their potential health risks in Palosai area, Peshawar, Khyber Pakhtunkhwa, Pakistan. Groundwater samples were collected from different groundwater sources in the area where the human blood samples were from the dependent residents. Pb concentration was analyzed using an atomic absorption spectrophotometer and compared with the permissible limits set by Pakistan Environmental Protection Agency and World Health Organization (WHO). The levels of physicochemical parameters were observed within the said safe limits, while the levels of Pb in different groundwater sources (tube wells and wells) showed a little bit variation. Health risk indicators such as chronic daily intake (CDI) and hazard quotient (HQ) were calculated for Pb. The calculated value of CDI and HQ for Pb via groundwater consumption was 0.001 mg/kg·day and $2.8E-02$ mg/kg·day, respectively; however, the overall HQ values of Pb in the groundwater were less than 1, indicating no health risk to the local depending community.

1. Introduction

Water is considered an important resource in the environment [1–3]. Water is an essential constituent of living beings; life of living beings without water is not possible. Total bodily water accounts for 60% of an adult human's body weight [4]. What is more, water contamination with heavy metals, for example, zinc (Zn), lead (Pb), nickel (Ni), manganese (Mn), copper (Cu), chromium (Cr), and cadmium (Cd), is an overall environmental issue [5, 6]. A variety of contaminants finds its way to the human body through different routes such as ingestion, inhalation, or direct skin contact. Heavy metals enter the human body through a variety of routes, including drinking contaminated water, eating contaminated food, and inhaling dust. Human exposure to heavy metals may be occupational and nonoccupational, living near, or working in an industrial site may increase human health risk [7]. When heavy metals contaminate food and water, they degrade their quality and induce toxicity [8]. Digestive issues, joint and muscle discomfort, high blood pressure, concentration and memory issues, nerve abnormalities, cataracts, and damage to sperm-producing organs in males are just a few of the damaging impacts of heavy metals [9, 10].

In both rural and urban areas of the world, the main source for drinking is groundwater. It is also an essential water source for the industrial and agricultural sectors. Lately, aquatic environmental contamination with metals has pulled in worldwide considerations inferable from its persistence, abundance, and environmental toxicity. Waste from anthropogenic activities, for example, agriculture waste, industrial effluents and urban waste, and additionally natural process, for example, mineral weathering, erosion, and atmospheric deposition, degrade surface and groundwater and impair their utilization for drinking, industrial, agricultural or other purposes [11]. The groundwater quality differs from region to region contingent on the topographical development. The trace metal concentrations and distribution vary from one place to another relying upon factors, i.e., hydrogeometry of aquifers, redox potential, geological location, and pH [12]. Heavy metal carcinogenicity and toxicity depends upon the amount of ingestion, individual body immunity, and duration of exposure [13]. Pb is a possible human carcinogen and can affect every system and organ of the human body [7]. Lead (Pb) is one of the most common elements that occur in the environment and accounts for about 13 mg/kg of the total earth crust [14]. Contamination of drinking water may be natural or anthropogenic [15], among the anthropogenic sources, mining, manufacturing, use of fertilizers, fossil fuel combustion, and industrial activities [7] are the most common sources of Pb contamination. Similarly, Pb and its compounds are used to produce ammunition, metal products, batteries, and X-ray shielding devices. Pb is also used in several products like paints and gasoline [7]. Pb is a component of the pipes and plumbing system used in water distribution channels [16]. The concentration of Pb in drinking water as a result of dissolution and leaching from pipelines is affected by pH, hardness, temperature, dissolved oxygen, and chloride concentration [17]. There are certain metals, i.e., K, Na, Mg, Ca, Zn, Fe, Cu, and Co, which are essential for the growth and function of normal human body. However, many are toxic and nonessential such as Pb, Ni, As, and Cd which causes health risk when ingested in sufficient quantity [6, 15].

Globally, environmental researchers have a prime focus on human health risk assessment associated with drinking water [18]. Many examinations have researched the heavy metals occurrence in surface and groundwater. In Bangladesh, Frisbie et al. [19] have analyzed toxic elements and arsenic concentrations in drinking water and results of the investigation affirmed that drinking water is polluted with other poisonous and arsenic that may influence human well-being and additionally the health of the biological community in Bangladesh. In Jharkhand, India, Giri et al. [20] have examined in groundwater the content of heavy metals in the proposed region of two uranium mining areas and the aftereffects of the examination demonstrated that the determined concentration of elements was inside the measures for drinking water of the WHO and Indian measures. Muhammad et al. [6] investigated heavy metal levels in drinking water in Kohistan, northern Pakistan, and found that most heavy metal levels were within the Pak EPA and WHO acceptable limits. In Jammu and Kashmir, India, Kumar et al. [21] have determined trace metal concentrations in drinking water and the results of water samples demonstrated that the metal concentrations were below the permissible level. Due to the lack of awareness, the general public thinks that groundwater is safe for drinking and it is free from contamination; hence, no treatment is required for groundwater. The present study investigates the assessment of lead concentration in groundwater in the Peshawar. The potential health risk of the occurrence of lead in groundwater has also been investigated by determining the concentration of lead in the blood samples of the inhabitants of the study area. The exploration work will give a base for the awareness campaign with respect to the significance of safe and pure potable water quality.

2. Materials and Methods

2.1. Study Area. The study area is located in district Peshawar, Khyber Pakhtunkhwa, Pakistan. Its geographical coordinates are 34° 2′ 29″ North, 71° 29′ 19″ East [22]. In summer, the mean maximum and minimum temperatures are over 40°C (104°F) and 25°C (77°F), respectively, while in winter the mean minimum and maximum temperature is 4°C (39°F) and 18.35°C (65.03°F), respectively. Unlike other regions of the country, Palosai is nonmonsoon region. Canal is the major source of irrigation originated from River Shalam. The stream water used for irrigation in the peripherals of Palosai is highly polluted by the effluents discharged from Hayatabad industrial zone. The major source of drinking water is groundwater obtained from tube wells, bore wells, hand pumps, and open wells. The sites for collection of water and blood samples are shown in the map of the study area (Figure 1).

2.2. Collection of Water Samples. Groundwater samples ($n = 13$) were collected from various sources such as tube wells (S_1 to S_8) and open wells (S_9 to S_{13}) in clean polythene bottles using the standard procedure of Khan et al. [9], [10] and Ilyas et al. [2] for sample collection. Separate bottles were used for the collection of samples for physicochemical and Pb analysis. A few drops of nitric acid (HNO_3) were added to the samples for Pb analysis to avoid changes in the Pb concentration. The samples were transported to the laboratory for physicochemical and Pb analysis.

2.3. Blood Sampling. Blood samples ($n = 40$) were collected from the local volunteers of the area belonging to different age groups, which included 1–12 years (children), 12–18 years (adolescents), 18–45 years (adults), and above 45 (old) both male and female [23]. Blood samples from all volunteers were collected upon their permission and the permission of the local committee was constituted by the residents. 2 mL of blood sample was collected from each individual in precleaned clean polypropylene tubes, and the samples were transported to the laboratory in ice cold conditions [24].

2.4. Instrumental Analysis

2.4.1. Water Samples. Analyses of physiochemical parameters of water samples including pH, electrical conductivity (EC), dissolved oxygen (DO), and salinity was carried out at the sample collection site, according to the standard procedure of Machado and Bordalo [25], using portable instruments (HI9828, Hanna Instruments, Woonsocket, RI, USA). Alkalinity and chloride (Cl^-) concentration was determined by titration methods using the standard procedure [26]. Concentration of sulphate (SO_4^{-2}) was determined by electrothermal

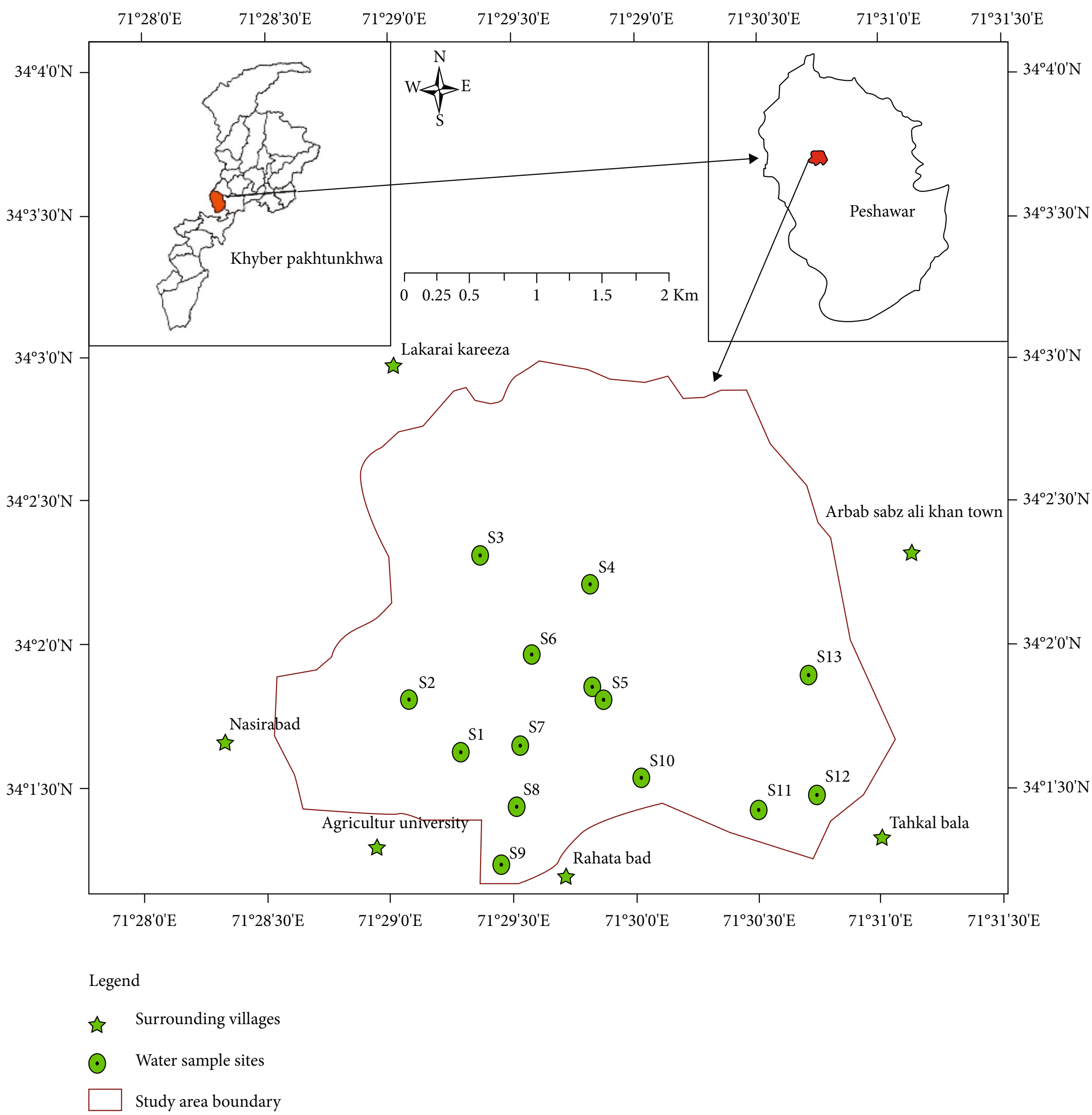

Figure 1: Location map of the study area showing the sampling sites in Peshawar, Pakistan.

atomic ultraviolet spectrophotometer, HACH-2800 [26]. Pb concentration was determined using atomic absorption spectrophotometer (Perkins Elmer-650), at the Centralized Resource Laboratories (CRL), University of Peshawar.

2.4.2. Blood Samples. For the determination of Pb concentration in blood samples using atomic absorption spectrophotometry (Perkins Elmer-650), blood and acid mixtures were used in different proportions to optimize the method. Standard reference materials (SRMs, Human blood, Batch 1701-3) were used to check the accuracy and precession of the analysis. Analytical grade concentrated percholric acid and nitric acid was used to wet digest 3 mL of blood sample. Briefly, in a conical flask, blood sample of 3 mL was put and then added percholric acid and nitric acid in 1 : 4 ratio. They were reserved immediately and then warmed at various standard temperatures on hot plates for obtaining a transparent solution. Subsequent to cooling, the extracts were separated and utilized exceedingly purified deionized water for dilution up to a volume of 100 mL [23].

2.5. Questionnaire Survey. A questionnaire survey was carried out to find the impacts of contaminated water on public health. The important information collected through a questionnaire proforma from the local residents ($n = 13$) included their socioeconomic conditions, major diseases, and water supply source-related information such as source of water, depth of well, drainage system, pollution sources, and water treatment facility.

2.6. Health Risk Assessment

2.6.1. Chronic Daily Intake. Heavy metals and other toxic substances enter our body through various routs including inhalation, dermal contact, and ingestion; among all these exposure pathways, oral intake is the most common [7]. The CDI of contaminants through water intake was calculated using the modified equation of US EPA [27]:

$$\mathrm{CDI} = \mathrm{Cmx}\frac{\mathrm{Ir}}{\mathrm{Bw}}, \quad (1)$$

where CDI is the chronic daily intake, Cm is the metal concentration (mg/L), Ir is the water ingestion rate (2 L/day), and Bw is the weight of the body (66 kg) [6].

2.6.2. Hazard Quotient (HQ). Human health risk assessment (HQ) was done using the standard equation reported elsewhere [28]

$$\mathrm{HQ} = \frac{\mathrm{CDI}}{\mathrm{RfD}}, \quad (2)$$

where RfD represents the oral reference dose. The oral toxicity reference dose value (RfD) of Pb is $3.6E - 02$ mg/kg·day according to US EPA database [29]. Exposed population is considered safe when $\mathrm{HQ} < 1$ [6, 28].

2.7. Statistical Analysis. All the data was statistically analyzed, and for all the result ranges, mean and standard deviations were calculated using Excel 2010 (Microsoft Office). The location map of the study area was prepared by the Arc geographic information system (Arc GIS).

3. Results and Discussion

3.1. Physical Parameters. Physiochemical characteristics of the water samples collected from any source, including springs, streams, well, and tube well, give a picture of the quality of water. These parameters can significantly affect the water quality and have a deep relation with environmental pollution and associated health hazards [30]. The levels of various physicochemical parameters of water samples collected from different sources are shown in Figure 2, and their mean concentrations are given in Table 1. Results indicate that the value of pH for all samples occurs in the range of 6.98 to 7.57. The minimum pH value of 6.98 was noted for the sample of tube well, while the maximum value of 7.57 was noted for the sample of open well at Palosai area; the rest of the samples showed no significant difference in pH values (Figure 2). It is clear from the data that the pH values of all the water samples are within the permissible limits according to WHO and Pak-EPA. These results are in agreement with the findings of Ullah et al. [31]. According to Hanipha and Hussain et al. [32], pH can be used as a tool to measure the degree of basicity and acidity of water. Literature shows that pH does not affect human health but indirectly it can affect human health by conferring better taste to drinking water [15] and affecting pathogen survival and solubility of different ions. pH is a good indicator to measure the degree of pollution of drinking water [33].

The levels of dissolved oxygen (DO) in water in different samples were found to be ranging between 3.08 and 3.23 mg/L, and the difference among sampling sites for DO was of slightest significance (Figure 2). The minimum and maximum values were noted for the tube well samples. The values of DO were within the permissible limits 8 mg/L [27]. Level of dissolved oxygen of water plays an important role in supporting aquatic life; it is a main factor in indicating the freshness of an aquatic system [34].

The EC values for different samples showed great variation ranging between 152 and 710 μS/cm. The maximum value of EC was observed for the sample collected from the tube well at Palosai (Sample S6), whereas the lowest value was noted for the sample of the open well from Palosai (Figure 2). EC is defined as the measure of the conductance of the water sample. Since the ability of electrical conductance depends upon the mobility of ions at a certain temperature, hence, it indicates the concentration of ions in the water sample. In other words, EC of water gives us an idea of total dissolved salts [35]. However, the toxicological effects can be determined from the nature of the ions through chemical analysis.

The values of salinity were found to be ranging from below the detection limit (BDL) to as high as 0.02%. The minimum values noted were for samples of well and tube well in the area, while the maximum value was also for the sample of tube well. Values of salinity determined in the groundwater samples collected from the area show no great variation (Figure 2). All of the physicochemical parameters are influenced upon the nature and concentration of dissolved minerals, which primarily depends upon the geological strata of the area [36]. The above results show that mostly the water samples collected from tube wells are rich in dissolved minerals, which is an indication of the fact that the deep geological strata of the area contain various types of soluble minerals. The value of physical parameters was in agreement with the findings of Giammanco et al. [36] and Neal et al. [37].

3.2. Chemical Parameters. Various chemical parameters examined for the water samples collected from different sources of the selected area included alkalinity, hardness, chloride, sulphate, and total dissolved solids (TDS). The results of the chemical parameters are graphically presented in Figure 3, while the mean concentrations of these parameters are shown in Table 2. Results indicated that the values of alkalinity for water samples collected from various sources were ranging between 75.3 and 191.45 mg/L. The data show that in the case of water samples collected from tube wells, the alkalinity was lower, ranging from 75 to 165 mg/L, with a mean value of 120.11, whereas for water samples collected from open wells the alkalinity was higher ranging from 128

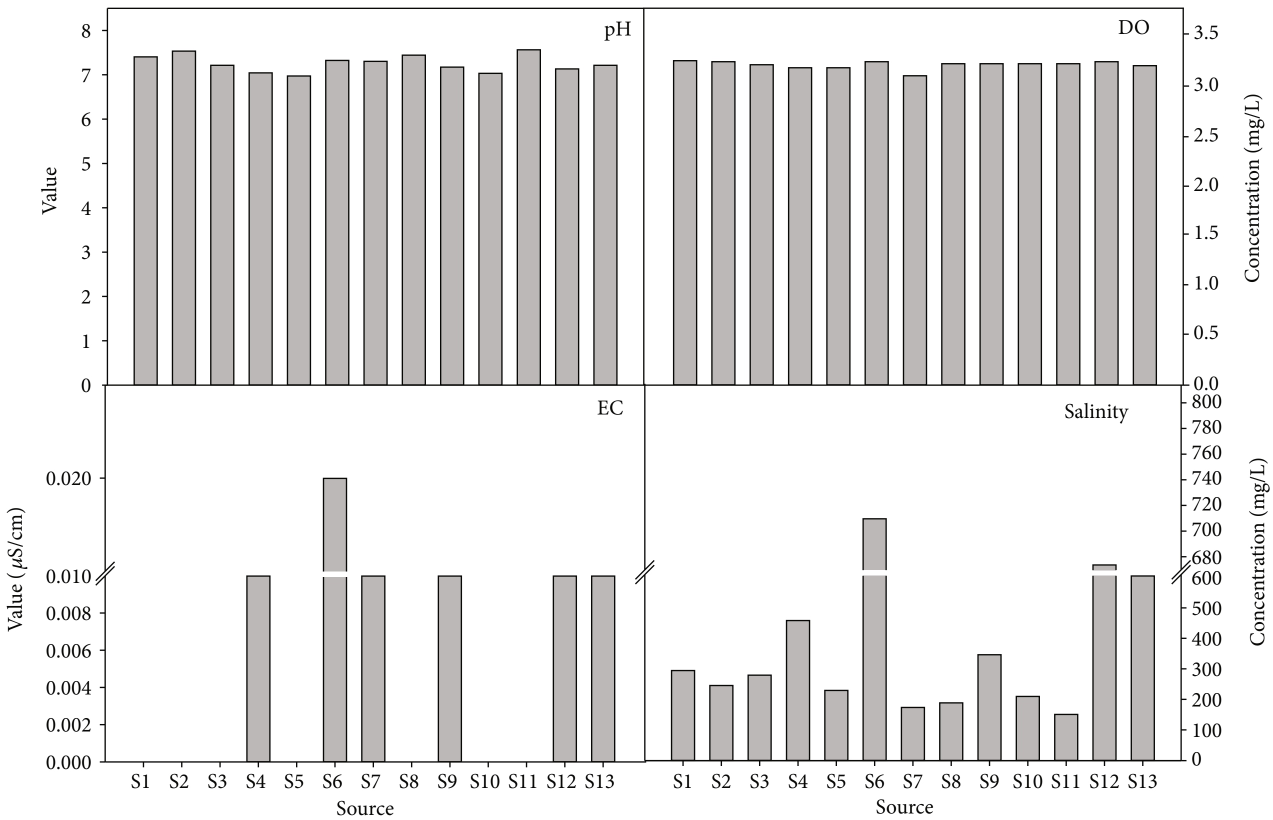

FIGURE 2: Physical parameters of the different water sources in the study area.

TABLE 1: Mean concentrations of physical parameters in the groundwater samples.

Parameters	Tube wells		Wells		Pak-EPA[a]	WHO[b]
	Ranges	Mean value	Ranges	Mean values		
pH	6.98-7.54	7.29	7.04-7.57	7.23	6.5-8.5	6.5-8.5
DO (mg/L)	3.08-3.23	3.18	3.18-3.22	3.2	4	4
EC (μs/cm)	175-710	323.75	152-674	398.2	1500	1500
Salinity (%)	*BDL-0.02	0.005	BDL-0.01	0.006	—	—

[a]Pakistan Environmental Protection Agency (2008), [b]World Health Organization (2008). *BDL: below detection limit.

to 191 mg/L with a mean value of 157.3. Among the different sites, the alkalinity shows a great variation; at S7 and S8, it has a lower value, while in S11, they show a significant higher value (Figure 3). The alkalinity represents the acid neutralizing capacity of the water sample, which depends upon the concentration of various anionic components of water, i.e., bicarbonate, sulphate, chloride, and carbonate. There is no specific guideline for the permissible limits of alkalinity; however, according to some researchers it is from 50 to 500 mg/L [38]. High alkalinity in drinking water may lead to the formation of kidney stones and irritation of skin and eyes, besides such water can damage the metallic pipes [39].

The values of TDS in water samples of various sources and sites were found to be ranging between 230 and 586 mg/L. Higher TDS values were observed for tube well samples (290-586 mg/L) with mean value of 380 mg/L, whereas for the well sample, TDS values were lower (230-428 mg/L) with a mean value of 291.4 mg/L. The permissible limit for TDS is 1000 mg/L according to WHO guidelines. The water samples with TDS levels higher than the permissible limit are harmful for human health causing damage to kidneys, irritation of gastrointestinal tract, and heart diseases [40]. Higher TDS in the water system increases the chemical and biological oxygen demand and ultimately depletes the dissolved oxygen level in water. TDS of the water sample represents all dissolved organic and inorganic substances; these may include sodium, potassium, calcium, magnesium, manganese, and chloride.

The values of hardness as $CaCO_3$ were ranging between 132.8 and 340 mg/L and except two samples where the hardness was higher than 400 mg/L. In the case of water samples from tube wells, the hardness levels ranged between 130.8 and 471 mg/L with a mean value of 273.9 mg/L, and in the

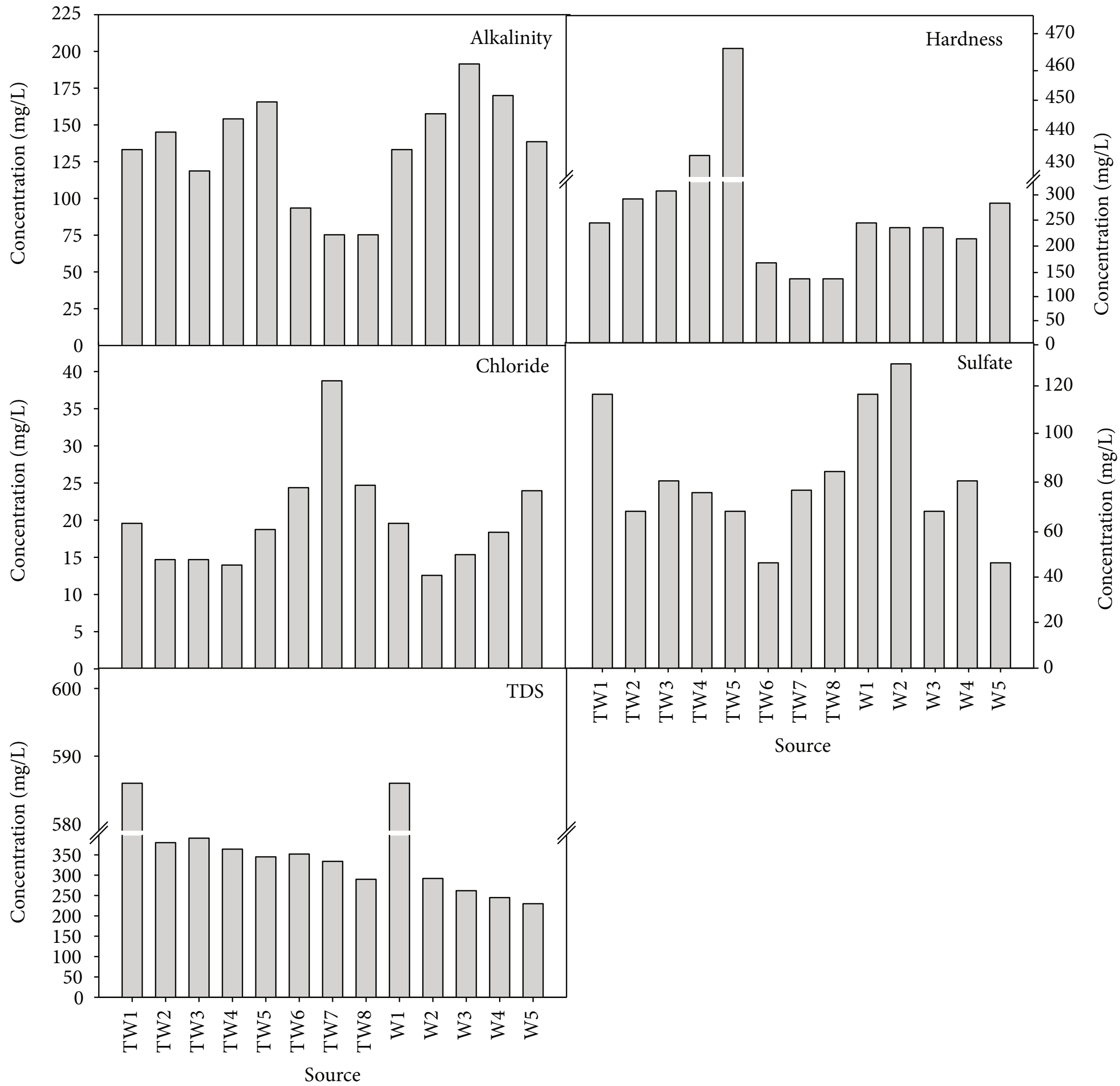

Figure 3: Chemical parameters of different water sources in the study area.

Table 2: Mean concentrations of chemical parameters in the groundwater samples.

Parameters	Tube wells		Wells		Pak-EPA[a]
	Ranges	Mean values	Ranges	Mean values	
Alkalinity (mg/L as $CaCO_3$)	75.3-165.65	120.11	128-191.45	157.13	500
TDS (mg/L)	290-586	380.75	230-428	291.4	1000
Hardness (mg/L as $CaCO_3$)	132.8-471	273.9	216-300.4	256.88	500
Chloride (mg/L)	13.96-38.75	21.18	9.7-23.96	15.99	250
Sulphate (mg/L)	45-117	76.38	45-130	76.4	1000

[a]Pakistan Environmental Protection Agency (2008).

case of water from open well, the hardness values were ranging between 216 and 300.4 mg/L with a mean value of 256.88 mg/L (Figure 3). The data shows that on overall basis the hardness level was high in samples collected from open wells, which are relatively shallow compared to tube wells in the case of which the hardness level was lower. Hardness of water is because of the presence of calcium and magnesium ions with bicarbonate, chloride, and sulphate. Most calcium comes in water from lime stone, industrial waste, and leaching from its minerals in rocks. Hardness of water causes no major harm to human health but may create digestive disorders. Results of hardness in the groundwater of the selected area were in consistence with the finding of Ullah et al. [41] at Konhaye Stream, Lower Dir (131 mg/L).

The level of chloride in water samples ranged between 9.7 and 38.75 mg/L and was within the permissible limits shown by Pak-EPA (250 mg/L). The maximum value of 38.75 mg/L and a minimum value of 9.57 mg/L were noted in the sample of tube well and well in the area, respectively. As for the concentration of chloride is concerned, it shows significant variation among the samples of various sites, the highest values were observed at S7 while the lowest value at S10 (Figure 3). Higher value of chloride is an indicator of pollution (Rakesh 2012). Chloride concentration in water increases due to domestic waste and industrial effluents. Soil permeability and porosity play a key role in building up the chloride concentration [42]. Chloride values higher than the acceptable limits harm metallic pipes and agricultural crops. It can also cause kidney and heart diseases in human [43]. Similarly, the concentration of sulphate was observed to be in the range of 45 to 130 mg/L. The results show that the water samples of the well contain high sulphate concentration compared to the tube well in the Palosai area. The highest values were observed at S6 and S13 while the lowest value at S10 (Figure 3).

3.3. Lead Concentration in Groundwater. Lead is a toxic element distributed worldwide which is continuously added to the environment in large amounts as a result of anthropogenic activities [44]. The results of Pb concentration determined in groundwater samples are given in Table 3. The data shows that in all the water samples collected from tube wells of different sites, the concentration of lead occurs in the range of 0.022-0.067 mg/L, whereas in the case of samples of open wells the lead was found to be in the range of 0.004-0.015 mg/L. According to WHO and Pak-EPA, the permissible limit for lead in water is 0.05 mg/L; this shows that in the case of tube wells at few sites, the lead concentration exceeds the permissible limit. Hence, the water of the open wells is safe for health whereas that of tube wells poses a potential health risk due to excess of lead (Figure 4). The major uses of Pb include radioactive emissions and making safety shields from X-rays and other radiations. Pb is found everywhere like other contaminants and can occur as inorganic ions, salts, and metallic lead [45]. Pb has no vital role in the human body. The most common routes for intake of Pb include drinking water, food, and air. Plant absorbs Pb from soil, and thus, Pb enters the food chain and finally finds its way to the human body. The use of lead-based pottery glazes is also a source of ingestion of lead [46]. Generally, ingestion accounts for 5 to 15% of lead intake while 20 to 50% through inhalation, whereby inorganic lead is absorbed [47]. Pb is distributed among mineralizing tissue, soft tissue, and blood [46]. Pb is the most toxic and hazardous metal found in the environment. Pb toxicity has more effects on children compared to adults and may cause memory problems, behavioral disturbances, and anemia. Lead may also some time cause toxic effects like headache, hypertension, abdominal pain, irritability, kidney damage, stomach cancer, lung cancer, and nerve damage [48]. The present study and some of the earlier studies show that drinking water sources contaminated chemically and with other heavy metals are the main causes of health risk to human [6, 8–10, 15]. In the study area, Pb concentrations in water were observed lower than those reported in drinking water by Muhammad et al. [6] from the Kohistan region, Pakistan.

Table 3: Lead concentrations (mg/L) in the groundwater samples.

Samples	Mean	Range	SD±	[a]Pak-EPA	[b]WHO
Tube wells	0.039	0.022-0.067	0.00	0.05	0.05
Wells	0.004	0.004-0.015	0.01		

[a]Pakistan Environmental Protection Agency (2008), [b]World Health Organization (2008); SD: std. deviation.

3.4. Distribution of Lead in the Blood Samples. The levels of Pb in human blood samples from Palosai area were determined. Pb concentrations (μg/L) in blood samples collected from peoples of different age groups of Peshawar are given in Table 4. From Table 4, it is clear that the mean concentration of Pb in blood samples of children were 0.01 μg/L for both males and females. In adolescent, mean concentration of Pb was 0.05 μg/L in males and 0.03 μg/L, in female. In adults, the mean concentrations of Pb were 0.10 μg/L in males and 0.06 μg/L in females. While in old age peoples, the mean concentration of Pb in blood was 0.16 μg/L in males and 0.10 μg/L in females. Overall concentration of Pb was higher in males compared to female; this may be attributed to body mass, diet habits, and some other factors related to the male community. In the study area, Pb concentration in blood samples of all the inhabitants was lower than the permissible levels [49]. However, on the overall basis, the above results reveal that the Pb concentration in the blood of old individuals is higher compared to children and adolescent, and this may be because of the slow accumulation of Pb in the body of old individuals over time. The cause of the Pb detected in the blood of human in the Palosai area may be associated to bioaccumulation from consumption of water from the tube well. The value of Pb of Palosai area determined in blood was in agreement with the result of Jan et al. [50]. The trace and heavy elements (i.e., Ni, Cr, Pb, Cu, Co, Fe, and Cd) in the waters of Peshawar area are within the acceptable concentration but Ni, Fe, Cr, and Pb concentrations are too high in certain areas which are a threat to people health. The possible source of contaminations in the area is both geogenic and anthropogenic sources. Industrial estates waste, underground pipes corrosion, and tannery industries are the anthropogenic sources, while ultramafic and mafic rocks in the northeast and northwest and sulphide seams are the geogenic sources of contamination [51]. Inam Ullah and Alam [52] collected groundwater samples from Peshawar in which the Pb and Mn quantities (2.97 and 8.26 mg/L) were high. These concentrations were high because of lack of awareness, lack of treatment facilities, lack of regulation of waste disposal, and mismanagement in the infrastructure of water distribution [52].

The use of plumbing materials and substandard pipes is one of the professed reasons for Pb contamination in the

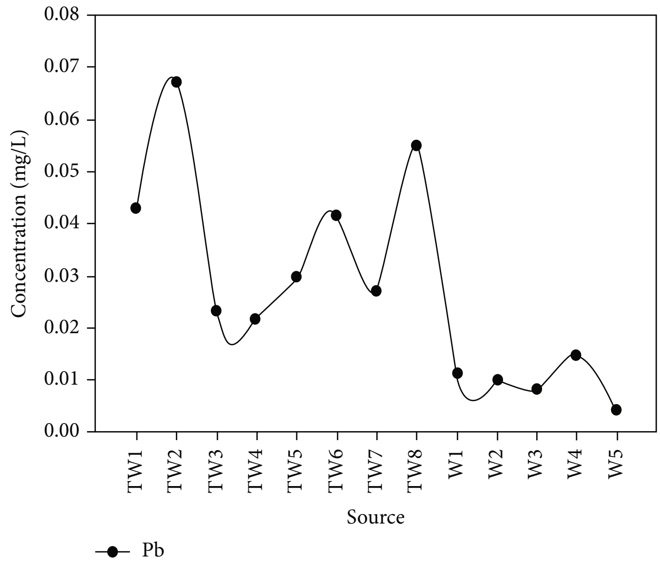

Figure 4: Pb concentrations of different water sources in the study area.

Table 4: Lead concentrations (μg/L) in the human blood of different age groups of people.

Mean	Range	SD±	Mean	Range	SD±
Children (male), $n = 10$				Children (female), $n = 10$	
0.01	0.00-0.06	0.00	0.01	0.00-0.35	0.00
Adolescent (male), $n = 10$				Adolescent (female), $n = 10$	
0.05	0.00-0.16	0.00	0.03	0.00-0.14	0.00
Adults (male), $n = 10$				Adults (female), $n = 10$	
0.1	0.00-0.20	0.00	0.06	0.00-0.64	0.00
Old age (male), $n = 10$				Old age (female), $n = 10$	
0.16	0.00-0.32	0.00	0.1	0.00-0.10	0.00

n: number of samples; SD±: standard deviation.

area. Under various climatic conditions, substandard pipes and uncovered water delivery systems are prone to corrosion. Quinn and Sherlock [16] stated that Pb is an essential part of plumbing materials. Pb in very small concentrations is found in natural water. Concentrations of Pb occur in home pipes or water distribution system. Thus, it can be concluded from the current study that at household levels, the pollution of Pb concentration is more because the water carries Pb through other distribution installations and pipes to the households.

3.5. Chronic Daily Intake (CDI) Indices and Hazard Quotient (HQ). CDI and HQ values for lead in water samples of both tube wells and wells were calculated. Results are shown in Table 5 for groundwater consumption. The CDI and HQ values of tube wells ranged from 0.01 to 0.002 μg/kg·day and $2.5E-02$ to $5.00E-02$ mg/kg·day for Pb, respectively. However, the CDI and HQ values were negligible for wells.

In the environment, e.g., water, soil, and atmosphere, Pb is found at various concentrations. Pb is found in food as residues due to their occurrence in the environment, as a result of anthropogenic activities such as from contamination during storage and processing of food, car exhaust, industry, or farming. Human are exposed to Pb by ingesting contaminated water or food or from the environment. Harmful effects are caused over time in the human body due to their accumulation [53]. Food contains metals such as Ca, Mg, K, Na, B, Fe, Se, Zn, and Cu. These metals are required in trace quantities for cellular processes maintenance. Other metals can be harmful found in the body if regularly consumed in the diet. In the earth's crust, most of the metals are found. Other elements and metals as a result of anthropogenic activities such as agricultural or industrial processes can enter food or occur in food naturally. Metals can exist chemically as pure, e.g., Pb or Sn or compounds formed by the combination of a nonmetallic element with a metallic element, e.g., chlorine in combination with sodium giving sodium chloride salt or an oxide giving by oxygen [54].

Pb, As, Cd, Hg, and Sn cause harmful effects in the body and are of major concern. Pb and Hg due to high atomic weight are considered as “heavy metals.” Uranium and chromium are also found in water or food as contaminants and are potentially toxic. In the workplace, individuals are often

Table 5: Chronic daily intake (CDI) and hazard quotient (HQ) of Pb through ground water consumption.

Chromic risk assessment	Tube wells		Wells	
	Ranges	Mean	Ranges	Mean
CDI[c] (mg/kg-day)	0.01-0.002	0.001	BDL	BDL
HQ[d] (mg/kg-day)	$2.5E-02-5.00E-02$	$2.80E-02$	BDL	BDL

[c]Chronic daily intake. [d]Hazard quotient.

Table 6: Disease wise representation of different age group below 18 years old.

S. no.	Family strength	Under eighteen	Nervous system and kidney damage	Learning disabilities	Speech, language and behavior problems	Poor muscle coordination	Decreased muscle and bone growth	Hearing damage
1	19	6	No	Yes	No	No	No	Yes
2	10	5	No	No	No	No	No	No
3	12	4	No	No	No	No	No	No
4	9	4	No	No	No	No	No	No
5	10	3	No	No	No	No	No	No
6	13	0	No	No	No	No	No	No
7	12	0	No	No	No	No	No	No
8	16	6	No	Yes	No	No	No	No
9	28	5	No	Yes	No	No	No	No
10	20	7	No	Yes	No	No	No	No
11	12	4	No	Yes	No	No	No	No
12	8	3	No	Yes	No	No	No	No
13	8	3	No	Yes	No	No	No	No

exposed to metals such as nickel and beryllium, which causes harmful effects in their body. The damaging effects of the latter group of metals are usually associated with metal dust inhalation, causing injury to the lung, and are not found in food at concentrations that could cause toxicity [55].

Exposure of children to Pb can affect children's behavior and development. Blood having Pb levels 0.1 mg/L are associated with delayed puberty, postnatal height or growth, cognitive performance, decreases in hearing, and increased behavioral effects. Blood having Pb levels less than 0.05 mg/L, including decreased academic achievement, increases in both attention related behaviors and behavioral problems, and lower IQ scores [56]. A number of health problems are caused in adults when exposed to Pb. As a common rule, the more health problems you will have, the more Pb you have in your body. Blood having high Pb levels greater than 0.15 mg/L are linked with decreased kidney function, nerve disorders, cardiovascular effects, and fertility problems, including delayed conception and adverse effects on semen and sperm, such as lower sperm motility and counts. Pb levels below 0.1 mg/L in blood are associated with hypertension, decreased kidney function, and incidence of essential tremor. There is also evidence of decreased kidney function in adults having a blood Pb levels less than 0.15 mg/L. Particularly, pregnant women require being careful about lead. Less than 0.05 mg/L of Pb in maternal blood is associated with reduced fetal growth [57]. Renal system, nervous system, and blood forming system are most sensitive to lead. Enzymatic systems in children are inhabited when the Pb levels are from 0.008 to 0.01 mg/L [58].

3.6. Questionnaire Survey. The information about the health problems commonly associated with Pb intake was collected through a questionnaire survey from the local residents of the area; summary of the data is presented in Tables 6 and 7. The tables represent two different age groups, i.e., age group below 18 years and above 18 years of peoples of Peshawar. Pb causes different diseases in young and adult peoples. Pb effect varies in both of these groups; it affects young children (under eighteen) more compared to adult peoples (above eighteen). In the study area, the diseases which were common in young individuals were learning disabilities and some with hearing damage, while no such problems were found in young individuals. As far as the adults were concerned, all had high blood pressure, muscle and joint pain, digestive problems, and some have memory and concentration problems. It is clear from the above table that the diseases caused by Pb were more in adults compared to young individuals. It is because of the chronic exposure of young individuals to Pb that accumulate in their body and show late effects on their body.

In the study area, majority of the population has low income level and they are residing in small villages. The people have no excess to pure and clean drinking water. The major sources from which the locals get their drinking water are tube well and well; however, the tube wells and their

Table 7: Disease wise representation of different age groups above 18 years olds.

S. no.	Family strength	Above eighteen	High blood pressure	Muscle and joint pain	Digestive problems	Nerve disorders	Memory and concentration problems	Damage to sperm-producing organs in men	Cataracts
1	19	13	Yes	No	Yes	No	Yes	No	No
2	10	5	Yes	No	Yes	No	No	No	No
3	12	8	Yes	Yes	Yes	No	No	No	No
4	9	5	Yes	No	Yes	No	No	No	No
5	10	7	Yes	No	Yes	No	No	No	No
6	13	13	Yes	No	Yes	No	No	No	No
7	12	12	Yes	No	Yes	No	No	No	No
8	16	10	Yes	No	Yes	No	No	No	No
9	28	23	Yes	No	Yes	No	No	No	No
10	20	13	Yes	Yes	Yes	No	No	No	No
11	12	8	Yes	Yes	Yes	No	No	No	No
12	8	5	Yes	Yes	Yes	No	No	No	No
13	8	5	Yes	Yes	Yes	No	No	No	No

ability to provide water to the households are in a very low quantity because of miss management. Because of the very low education level and due to lack of awareness, people are of the opinion that groundwater is safe. Some people even think that water lying below the gravel (underground rocks) is free from contamination. Therefore, they do not feel the need of any type of treatment for their groundwaters. The majority of the population is of low-income class and also the government and is not spending much in the field of safe drinking water provision to the community, and so, the bad transportation condition of water supply is leading to so many problems. Ilyas et al. [1] determined the heavy metals including lead (Pb), chromium (Cr), nickel (Ni), and zinc (Zn) in drinking water in the selected area of Lower Dir, Pakistan. The heavy metal results showed that all the metals were within the permissible limit except Cr (0.18 mg/L) and Pb (0.04 mg/L).

4. Conclusion

In this study, the groundwater quality and associated health risks was carried out in Palosai area, Peshawar, Khyber Pakhtunkhwa, Pakistan. The groundwater samples were analyzed for physicochemical parameters based on standard guidelines. Results revealed that the physiochemical parameters were within the permissible limits. Pb result shows that in the case of tube wells at few sites the lead concentration exceeds the permissible limits. It can be concluded from the current study that consumption of groundwater increases the concentration of lead in the blood of human. However, the overall HQ values of Pb in the groundwater were less than 1, indicating no health risk to the local depending community.

5. Recommendations

Provision of clean and safe water for domestic purposes, banning of water from contaminated sites, treatment of rural and wastewater, and good transportation condition of drinking water supply in the study area are recommended.

Data Availability

All relevant data are included in the paper.

Conflicts of Interest

The authors state no conflict of interest.

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References

[1] M. Ilyas, S. Khan, A. Khan, R. Amin, A. Khan, and M. Aamir, "Analysis of drinking water quality and health risk assessment-a case study of Dir Pakistan," *Journal of Himalayan Earth Sciences*, vol. 50, pp. 100–110, 2017.

[2] M. Ilyas, W. Ahmad, H. Khan, S. Yousaf, M. Yasir, and A. Khan, "Environmental and health impacts of industrial wastewater effluents in Pakistan: a review," *Reviews on Environmental Health*, vol. 34, no. 2, pp. 171–186, 2019.

[3] S. Yousaf, M. Shakil, A. Khan et al., "Seasonal characterization and potential human health risk of heavy metals contamination in sediments of the river Jindi," *Pakistan. Journal of Himalayan Earth Science*, vol. 53, no. 1, 2020.

[4] L. Petraccia, G. Liberati, S. G. Masciullo, M. Grassi, and A. Fraioli, "Water, mineral waters and health," *Clinical Nutrition*, vol. 25, no. 3, pp. 377–385, 2006.

[5] M. Ilyas, W. Ahmad, H. Khan, and S. Yousaf, "Potentially poisonous elements removal from vehicle-wash wastewater and aqueous solutions using composite adsorbents," *Desalination and Water Treatment*, vol. 224, pp. 331–342, 2021.

[6] S. Muhammad, M. T. Shah, and S. Khan, "Health risk assessment of heavy metals and their source apportionment in

drinking water of Kohistan region, northern Pakistan," *Microchemical Journal*, vol. 98, no. 2, pp. 334–343, 2011.

[7] ATSDR, *Agency for toxic substances disease registry toxicological profile for arsenic*, U.S. Department of Health & Human Services, Atlanta, Georgia, 2000.

[8] M. T. Shah, J. Ara, S. Muhammad, S. Khan, and S. Tariq, "Health risk assessment via surface water and sub-surface water consumption in the mafic and ultramafic terrain, Mohmand agency, northern Pakistan," *Journal of Geochemical Exploration*, vol. 118, pp. 60–67, 2012.

[9] S. Khan, M. Shahnaz, N. Jehan, S. Rehman, M. T. Shah, and I. Din, "Drinking water quality and human health risk in Charsadda district, Pakistan," *Journal of Cleaner Production*, vol. 60, pp. 93–101, 2013.

[10] K. Khan, Y. S. Lu, A. A. Khan, L. Wei, and T. Wang, "Health risks associated with heavy metals in the drinking water of Swat, northern Pakistan," *Journal of Environmental Sciences*, vol. 25, no. 10, pp. 2003–2013, 2013.

[11] M. S. Islam, M. K. Ahmed, M. Raknuzzaman, M. Habibullah-Al-Mamun, and M. K. Islam, "Heavy metal pollution in surface water and sediment: a preliminary assessment of an urban river in a developing country," *Ecological Indicators*, vol. 48, pp. 282–291, 2015.

[12] S. G. Donaldson, J. Van Oostdam, C. Tikhonov et al., "Environmental contaminants and human health in the Canadian Arctic," *Science of the Total Environment*, vol. 408, no. 22, pp. 5165–5234, 2010.

[13] G. Goyer, *Issue paper on the human health effects of metals*, US Environmental Protection Agency, Risk Assessment Forum, Washington, DC, USA, 2004.

[14] WHO, "World Health Organization guidelines for drinking water quality," in *Recommendations, vol 1.*, WHO, Geneva, Switzerland, 4th edition, 2011.

[15] S. Muhammad, M. T. Shah, and S. Khan, "Arsenic health risk assessment in drinking water and source apportionment using multivariate statistical techniques in Kohistan region, northern Pakistan," *Food and Chemical Toxicology*, vol. 48, no. 10, pp. 2855–2864, 2010.

[16] M. J. Quinn and J. C. Sherlock, "The correspondence between U.K. 'action levels' for lead in blood and in water," *Food Additives and Contaminants*, vol. 7, no. 3, pp. 387–424, 1990.

[17] M. R. Schock, "Causes of temporal variability of lead in domestic plumbing systems," *Environmental Monitoring and Assessment*, vol. 15, no. 1, pp. 59–82, 1990.

[18] S. E. Spayd, M. G. Robson, R. Xie, and B. T. Buckley, "Importance of arsenic speciation in populations exposed to arsenic in drinking water," *Human and Ecological Risk Assessment*, vol. 18, no. 6, pp. 1271–1291, 2012.

[19] S. H. Frisbie, R. Ortega, D. M. Maynard, and B. Sarkar, "The concentrations of arsenic and other toxic elements in Bangladesh's drinking water," *Environmental Health Perspectives*, vol. 110, no. 11, pp. 1147–1153, 2002.

[20] S. Giri, M. K. Mahato, G. Singh, and V. N. Jha, "Risk assessment due to intake of heavy metals through the ingestion of groundwater around two proposed uranium mining areas in Jharkhand, India," *Environmental Monitoring and Assessment*, vol. 184, no. 3, pp. 1351–1358, 2012.

[21] A. Kumar, R. Vij, M. Gupta, S. Sharma, and S. Singh, "Risk assessment of exposure to radon concentration and heavy metal analysis in drinking water samples in some areas of Jammu & Kashmir, India," *Journal of Radioanalytical and Nuclear Chemistry*, vol. 304, no. 3, pp. 1009–1016, 2015.

[22] D. N. Ali, *District health profile (District Peshawar)*, P. Pakistan Initiative for Mothers and Newborns Islamabad o. Document Number, 2009.

[23] F. A. Jan, M. Ishaq, S. Khan et al., "Bioaccumulation of metals in human blood in industrially contaminated area," *Journal of Environmental Sciences (China)*, vol. 23, no. 12, pp. 2069–2077, 2011.

[24] K. Khan, H. Khan, Y. Lu et al., "Evaluation of toxicological risk of foodstuffs contaminated with heavy metals in Swat, Pakistan," *Ecotoxicology and Environmental Safety*, vol. 108, no. 1, pp. 224–232, 2014.

[25] A. Machado and A. A. Bordalo, "Analysis of the bacterial community composition in acidic well water used for drinking in Guinea-Bissau, West Africa," *Journal of Environmental Sciences*, vol. 26, no. 8, pp. 1605–1614, 2014.

[26] APHA, *Standard Methods for the Examination of Water and Wastewater*, American Public Health Association and Water Environmental Foundation EPS Group, Inc., Maryland, USA, 18th ed. edition, 1992.

[27] USEPA (US Environmental Protection Agency), "United States Environmental Protection Agency, Arsenic, inorganic integrated risk information system (IRIS), (CASRN 7440–38–2)," 1998, http://www.epa.gov/iris/subst/0278.htm.

[28] S. Khan, Q. Cao, Y. M. Zheng, Y. Z. Huang, and Y. G. Zhu, "Health risks of heavy metals in contaminated soils and food crops irrigated with wastewater in Beijing, China," *Environmental Pollution*, vol. 152, no. 3, pp. 686–692, 2008.

[29] USEPA (US Environmental Protection Agency), *Guidelines for carcinogen risk assessment. EPA/630/P-03/001F.*, Risk Assessment Forum, Washington, DC, USA, 2005.

[30] A. Mora, A. C. Mac-Quhae, M. Calzadilla, and L. Sanchez, "Survey of trace metals in drinking water supplied to rural populations in the eastern Llanos of Venezuela," *Journal of Environmental Management*, vol. 90, no. 2, pp. 752–759, 2009.

[31] H. Ullah, I. Khan, and I. Ullah, "Impact of sewage contaminated water on soil, vegetables, and underground water of peri-urban Peshawar, Pakistan," *Environmental Monitoring and Assessment*, vol. 184, no. 10, pp. 6411–6421, 2012.

[32] M. M. Hanipha and Z. A. Hussain, "Study of ground water quality at Dindigul town, Tamilnadu, India," *International Research Journal of Environment Sciences*, vol. 2, no. 1, pp. 68–73, 2013.

[33] S. B. Jonnalagadda and G. Mhere, "Water quality of the Odzi River in the eastern highlands of Zimbabwe," *Water Research*, vol. 35, no. 10, pp. 2371–2376, 2001.

[34] S. O. Fakayode, "Impact assessment of industrial effluent on water quality of the receiving Alaro in Ibandan, Nigeria," *Ajeam-Ragee*, vol. 10, pp. 1–13, 2005.

[35] WHO, *Guidelines for drinking-water quality. Vol. 2*, Health criteria and other supporting information, World Health Organization, Geneva, 1995.

[36] S. Giammanco, M. Ottaviani, M. Valenza et al., "Major and trace elements geochemistry in the ground waters of a volcanic area: Mount Etna (Sicily, Italy)," *Water Research*, vol. 32, no. 1, pp. 19–30, 1998.

[37] C. Neal, W. A. House, H. P. Jarvie, M. Neal, L. Hill, and H. Wickham, "Phosphorus concentrations in the River Dun, the Kennet and Avon Canal and the River Kennet, southern England," *Science of the Total Environment*, vol. 344, no. 1-3, pp. 107–128, 2005.

[38] M. Jaffar, M. Ashraf, and M. Saleem, "A comparative study of physico-chemical parameters and trace metal contents of holy water zamzam and local potable as well as hot spring waters," *Pakistan Journal of Scientific and Industrial Research*, vol. 30, no. 3, 1986.

[39] G. R. Chhatwal, T. Katyal, M. Katlyal, M. C. Mehra, M. Satake, and T. Nagahiro, *Environmental Water Pollution and Control*, Anmol Publications, New Delh, 1989.

[40] C. K. Jain, C. P. Kumar, and M. K. Sharma, "Ground water qualities th of Ghataprabha command area Karnataka," *Indian Journal of Environment and Ecoplanning*, vol. 7, no. 2, pp. 251–262, 2003.

[41] S. Ullah, N. Ullah, K. Rahman, T. M. Khan, M. A. Jadoon, and T. Ahmad, "Study on physicochemical characterization of Konhaye Stream District Dir Lower, Khyber Pakhtunkhwa Pakistan," *World Journal of Fish and Marine Sciences*, vol. 6, no. 5, pp. 461–470, 2014.

[42] C. K. Jain, K. K. Bhatio, and S. R. Kumar, "Ground water quality in Malaprabha sub-basin Karnataka," *International Journal of Environmental Protection*, vol. 23, no. 3, pp. 321–329, 2005.

[43] A. D. Chapolikar and M. B. Ubale, "A correlation study on physico- chemical characteristics of ground water in Thane-Belapur industrial area, Mumbai," *Current World Environment*, vol. 5, no. 1, pp. 67–71, 2010.

[44] J. Oehlenschläger, "Identifying heavy metals in fish In," in *Safety and Quality Issues in Fish Processing*, H. A. Bremner, Ed., pp. 95–113, Woodhead Publishing Limited, Cambridge, 2002.

[45] N. Harrison, "Inorganic contaminantsin food," in *In: Food Chemical Safety Contaminants*, D. H. Watson, Ed., pp. 148–168, Woodhead Publishing, Cambridge, 2001.

[46] Y. Ming-Ho, *Environmental Toxicology: Biological and Health Effects of Pollutants, Chap. 12*, CRC Press LLC, Boca Raton, USA, 2nd Edition edition, 2005.

[47] A. Ara and J. A. Usmani, "Lead toxicity: a review," *Interdisciplinary toxicology*, vol. 8, no. 2, pp. 55–64, 2015.

[48] K. Steenland and P. Boffetta, "Lead and cancer in humans: where are we now?," *American Journal of Industrial Medicine*, vol. 38, no. 3, pp. 295–299, 2000.

[49] WHO, *Trace elements in human nutrition and health*, World Health Organization, Geneva, Switzerland, 1996.

[50] F. A. Jan, M. Ishaq, S. Khan, I. Ihsanullah, I. Ahmad, and M. Shakirullah, "A comparative study of human health risks via consumption of food crops grown on wastewater irrigated soil (Peshawar) and relatively clean water irrigated soil (lower Dir)," *Journal of Hazardous Materials*, vol. 179, no. 1-3, pp. 612–621, 2010.

[51] S. Nasreen, *Monitoring of surface water ground water air and soil in Peshawar basin against time the 3rd dimension*, Higher Education commission Pakistan, 2006.

[52] E. Inam Ullah and A. Alam, "Assessment of drinking water quality in Peshawar, Pakistan," *Bulgarian Journal of Agricultural Science*, vol. 20, no. 3, pp. 595–600, 2014.

[53] M. R. Moore, "Prenatal exposure to lead and mental retardation," in *Low Level Lead Exposure: The Clinical Implications of Current Research*, H. L. Needleman, Ed., pp. 53–65, Raven Press, New York, 1980.

[54] W. Yule and R. Landsdown, "Lead and children's development: recent findings," in *Heavy Metals in the Environment*, pp. 912–916, CEP Consultants Ltd, Edinburgh, Heidelberg, 1983.

[55] H. Hussein, S. Farag, K. Kandil, and H. Moawad, "Tolerance and uptake of heavy metals by _Pseudomonads_," *Process Biochemistry*, vol. 40, no. 2, pp. 955–961, 2005.

[56] F. W. Alexander, H. T. Delves, and B. E. Clayton, "The uptake and excretion by children of lead and other contaminants," in *Environmental Health Aspects of Lead. Commission of the European Communities Directorate General for Dissemination of Knowledge Centre for Information and Documentation*, pp. 319–330, Luxembourg, 1973.

[57] J. Lin-Fu, *Lead poisoning and undue lead exposure in. Children: History and Current Status*, Raven Press, New York, 1980.

[58] H. S. Peavy, D. R. Rowe, and G. Tchobanoglous, *Environmental Engineering*, 1985.