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Assessment of Cadmium Toxicity in Drinking Water of Eight Talukas of Upper Sindh

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Abstract

In the present study, 240 groundwater samples were collected from eight Talukas of upper Sindh. The cadmium (Cd) content was determined by atomic absorption spectrophotometer. Concentration (µg/L), Daily Intake of Metals (DIM), Health Risk Indexes (HRI) for children and adults caused due to Cd were measured through equations of EPA and WHO. Mean concentration of Cd in different Talukas of upper Sindh was found as; Daharki (6.20 µg/L), Ubauro (7.73 µg/L), Kashmore (7.53 µg/L), Tangwani (7.73 µg/L), Garhi Khairo (6.20 µg/L), Thul (5.00 µg/L), Qambar (7.674 µg/L) and Miro Khan (7.47 µg/L). Moreover, percent contamination of each Taluka was found as, Daharki (80%), Ubauro (93%), Kashmore (93%), Tangwani (93%), Gharhi Khairo (70%), Thul (56%), Qambar (93%) and Miro Khan (93%). The DIM of Cd for adult and children was calculated the range for adults was found as; Daharki (0.06 - 0.36), Ubauro (0.06 - 0.42), Kashmore (0.06 - 0.36), Tangwani (0.06 - 0.42), Garhi Khairo (0.03 - 0.56), Thul (0.03 - 0.56), Qambar (0.08 - 0.39) and Miro Khan (0.08 - 0.39) mg/kg-d, whereas, for children DIM of Cd was found lower than adults. The HRI values show that children compared to adults are under the potential risk threat due to HRI values > 1. Therefore, it can be suggested that groundwater found in above stated areas is unsafe for drinking purposes and must be treated before consumption.

Keywords: Cadmium, Upper Sindh, Talukas, Groundwater, atomic absorption spectrophotometer

Introduction

Drinking water must be safe from contaminants because it is life; therefore, we must be anxious about its safety. Close connection has been observed between the geologic environment and chronic diseases. The geochemical atmosphere is responsible for the casual aspect of severe health issues [1].Various researchers have conducted studies to interpret the relation between potable water, geochemical environment, and diseases among humans [2]. Integral parts of suspended sediments or dissolved substances are considered the primary source of water elements. Nevertheless, dissolved materials in streams or rivers have the maximum potential of causing the most harmful effects. Consequently, groundwater contamination may be caused when elements stored in sediments of the riverbed percolate into the subterranean water. The contamination level of groundwater depends on the closeness of the well to the geological source [3,4]. Evaluation of potable water's physical and chemical properties is critical for determining that the water is safe for drinking and cooking purposes [5]. Diseases and health problems may be caused due to Inorganic elements and pathogens [6]. Cadmium (Cd) is a trace and toxic element and may be found in petroleum, coal, and rocks. No evidence for the essentiality of Cd is indicated to humans. Groundwater and surface water may be contaminated with Cd by geologic deposits when in contact with water [7]. The Cd is highly toxic, damages kidneys and heart, and may cause cancer. Low intake of Cd may cause vomiting, nausea, headache, and cough, whereas its higher dose may cause liver, kidney failure, human hypertension, renal failure, and bone disorder [8]. Potable water contaminated with Cd may cause chronic anemia by prolonged exposure. When it is induced to activity by Cd, it gets bound to zinc and copper [9].

Chronic exposure to Cd is responsible for a broad range of chronic and acute effects in humans. Accumulation of Cd in the human body occurs in kidneys, causing renal tubular damage, which is an important health consequence. Development of kidney stones, hypercalciuria, and disturbance in calcium metabolism are also effects of Cd exposure. Poor water quality that may produce Cd poisonous effect has produced an international dilemma [10]. Besides Cr, Hg, Pb, and As, no physiological function of Cd is found and is believed to be a toxin [11]. During lactation, Cd eliminates from the body slowly through milk, saliva, urine, and kidneys. Various adverse effects of Cd are resulted due to Cd exposure in humans, like harm to the hemopoietic, adrenal structure, osteomalacia, testicular damage, pulmonary edema, and hepatic and renal dysfunction [12]. The sight, hearing weakness, damage of skeletal, liver, cardiovascular, and kidneys systems may occur due to low levels of Cd [13]. The main purpose of the current study was to evaluate the concentration of Cd and its human health risk assessment, calculate the Daily Intake of Cd and determine the toxic level of Cd in the drinking water of upper Sindh.

Materials and Methods

Study Area

The weather condition of upper Sindh is excessively warm in summer and modest in winter (Fig. 1). The maximum and minimum temperatures noted are 52.8 ºC and –3.9 ºC, respectively. The mean rainfall per annum in this area is 122.5 mm, usually in the monsoon season from July to September.

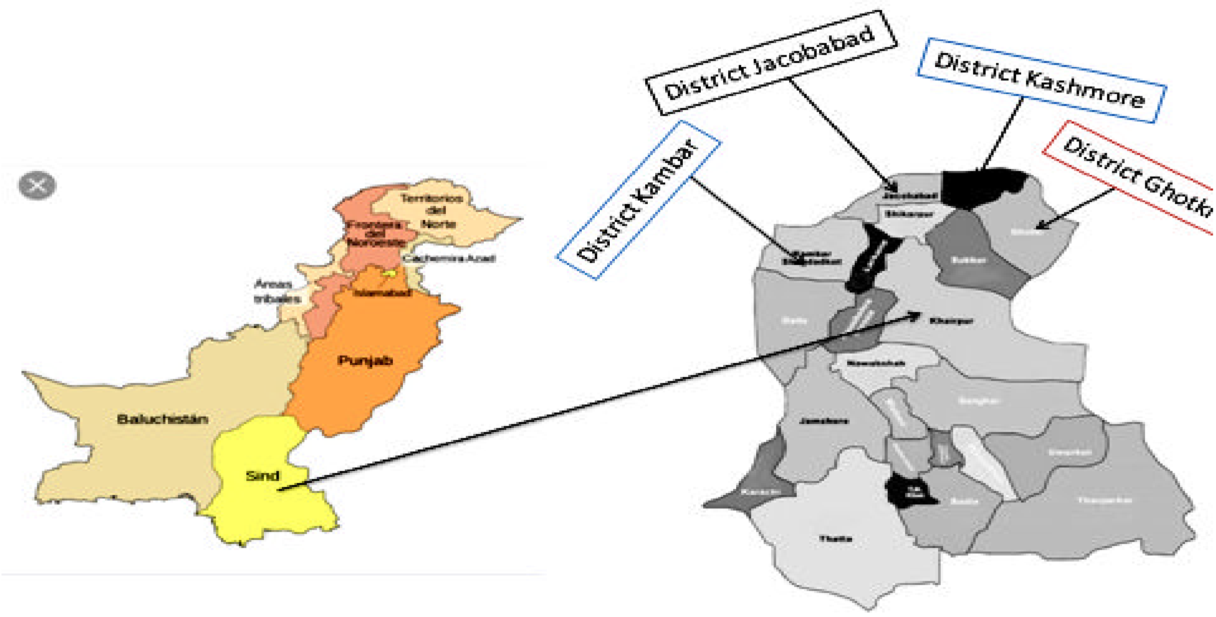

Figure 1. **The map of the Study area**

The air is generally dry because the thermal equator passes from the upper Sindh. The area of upper Sindh is 6,790 square kilometers and is located at 27° 56' and 28° 27' N. and 68°, and 69° 44' E. Upper Sindh has the Thar Desert on the eastern side, Suleman Range in North, Bahurai range in the west and Khirthar range in Southwest. The massive Indus river flows from north to south at the south-eastern side of Jacobabad; moreover, so many canals and streams consisting of the Bolan river are present on the western and northern sides. The flow of nonperennial streams is always found towards Sindh since the south western, western, and northern parts belong to the Baluchistan plateau [14].

Chemicals and Reagents

Reagents used to prepared a standard solution of Cd were bought from Merck (Darmstadt, Germany), and de-ionized water was used to prepare the required strength for Cd analysis.

Sampling

To get groundwater samples, it is necessary to run hand pumps for at least five minutes to eliminate insoluble impurities and sand particles andbring depth water of required elemental amounts [15]. Water used for drinking purposes was obtained from hand pumps whose depth was 30 – 70 feet. Plastic bottles were used to collect samples of 1500 mL of water. Eight Talukas of upper Sindh were selected to get water samples from various hand pumps to draw water from the ground with a depth of 30 – 70 feet. The global positioning system method was used to collect water samples from upper Sindh. In total, 240 potable water samples were collected from eight Talukas of upper Sindh. Collected water samples were acidified with 1 mL of HNO_3 at the sampling location. Samples were transferred and placed in the dark at 4°C for Cd analysis [16].

Analytical Procedures

Atomic Absorption Spectrophotometer (Analytic Jena) was used to analyze the concentration of Cd in water samples under standard operating conditions in Pakistan Council of Research in Water Resources Islamabad, Ministry of Science and Technology, Islamabad. Triplicate water samples were analyzed for data quality assurance. Three standards of 1.25 mg/L, 2.5 mg/L, and 5.0 mg/L were analyzed after every ten samples to check the results of the instrument. At a confidence level of 95%, the reproducibility of results was observed. Thus, for results, average interpretation values were utilized. All glassware was washed with 2% HNO_3, and the chemicals used in this work were of analytical grade [17].

Health Risk Assessment for Human

Health risk assessment for humans by using contaminated drinking water by Cd was assessed through formulas for health risks such as Daily Intake of Metals (DIM) and Health Risk Indexes (HRI).

Daily Intake of Metals (DIM)

Oral ingestion plays a critical role in Cd intake in humans. However, there are different pathways through which heavy metals may be contacted to the human body, for example, oral intake, inhalation, food chain, and dermal interaction [18]. The following equation was used to calculate the DIM adapted from

$$\mathrm{DIM} = \frac{\mathrm{Cm} \times \mathrm{DIW}}{\mathrm{Bw}} \quad (1)$$

Where *Cm, Dlw and BW* are the concentration of heavy metals in water, average daily intake of water (2 L per day for adults and 1 L per day for children) [19], and average body weight (72 and 23.7 kg for adults and children, respectively) [19].

Health Risk Indexes (HRIs) of Heavy Metals

Formula (ii) given below was used to calculate HRIs of toxic metals by ingestion of water [20].

$$HTI = \frac{DIM}{RfD} \quad (2)$$

Where *DIM and RfD* are the average daily intake and toxicity oral reference dose of heavy metals. The *RfD* value of Cd is given as 0.5 µg/kg-day. The level of Cd is considered safe when HRIs are less than 1 [21].

Results and Discussion

Cadmium Contamination

Cd has no known physiological function in mammals and is one of the most lethal metals for human beings. Its exposure to humans may occur through water, food, and cigarettes inhalation. Once absorbed in the human body, Cd retains strongly all over life, having a half-life of 25 to 30 years [22].There are many industrial uses of Cd, such as plastics, batteries, coatings, alloys, pigments, and paints. For the production of alkaline batteries, most of the Cd is used as an electrode. Cd elimination occurs from industrial processes as well as from Cd smelters into groundwater, fertilizers, and sewage sludge which may stay in sediments and soils for various years and be absorbed by plants [22]. Thus, noteworthy contact of Cd to humans may be absorbed by polluted goods, particularly vegetables, fruits, grains, cereals, and polluted beverages. Moreover, Cd may be inhaled via municipal waste burning [10].

Mean concentration of Cd in different Talukas of upper Sindh was found as; Daharki (6.20 µg/L), Ubauro (7.73 µg/L), Kashmore (7.53 µg/L), Tangwani (7.73 µg/L), Garhi Khairo (6.20 µg/L), Thul 5.0 µg/L), Qambar (7.674 µg/L) and Miro Khan (7.47 µg/L). Moreover, percent contamination of each Taluka was found as, Daharki (80%), Ubauro (93%), Kashmore (93%), Tangwani (93%), Gharhi Khairo (70%), Thul (56%), Qambar (93%) and Miro Khan (93%). It can be observed from the mean results of Cd that water samples of all eight Talukas of Upper Sindh are found contaminated compared with the WHO limit of 3 µg/L (Table 1). Cd concentration in water of the different parts of the world and various parts of Pakistan can be seen in Table 2. Maximum Cd content of 170.0 µg/L was found in the water of Indonesia [30], while according to literature,the water of Germany displayed a minimum of 4.8 µg/L [35]. The highest Cd content of 251 µg/L was determined from Chiniot, Pakistan [37], while the lowest of 1.4 µg/L was observed from Multan [36].

***Table 1.* Concentration (µg/L) of cadmium in drinking water of upper Sindh.**

Sample No.	DK	UB	KM	TW	GK	TH	QB	MK
1	4	4	4	13	3	4	3	3
2	4	4	12	11	8	9	4	4
3	4	7	4	5	6	4	6	6
4	2	7	8	7	8	3	5	5
5	3	12	13	12	8	8	3	3
6	2	7	8	4	7	5	4	4
7	2	9	8	4	6	9	14	14
8	9	12	4	7	20	20	4	4
9	6	14	2	14	8	7	14	14
10	6	15	9	15	4	6	13	13
11	6	13	6	13	9	9	9	9
12	7	13	5	5	8	8	7	7
13	7	6	8	9	9	4	4	4
14	3	7	2	7	3	3	7	7
15	11	7	4	3	1	1	11	11
16	13	7	11	7	4	4	6	6
17	11	7	7	7	4	2	7	7
18	6	6	5	6	3	3	9	9
19	4	2	13	2	9	1	5	5
20	4	6	9	13	2	2	4	4
21	6	9	11	6	3	5	4	4
22	3	7	13	7	3	3	13	13
23	4	3	9	7	7	2	8	8
24	11	4	8	4	8	8	9	9
25	8	5	9	5	9	2	8	8
26	7	5	6	5	3	3	7	7
27	7	6	6	6	9	9	8	8
28	8	11	8	7	1	1	13	13
29	9	12	7	9	8	4	11	11
30	9	5	7	12	5	1	4	4
Min	2	2	2	2	1	1	3	3
Max	13	15	13	15	20	20	14	14
Mean	6.2	7.7	7.5	7.7	6.2	5.0	7.5	7.5
SD	3.0	3.5	3.1	3.6	3.7	3.9	3.5	3.5

Table 2. **Cadmium Content (μg/L) in various parts of world and Pakistan.**

Different Countries		Ref	Different parts of Pakistan		Ref
India	60.0	[23]	Ghorabari	80.0	[32]
Iran	8.36	[24]	Mardan	80.0	[33]
Germany	4.80	[25]	Vehari	10.0	[34]
Algeria	32.80	[26]	Khanewal	200.0	[35]
Lebanon	81.32	[27]	Multan	1.40	[36]
India	10.0	[28]	Chiniot	251.0	[37]
Bangladesh	7.0	[29]	Northern Sindh	10.90	[38]
Indonesia	170.0	[30]	Sijawal Junejo	25.90	[39]
Malaysia	3.43	[31]	Rato Dero	13.70	[40]

Daily Intake (DIM) of Cadmium

The Daily Intake of Cd in groundwater of study area for adults was found from all of the eight Talukas as, Daharki (0.06 - 0.36 µg/kg-day), Ubauro (0.06 - 0.42 µg/kg-day), Kashmore (0.06 - 0.36 µg/kg-day), Tangwani (0.06 - 0.42 µg/kg-day), Garhi Khairo (0.03 - 0.56 µg/kg-day), Thul (0.03 - 0.56 µg/kg-day), Qambar (0.08 - 0.39 µg/kg-day) and Miro Khan (0.08 - 0.39 µg/kg-day) (Table 3). The average daily intake of Cd in groundwater of upper Sindh was found as, 0.17, 0.21, 0.21, 0.21, 0.17, 0.14, 0.21 and 0.21 µg/kg-day from Daharki, Ubauro, Kashmore, Tangwani, Garhi Khairo, Thul, Qambar and Miro Khan, respectively (Table 3). While for children daily intake of Cd was observed as, Daharki (0.08 - 0.55 µg/kg-day), Ubauro (0.08 - 0.63 µg/kg-day), Kashmore (0.08 - 0.55 µg/kg-day), Tangwani (0.08 - 0.63 µg/kg-day), Garhi Khairo (0.04 - 0.84 µg/kg-day), Thul (0.04 - 0.84 µg/kg-day), Qambar (0.13 - 0.59 µg/kg-day) and Miro Khan (0.13 - 0.59 µg/kg-day). The average daily intake of Cd for children from upper Sindh was as under, 0.26, 0.33, 0.32, 0.33, 0.26, 0.21, 0.32 and 0.32 µg/kg-day in Talukas Daharki, Ubauro, Kashmore, Tangwani, Garhi Khairo, Thul, Qambar and Miro Khan, respectively (Table 4).

Table 3. **Daily intake of cadmium (µg/kg-day) for adults in the drinking of upper Sindh.**

Sample No.	DK	UB	KM	TW	GK	TH	QB	MK
1	0.11	0.11	0.11	0.36	0.08	0.11	0.08	0.08
2	0.11	0.11	0.33	0.31	0.22	0.25	0.11	0.11
3	0.11	0.19	0.11	0.14	0.17	0.11	0.17	0.17
4	0.06	0.19	0.22	0.19	0.22	0.08	0.14	0.14
5	0.08	0.33	0.36	0.33	0.22	0.22	0.08	0.08
6	0.06	0.19	0.22	0.11	0.19	0.14	0.11	0.11
7	0.06	0.25	0.22	0.11	0.17	0.25	0.39	0.39
8	0.25	0.33	0.11	0.19	0.56	0.56	0.11	0.11
9	0.17	0.39	0.06	0.39	0.22	0.19	0.39	0.39
10	0.17	0.42	0.25	0.42	0.11	0.17	0.36	0.36
11	0.17	0.36	0.17	0.36	0.25	0.25	0.25	0.25
12	0.19	0.36	0.14	0.14	0.22	0.22	0.19	0.19
13	0.19	0.17	0.22	0.25	0.25	0.11	0.11	0.11
14	0.08	0.19	0.06	0.19	0.08	0.08	0.19	0.19
15	0.31	0.19	0.11	0.08	0.03	0.03	0.31	0.31
16	0.36	0.19	0.31	0.19	0.11	0.11	0.17	0.17
17	0.31	0.19	0.19	0.19	0.11	0.06	0.19	0.19
18	0.17	0.17	0.14	0.17	0.08	0.08	0.25	0.25
19	0.11	0.06	0.36	0.06	0.25	0.03	0.14	0.14
20	0.11	0.17	0.25	0.36	0.06	0.06	0.11	0.11
21	0.17	0.25	0.31	0.17	0.08	0.14	0.11	0.11
22	0.08	0.19	0.36	0.19	0.08	0.08	0.36	0.36
23	0.11	0.08	0.25	0.19	0.19	0.06	0.22	0.22
24	0.31	0.11	0.22	0.11	0.22	0.22	0.25	0.25
25	0.22	0.14	0.25	0.14	0.25	0.06	0.22	0.22
26	0.19	0.14	0.17	0.14	0.08	0.08	0.19	0.19
27	0.19	0.17	0.17	0.17	0.25	0.25	0.22	0.22
28	0.22	0.31	0.22	0.19	0.03	0.03	0.36	0.36
29	0.25	0.33	0.19	0.25	0.22	0.11	0.31	0.31
30	0.25	0.14	0.19	0.33	0.14	0.03	0.11	0.11
Min:	0.06	0.06	0.06	0.06	0.03	0.03	0.08	0.08
Max:	0.36	0.42	0.36	0.42	0.56	0.56	0.39	0.39
Mean	0.17	0.21	0.21	0.21	0.17	0.14	0.21	0.21
SD	0.08	0.10	0.09	0.10	0.10	0.11	0.10	0.10

***Table 4*. Daily intake of cadmium (µg/kg-day) for children in the drinking of upper Sindh.**

Sample No.	DK	UB	KM	TW	GK	TH	QB	MK
1	0.17	0.17	0.17	0.55	0.13	0.17	0.13	0.13
2	0.17	0.17	0.51	0.46	0.34	0.38	0.17	0.17
3	0.17	0.30	0.17	0.21	0.25	0.17	0.25	0.25
4	0.08	0.30	0.34	0.30	0.34	0.13	0.21	0.21
5	0.13	0.51	0.55	0.51	0.34	0.34	0.13	0.13
6	0.08	0.30	0.34	0.17	0.30	0.21	0.17	0.17
7	0.08	0.38	0.34	0.17	0.25	0.38	0.59	0.59
8	0.38	0.51	0.17	0.30	0.84	0.84	0.17	0.17
9	0.25	0.59	0.08	0.59	0.34	0.30	0.59	0.59
10	0.25	0.63	0.38	0.63	0.17	0.25	0.55	0.55
11	0.25	0.55	0.25	0.55	0.38	0.38	0.38	0.38
12	0.30	0.55	0.21	0.21	0.34	0.34	0.30	0.30
13	0.30	0.25	0.34	0.38	0.38	0.17	0.17	0.17
14	0.13	0.30	0.08	0.30	0.13	0.13	0.30	0.30
15	0.46	0.30	0.17	0.13	0.04	0.04	0.46	0.46
16	0.55	0.30	0.46	0.30	0.17	0.17	0.25	0.25
17	0.46	0.30	0.30	0.30	0.17	0.08	0.30	0.30
18	0.25	0.25	0.21	0.25	0.13	0.13	0.38	0.38
19	0.17	0.08	0.55	0.08	0.38	0.04	0.21	0.21
20	0.17	0.25	0.38	0.55	0.08	0.08	0.17	0.17
21	0.25	0.38	0.46	0.25	0.13	0.21	0.17	0.17
22	0.13	0.30	0.55	0.30	0.13	0.13	0.55	0.55
23	0.17	0.13	0.38	0.30	0.30	0.08	0.34	0.34
24	0.46	0.17	0.34	0.17	0.34	0.34	0.38	0.38
25	0.34	0.21	0.38	0.21	0.38	0.08	0.34	0.34
26	0.30	0.21	0.25	0.21	0.13	0.13	0.30	0.30
27	0.30	0.25	0.25	0.25	0.38	0.38	0.34	0.34
28	0.34	0.46	0.34	0.30	0.04	0.04	0.55	0.55
29	0.38	0.51	0.30	0.38	0.34	0.17	0.46	0.46
30	0.38	0.21	0.30	0.51	0.21	0.04	0.17	0.17
Min:	0.08	0.08	0.08	0.08	0.04	0.04	0.13	0.13
Max:	0.55	0.63	0.55	0.63	0.84	0.84	0.59	0.59
Mean	0.26	0.33	0.32	0.33	0.26	0.21	0.32	0.32
SD	0.13	0.15	0.13	0.15	0.16	0.17	0.15	0.15

Health Risk Indexes (HRIs) of Cadmium

The range of HRI values of Cd in drinking water for adults in various Talukas of upper Sindh under study were observed as, Daharki (0.1 - 0.7), Ubauro (0.1 – 0.8), Kashmore (0.1 – 0.7), Tangwani (0.1 – 0.8), Garhi Khairo (0.2 - 1.1), Thul (0.1 - 1.1), Qambar (0.2 - 0.8) and Miro Khan (0.2 - 0.8). Two Talukas Garhi Khairo and Thul of upper Sindh showed HRI value of Cd > 1 in groundwater. All the other Talukas understudy declared the HRI value of Cd within the safe limit (Table 5).

The HRI of Cd for children in groundwater of different Talukas of upper Sindh was found as, Daharki (0.2 - 1.1), Ubauro (0.2 - 1.3), Kashmore (0.2 - 1.1), Tangwani (0.2 - 1.3), Garhi Khairo (0.1 - 1.7), Thul (0.08 - 1.7), Qambar (0.3 - 1.2) and Miro Khan (0.1 - 1.0). The mean value of HRI of Cd in groundwater of various Talukas of upper Sindh was observed as, Daharki (0.52), Ubauro (0.65), Kashmore (0.64), Tangwani (0.65), Garhi Khairo (0.52), Thul (0.42), Qambar (0.63) and Miro Khan (0.52) (Table. 5).

***Table 5*. Health risk index of cadmium in drinking water of upper Sindh.**

Sample No.	Adults								Children							
	DK	*UB*	*KM*	*TW*	*GK*	*TH*	*QB*	*MK*	*DK*	*UB*	*KM*	*TW*	*GK*	*TH*	*QB*	*MK*
1	0.2	0.2	0.2	0.7	0.2	0.2	0.2	0.7	0.3	0.3	0.3	1.1	0.3	0.3	0.3	1.0
2	0.2	0.2	0.7	0.6	0.4	0.5	0.2	0.6	0.3	0.3	1	0.9	0.7	0.8	0.3	0.9
3	0.2	0.4	0.2	0.3	0.3	0.2	0.3	0.2	0.3	0.6	0.3	0.4	0.5	0.3	0.5	0.3
4	0.1	0.4	0.4	0.4	0.4	0.2	0.3	0.2	0.2	0.6	0.7	0.6	0.7	0.3	0.4	0.3
5	0.2	0.7	0.7	0.7	0.4	0.4	0.2	0.6	0.3	1	1.1	1	0.7	0.7	0.3	0.9
6	0.1	0.4	0.4	0.2	0.4	0.3	0.2	0.2	0.2	0.6	0.7	0.3	0.6	0.4	0.3	0.3
7	0.1	0.5	0.4	0.2	0.3	0.5	0.8	0.2	0.2	0.8	0.7	0.3	0.5	0.8	1.2	0.3
8	0.5	0.7	0.2	0.4	1.1	1.1	0.2	0.2	0.8	1	0.3	0.6	1.7	1.7	0.3	0.3
9	0.3	0.8	0.1	0.8	0.4	0.4	0.8	0.3	0.5	1.2	0.2	1.2	0.7	0.6	1.2	0.4
10	0.3	0.8	0.5	0.8	0.2	0.3	0.7	0.6	0.5	1.3	0.8	1.3	0.3	0.5	1.1	0.8
11	0.3	0.7	0.3	0.7	0.5	0.5	0.5	0.3	0.5	1.1	0.5	1.1	0.8	0.8	0.8	0.4
12	0.4	0.7	0.3	0.3	0.4	0.4	0.4	0.4	0.6	1.1	0.4	0.4	0.7	0.7	0.6	0.7
13	0.4	0.3	0.4	0.5	0.5	0.2	0.2	0.3	0.6	0.5	0.7	0.8	0.8	0.3	0.3	0.5
14	0.2	0.4	0.1	0.4	0.2	0.2	0.4	0.1	0.3	0.6	0.2	0.6	0.3	0.3	0.6	0.2
15	0.6	0.4	0.2	0.2	0.1	0.1	0.6	0.2	0.9	0.6	0.3	0.3	0.1	0.1	0.9	0.3
16	**0.7**	0.4	0.6	0.4	0.2	0.2	0.3	0.4	1.1	0.6	0.9	0.6	0.3	0.3	0.5	0.6
17	0.6	0.4	0.4	0.4	0.2	0.1	0.4	0.7	0.9	0.6	0.6	0.6	0.3	0.2	0.6	1
18	0.3	0.3	0.3	0.3	0.2	0.2	0.5	0.4	0.5	0.5	0.4	0.5	0.3	0.3	0.8	0.6
19	0.2	0.1	0.7	0.1	0.5	0.1	0.3	0.4	0.3	0.2	1.1	0.2	0.8	0.1	0.4	0.6
20	0.2	0.3	0.5	0.7	0.1	0.1	0.2	0.1	0.3	0.5	0.8	1.1	0.2	0.2	0.3	0.1
21	0.3	0.5	0.6	0.3	0.2	0.3	0.2	0.2	0.5	0.8	0.9	0.5	0.3	0.4	0.3	0.3
22	0.2	0.4	0.7	0.4	0.2	0.2	0.7	0.6	0.3	0.6	1.1	0.6	0.3	0.3	1.1	0.8
23	0.2	0.2	0.5	0.4	0.4	0.1	0.4	0.3	0.3	0.3	0.8	0.6	0.6	0.2	0.7	0.5
24	0.6	0.2	0.4	0.2	0.4	0.4	0.5	0.5	0.9	0.3	0.7	0.3	0.7	0.7	0.8	0.8
25	0.4	0.3	0.5	0.3	0.5	0.1	0.4	0.4	0.7	0.4	0.8	0.4	0.8	0.2	0.7	0.6
26	0.4	0.3	0.3	0.3	0.2	0.2	0.4	0.2	0.6	0.4	0.5	0.4	0.3	0.3	0.6	0.3
27	0.4	0.3	0.3	0.3	0.5	0.5	0.4	0.1	0.6	0.5	0.5	0.5	0.8	0.8	0.7	0.2
28	0.4	0.6	0.4	0.4	0.1	0.1	0.7	0.5	0.7	0.9	0.7	0.6	0.1	0.1	1.1	0.8
29	0.5	0.7	0.4	0.5	0.4	0.2	0.6	0.3	0.8	1	0.6	0.8	0.7	0.3	0.9	0.4
30	0.5	0.3	0.4	0.7	0.3	0.1	0.2	0.2	0.8	0.4	0.6	1	0.4	0.1	0.3	0.3
Min:	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.2	0.2	0.2	0.2	0.1	0.1	0.3	0.1
Max	0.7	0.8	0.7	0.8	1.1	1.1	0.8	0.7	1.1	1.3	1.1	1.3	1.7	1.7	1.2	1.0
Mean	0.33	0.43	0.40	0.43	0.34	0.28	0.41	0.35	0.53	0.65	0.64	0.65	0.54	0.44	0.63	0.52
SD	0.16	0.20	0.17	0.20	0.19	0.21	0.19	0.18	0.25	0.30	0.27	0.31	0.32	0.33	0.30	0.26

Table 6. **Correlation of Cadmium among potable water of upper Sindh.**

Talukas	Daharki	Ubauro	Kashmore	Tangwani	Garhi Khairo	Thul	Qambar	Miro Khan
Daharki	1							
Ubauro	.065	1						
Kashmore	-.157	-.221	1					
Tangwani	-.111	0.401*	-.034	1				
Garhi Khairo	.024	0.182	-.049	-.032	1			
Thul	.012	0.442*	-.151	.119	0.755**	1		
Qambar	.120	0.409*	-.165	-.034	-.239	-.068	1	
Miro Khan	.120	0.409*	-.165	-.034	-.239	-.068	1.000**	1

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Statistical Analysis

Pearson correlation among potable water of eight Talukas of upper Sindh is shown in Table 6. A positive correlation was observed among Taluka Tangwani and Ubauro (0.401*). Cd in potable water of Taluka Thul and Ubauro also showed a positive correlation of 0.442*, whereas the Taluka Kambar and Ubauro also displayed a positive correlation of 0.409*. Taluka Thul and Garhi Khairo displayed a strong positive correlation of 0.755**. The strongest positive correlation of 1.000** was observed between Miro Khan and Qambar. All relations were observed significant at the level of 0.05 and 0.01, respectively.

Conclusion

From the present study, it can be concluded that most of the potable water samples were contaminated due to higher Cd content. About 93% of water samples of Talukas Qambar, Miro Khan, Ubauro, Kashmore, and Tangwaniwere found contaminated. HRI values of most of the samples were found greater than one, which shows that the water of the study area is unsafe for the local population. HRI was found higher for children as compared toadults. The present work shows that groundwater in the study areas is hazardous for drinking purposes and must be treated before consumption. Therefore, this study suggests that the government should provide safe drinking water by installing reverse osmosis plants where people use unsafe water for drinking and cooking purposes.

Conflict of Interest

The authors declare that there is no conflict of interest.

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