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Groundwater Arsenic Contamination and Its Health Impacts in Tando Muhammad Khan District, Sindh, Pakistan

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INFORMATION

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ABSTRACT

Present study is aimed at correlation of clinical manifestations on skin with drinking high arsenic groundwater in Tando Muhammad Khan district. A section of population is reported to be afflicted by arsenic ranging between mild to severe arsenicosis. Arsenic poisoning through skin manifestations are observed mainly in rural parts of study area. Some other clinical manifestations such as weakness, muscles cramps and gastrointestinal problems like hepatitis and stomach disorder were also observed. Total 37 sites in the whole district have been reported for the occurrence of gastroenteritis and skin related diseases out of which Taluka Tando Muhammad Khan has been found worst affected by arsenicosis. The confounder of health effects was high arsenic contents in drinking water. Some cases of hyper pigmentation and diffused melanosis were observed in Baqar Nizamani Goth of Taluka Tando Muhammad Khan. Moreover, the dominant class suffering with stomach disorder and skin irritation problem is children while next class belongs to youngsters (20-25 years old). Clinical manifestation of exposed subjects revealed keratosis development in palm and soles of both adult and children. Similarly, few cases were also suspected for black foot disease. It is concluded that residents of study area are severely affected by arsenicosis due to drinking high arsenic groundwater (10-600 ppb). Hence, a detailed study is needed to establish the clinical correlation of skin manifestations with drinking high arsenic water leading to cause cancer.

1. Introduction

Groundwater arsenic poses health problems through drinking in many parts of the world (Abdul et al., 2001). Human enzyme system is inactivated by binding through various biological ligands if arsenic is absorbed through gastrointestinal tract (Nagvi et al., 1994). Serious health hazards occur after a long period (5-15 years) by drinking arsenic contaminated water but high exposure will show reactions in a short (2.5 years) time period (Harvey et al., 2006). Dark spots are developed on the skin as a result of early symptoms which leads to hardening of the skin into nodules commonly on the palms and soles (Kazi et al., 2009). These features are typically diagnosed as hyper-pigmentation and keratosis respectively. Likewise, colorless freckled raindrop spots are known as diffuse melanosis which appears on the trunk and extremities. Advance stage of arsenical dermatitis is called keratosis which is seen by the appearance of bilateral thickening of the palms and soles. It may be with or without raised pattern (Hindmarsh, 2002). The thickening of the affected parts (palms and soles) may be painful for the subject that make walking and fetching water difficult (Yu et al., 2003). Moreover, long term arsenicosis may harm

crucially in terms of social and economic consequences which ultimately deteriorate quality of life (Safiuddin and Karim, 2001). Groundwater arsenic contamination in Indus deltaic flood plain has been reported by various workers (Naseem, 2012; Khan et al., 2014; Khan et al., 2017a; Khan et al., 2017b; Khan and Husain, 2019a; Khan and Husain, 2019b) highlighting the geogenic and anthropogenic factors responsible for releasing arsenic from its natural host (sediments). The whole district is affected by groundwater arsenic contamination but severity is more intense in Tando Muhammad Khan Taluka which lies near Indus River including oxbow lakes. These natural water bodies are enriched in organic matter which is fresh, young and reactive. A cluster of arsenic contaminated wells occurs in the proximity of Indus River where many oxbow lakes and meander scars are located suggesting strong control of geomorphic features in groundwater arsenic contamination. It was also noticed that no linear relationship between arsenic concentration and spatial variation exist. Two nearby wells have drastically changed concentration of arsenic which suggests patchy distribution of this element in the whole study area. Surface derived organic matter from sewage and other sources (pit latrines, ponds, and free roaming animal feces) are also triggering the release of arsenic from its source. It is evident by the concomitant occurrence of high arsenic groundwater with sewage derived bacteria in 28% and 20% samples from Bhulri Shah Karim and Tando Muhammad Khan Taluka, respectively (Khan and Husain 2019a). Various natural and anthropogenic factors analyzed during the field in the present study includes seasonal fluctuation in water table, low hydraulic gradient, land use pattern, patchy distribution (small scale redox zonation), over extraction, flood irrigation, poor drainage, waste water ponds, canals and unlined sewage disposal. All these factors worked in combination to mobilize arsenic from surface sediments and transported to well depths through aquifers. The role of multiple factors is reflected by weak relationship between arsenic and physicochemical parameters.

However, clinical correlation between high arsenic drinking water and its health impacts in Indus deltaic flood plain has not been carried out so far. Hence, present study is aimed at correlation of clinical manifestations on skin with high arsenic groundwater in Tando Muhammad Khan district.

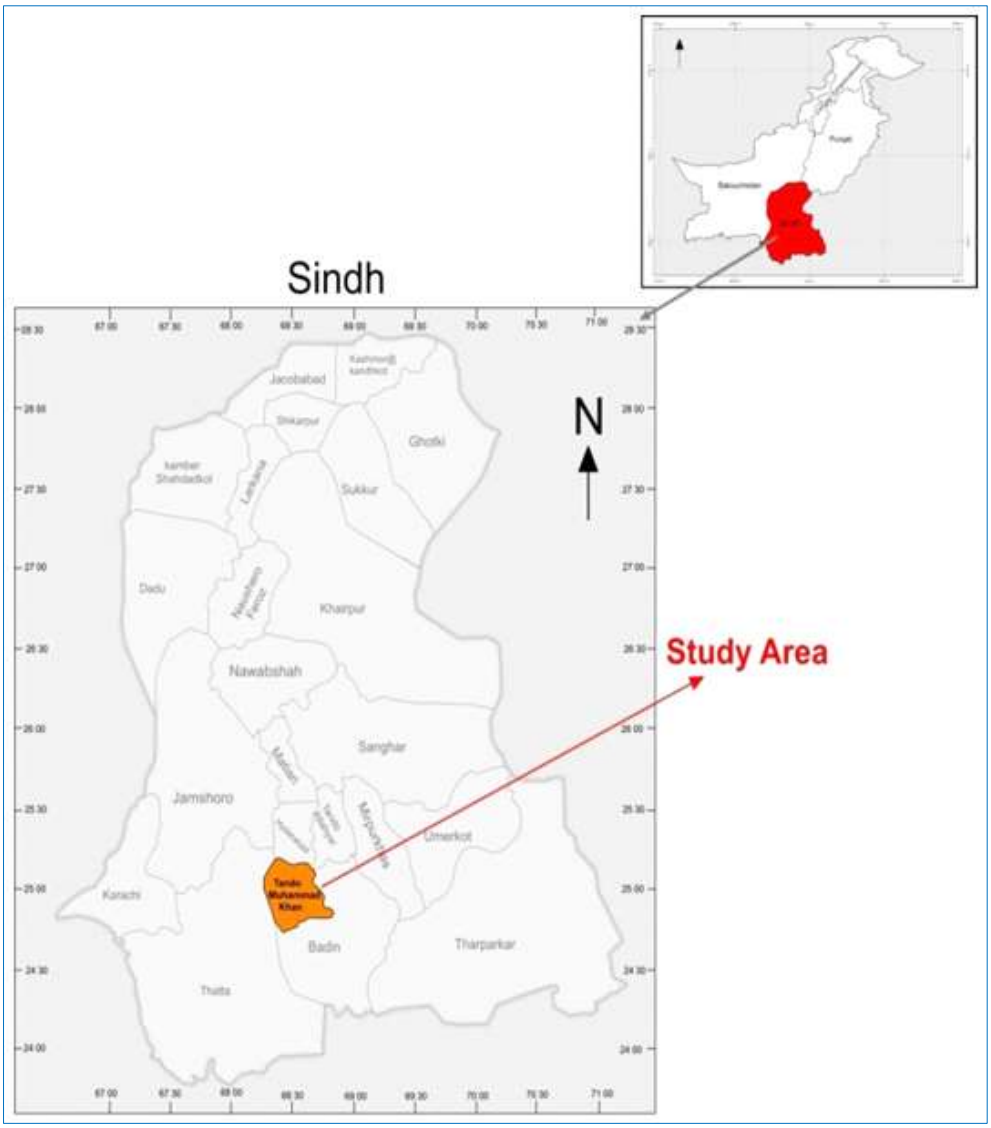

Fig. 1. Location of the study area

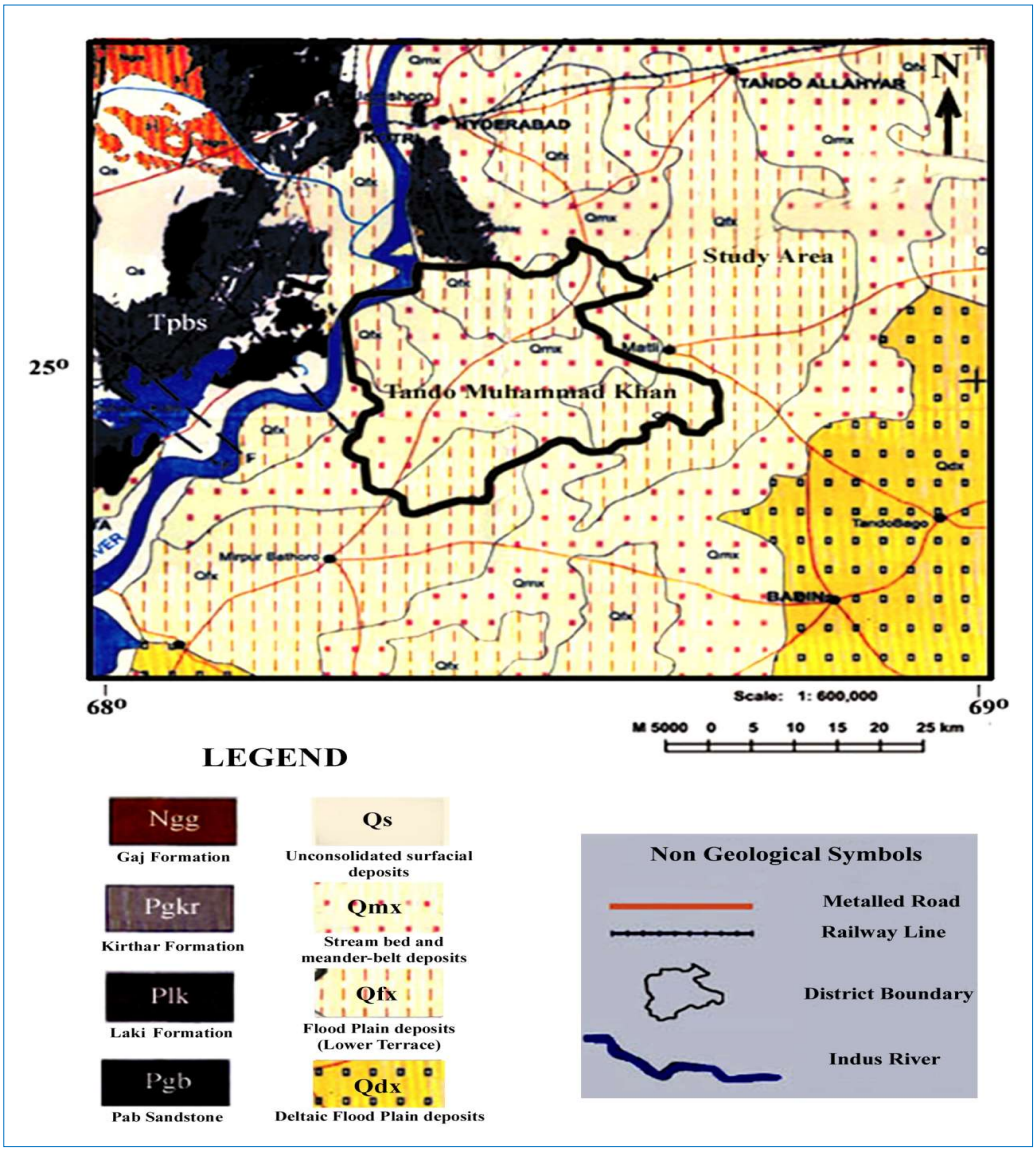

Fig. 2 Geology of Tando Muhammad Khan district (after Akhtar et al., 2012)

2. Materials and Methods

2.1. Study area

Tando Muhammad Khan district lies in the south west of Sindh province about 35 km from Hyderabad on Badin-Hyderabad national highway between 68°15'E-68°45'E longitudes and 25°00'N-25°30'N latitudes, covering an area of 2600 sq. km (Fig. 1). This district comprises of three talukas viz. Tando Ghulam Hyder, Bulri Shah Karim and Tando Muhammad Khan. Central municipal sewerage treatment systems do not exist in the study area. Municipal waste water is generally drained in canals, sewage ponds or low-lying areas. Climate of this area is semi-arid subtropical with an average rainfall of about 220 cm. study area enjoys the average humidity of about 76% with mean annual temperature of 84.2 °F (Kureshy, 1977; Haq, 1999; Memon, 2005). Except cyclic flood season, rainfall does not exceed 260 mm. Diurnal temperature variation may be as low as 10.5 °C while maximum difference may reach up to 17.0 °C. Semi-arid climate and scarce rainfall in Tando Muhammad Khan district have constrained the irrigation system to switch from surface water source to groundwater.

Winter season remains cold with the lowest annual temperature of about 6 °C in the month of January. Likewise, average monthly temperature of adjoining areas ranges between 18.2 °C (in January) to 33.6 °C (in May). The high temperature period starts from March and continues up to June. On the other hand, duration of December to February is cold. The relative humidity is low but increases when sea breezes are at their peak. Monsoon season stretches between July to mid-September (Memon, 2005). Agricultural development is constrained by high temperature, low rainfall and low humidity which is common throughout the province and affecting the irrigation system. However, still climate is favorable for a variety of crops (sugarcane, wheat, rice, cotton, mango and banana plantations, vegetables and oil seeds) in the irrigated areas.

Tando Muhammad Khan district occupies arable land which rest on huge quantities of alluvium (up to the depth of more than 200 meters) deposited by Indus River and many of its tributaries during the Holocene time (Chauhan and Almeida, 1993; Kazmi and Jan, 1997; Ansari and Vink 2007). Tertiary

rocks occur in subsurface and exposed on the western margin of study area while Quaternary deposit has covered the central and eastern parts of Lower Indus Basin (Fig. 2).

2.2. Sample collection and analysis

The sampling of groundwater was carried out at the onset of dry season. About 212 groundwater samples were collected which have been discussed by Khan et al., 2014; Khan et al., 2017a; Khan et al., 2017b; Khan and Husain, 2019; Khan et al., 2019. Out of these 212, only 37 groundwater samples have been discussed in present study. These samples have been selected on the basis of sites where clinical manifestations have been observed by drinking high arsenic water.

Field studies included the collection of groundwater samples from wells at a depth range of 4.6-61 meters. The water samples were collected from hand pump wells, tube wells and boring wells after pumping for at least 5-10 minutes to get representative samples of the groundwater. Water samples were not filtered so that accurate value of arsenic could be obtained as that would be consumed by well users. Location of the wells was marked with the Global Positioning System (GPS) on the topographic survey sheet. Groundwater samples were collected in plastic bottles (0.5- and 1-liter capacity) for physico-chemical analysis. These bottles were washed properly and rinsed thoroughly with deionized water and then with the groundwater. Electrical conductivity, temperature and pH were measured immediately after sampling at each site using a portable meter. Arsenic concentration in groundwater was determined at each site using Merk field testing kit (Cat No. 1.17926.0001, Germany, 0.01-0.5 mg/l). The concentration of arsenic was measured by visual comparison of the reaction zone of analytical test strip with the fields of color scale. This method gives semi-quantitative estimation of arsenic which was confirmed by checking 10% of the total collected samples on Perkin-Elmer A Analyst 600 Graphite Furnace Atomic Absorption Spectrophotometer. The electrical conductivity and total dissolved solids (TDS) of collected groundwater samples (n = 37) were measured with EC meter (Eutech Cyber Scan CON II).

Survey for arsenic affected areas was carried out using the data of high arsenic groundwater in boring/ hand pump wells installed in all villages and semi urban parts of study area. Human subjects were screened for skin manifestations of suspected arsenicosis using visual observations. All the subjects showing skin manifestations were interviewed. A detailed inventory of manifestation type, age, gender, groundwater arsenic in corresponding well and TDS content was prepared.

3. Results and Discussion

This study reports many cases of arsenic affected people ranging is severity between mild to severe arsenicosis in Tando Muhammad Khan District, Sindh. Arsenic poisoning through skin manifestations were observed mainly in rural parts of study area. Some other clinical manifestations such as weakness, muscles cramps and gastrointestinal problems like hepatitis and stomach disorder were also observed. Taluka wise clinical manifestations and the associated factors have been summarized in Tables 1-3. Total 37 sites in the whole district have been reported for the occurrence of gastroenteritis and skin related diseases out of which Taluka Tando Muhammad Khan has been found worst affected by arsenicosis. The confounder of health effects was high arsenic contents in drinking water. Some cases of hyper pigmentation and diffused melanosis were observed in Baqar Nizamani Goth of Tando Muhammad Khan Taluka (Fig. 3a and b) which is also reported by Arain et al. (2009) near Manchar Lake, Sindh. Moreover, the dominant class suffering with stomach disorder and skin irritation problem is children while next class belongs to youngsters (20-25 years old). It may be due to the fact that women and children are more vulnerable due to their low immune system. Low immunity is related to under-nourishment which may exacerbate arsenic toxicity.

During health survey of Tando Muhammad Khan district, the affected public was found unaware about health impacts of drinking arsenic contaminated water for long time. It can be explained by the social status of the villagers which is influenced by poverty, illiteracy and ignorance for sanitation. Clinical manifestation of exposed subjects revealed keratosis development in palm and soles of both adult and children (Figs. 4a and b). Similarly, few cases were also suspected for black foot disease (Fig. 5b) which needs to be confirmed by epidemiological investigation in study area. Black foot disease has been reported from Taiwan due to drinking arsenic contaminated groundwater (Lu, 1990; Liao and Ling, 2003; Chen et al., 2001; Lin et al., 2001).

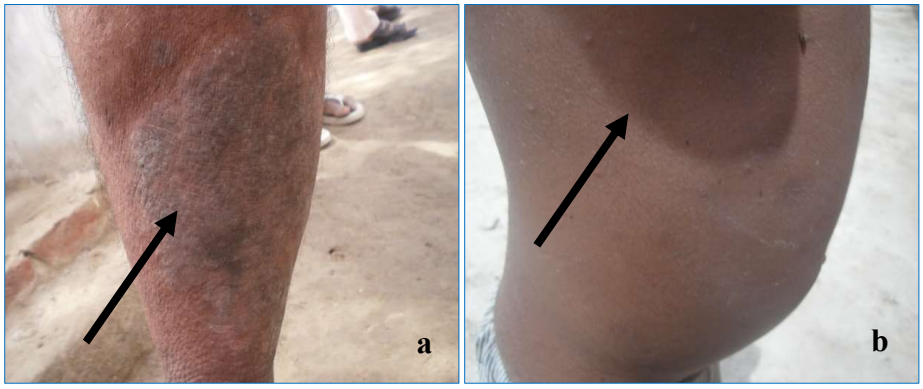

Fig. 3. Showing (a) hyper pigmentation in legs and (b) diffused melanosis on trunk

Fig. 4. Showing keratosis (a) palms and (b) soles

Fig. 5. Showing (a) de-pigmentation on face and (b) black foot disease

Fig. 6. Poor drainage causing groundwater contamination in study area

Generally, these health issues are concerned with areas located in depressions where stagnant sewage water or waste water near hand pump wells (due to poor drainage) seeps into the ground (Fig. 6) and contaminate the same groundwater.

Moreover, the role of land use cannot be neglected in the prevalence of stomach or arsenic related diseases. The localities of Tando Muhammad Khan and Bhulri Shah Karim Talukas are influenced by sewage water drained in ponds and lakes, sugar mill waste disposal and oil field site. On the other hand, Tando Ghulam Hyder Taluka is less affected by health issues due to thin population, scarce cultivation and lack of industries. Detailed studies of arsenic-induced cancers in afflicted parts of Sindh province including Tando Muhammad Khan district have not been conducted to date. Arsenic-induced skin and internal cancers are reported from Taiwan where people are exposed to this ailment far longer than Bangladesh.

It is expected that persistence of present concentrations of arsenic (10-600 µg/L) in the wells of Tando Muhammad Khan district (Khan and Husain, 2019a) may lead to substantial occurrences of arsenic-induced cancers. The knowledge of as (arsenic) exposure and related health effects will help in estimation of health hazard and prevention of as poisoning in the future among the resident in areas of endemic as poisoning and also among the workers occupationally exposed to as (Chowdhury et al., 2001; Yoshida et al., 2004).

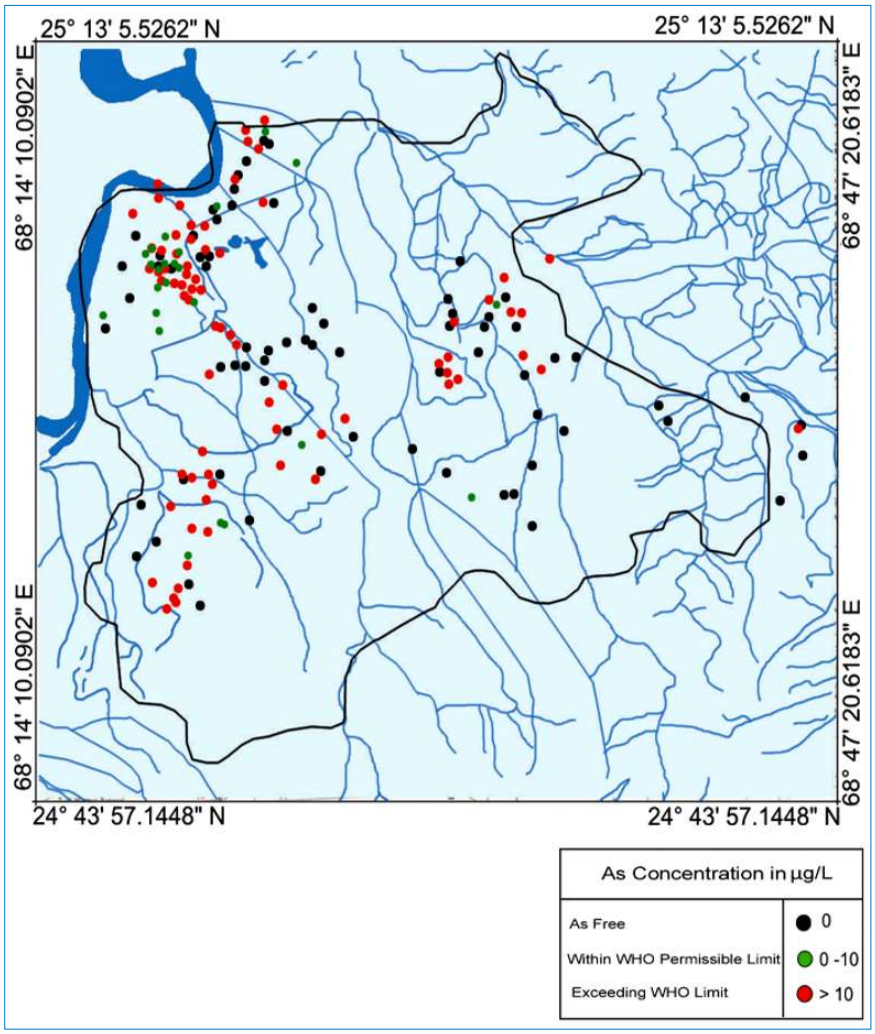

Fig. 7. Arsenic distribution in the groundwater of Tando Muhammad Khan district, Sindh, Pakistan

3.1. Arsenic distribution in groundwater

Tando Muhammad Khan district is among the greatest incidence of as contamination in Sindh (Husain, 2009) like other parts of the world (Smedley and Kinniburgh, 2002; Garcia-Sanchez and Alvarez-Ayuso, 2003). Arsenic pollution occurs throughout the study area but its poisoning is more alarming on the western part of Tando Muhammad Khan district near Indus River (Khan, 2014). Total 212 groundwater samples were collected from shallow hand pump wells and tube wells from three talukas of Tando Muhammad Khan district by Khan (2014). Out of which, 99 samples show elevated arsenic concentration in the range of 10-600 µg/L (Fig. 7).

3.2. Taluka wise descriptions of arsenic and other diseases

3.2.1. Tando Muhammad Khan Taluka

Large number of patients is reported from Tando Muhammad Khan Taluka suffering from arsenic induced and other diseases (Table 1) as compared to other sites of study areas. It is consistent with the occurrence of large number of arsenic contaminated wells (n = 67) from Tando Muhammad Khan Taluka as compared to Bhulri Shah Karim (n = 25) and Tando Ghulam Hyder Taluka (n = 7) as described by Khan et al. (2014), Khan et al. (2017a), Khan et al. (2017b) and Khan and Husain (2019). It suggests that health issues are more pronounced in those areas where arsenic in groundwater is more prevalent. Twenty-four sites have been reported for the prevalence of gastro and skin related diseases in Tando Muhammad Khan Taluka which is the densest populated and semi-urban Taluka (Table 1). Fourteen of these well sites (n = 24) are those where skin irritation problem is common both in children and adults. The well depths of these health impacted sites are very shallow (9-23 m) where arsenic concentration ranges between 10-100 µg/L. However, one site has relatively deep aquifer where tube well is installed at 55 meters and the

arsenic is found to be 100 µg/L. Those parts of Tando Muhammad Khan Taluka where skin and stomach problems (diarrhea, dysentery and hepatitis) prevail, arsenic content in the groundwater ranges between 5-250 µg/L. It seems to be partly controlled by unlined sanitation which is due to dense population and extensive human settlements (Wilson,1981; Foster and Chilton, 2003; Morris et al., 2005; Naik et al., 2008; McArthur et al., 2001; Acharyya et al., 2000).

On the other hand, six aquifer sites are those where skin irritation is recorded in adults. These six sites have shallow aquifers (9-25 m) where a wide range of arsenic (40-250 µg/L) is found in the groundwater. This can be attributed to visit of farmers to the fields of sugarcane and/or paddy crop where they work whole day and drink saline water (TDS: 668-2451 mg/L). Interestingly, sites with skin problem (both in children and adults) are those where oxbow lake or sugar mill occurs. Besides, sewage water is drained in depression areas near the villages. A sympathetic relationship occurs between gastro related diseases (e.g., Hepatitis, Diarrhea and dysentery) and arsenic contents that varies between 5-250 µg/L (Table 1).

Table 1. Relationship between prevalent diseases/disorders and arsenic in Tando Muhammad Khan Taluka

No	Sample Code	Well depth (m)	As (µg/l)	TDS (mg/l)	Disease/Disorder	Remarks
1	TMK-1	13.71	150	774	Skin irritation common in adults	Mango orchard
2	TMK-2	24.38	150	1491	Skin irritation common in adults	Sugarcane cropped field
3	TMK-3	21.33	60	2451	Skin irritation common adults	Sugarcane field
4	TMK-4	21.33	30	2458	Skin irritation and lesion, common both in children and adults	Sewage water is drained in depression near the village
5	TMK-5	12.19	20	1229	Skin irritation and lesion, common both in children and adults	Canal Branch present, Sewage water is drained in depression near the village
6	TMK-6	15.24	*BDL	1946	Skin irritation common in adults	Paddy cropped field
7	TMK-7	22.86	*BDL	469	Skin irritation common both in children and adults	Paddy cropped field; Sugar Mill present
8	TMK-8	15.24	*BDL	731	Skin irritation common both in children and elders	Smell in groundwater reported
9	TMK-9	19.81	20	762	Gastro problem prevalent both in children and adults	Sewage water is drained in depression near the village
10	TMK-10	13.71	10	1651	Gastro and skin irritation problem both in children and adults	Wheat field, Sewage water is drained in depression near the village
11	TMK-11	15.24	250	683	Diarrhea, (dysentery in children) cough and skin irritation/lesion common	Sewage water is drained in depression near the village
12	TMK-12	15.24	40	639	Gastro, skin irritation and lesion problem both in children and adults	Groundwater with yellow color, causing problem in cooking
13	TMK-13	15.84	20	848	Gastro, skin irritation and lesion problem both in children and adults	Sewage water is drained in depression near the village
14	TMK-14	9.14	40	668	Skin lesion common in adults	Paddy and sugarcane cropped area
15	TMK-15	6.09	5	1433	Skin and Gastro problem prevalent	Sewage water is drained in depression near the village
16	TMK-16	12.19	*BDL	1683	Skin irritation common children and adults	Sewage water is drained in depression near the village
17	TMK-17	15.24	60	883	Skin irritation common in children and adults	Sewage water is drained in depression near the village
18	TMK-18	54.86	100	1894	Skin irritation common children and adults	Groundwater sample collected from tube well
19	TMK-19	10.66	5	737	Skin irritation common in children and adults	Groundwater is recharged by recent floods of 2011
20	TMK-20	12.19	25	700	Skin irritation common in children and adults	Sugarcane cropped field
21	TMK-21	18.28	250	694	Skin irritation (mainly adults) and Gastro problem	Paddy and sugarcane cropped area
22	TMK-22	7.62	5	708	Gastro and skin irritation problem	Sewage water is drained in depression near the village
23	TMK-23	13.71	*BDL	593	Skin irritation common in children and adults	Kolab Lake present near village
24	TMK-24	9.14	*BDL	720	Skin lesion common in children and adults	Oxbow Lake present near village

*Note: *BDL: Below Detection Limit*

These seven sites are those where sewage water is drained in depressed areas at shallow (7-19 m) screening depth. Water borne diseases including diarrhea, nausea, gastroenteritis, typhoid, dysentery is mainly related with pathogens (microbes) occurring in groundwater by sewage mixing (PCRWR, 2005; Shar et al., 2008). The children and person with low immune system are more vulnerable for the exposure of these water borne diseases (PCRWR, 2005).

3.2.2. Bhulri Shah Karim Taluka

The prevalence of stomach disorder, hepatitis C, skin irritation and skin lesions are quite frequent in Bhulri Shah Karim Taluka. Two sampling sites, which occur near Indus River or city area, show skin irritation and hepatitis only in children. However, other nine sites are reported for the prevalence of these diseases both in children and adults (Table 2). Further, the arsenic concentration in groundwater of these health impacted areas ranges between 5-250 µg/L and almost all the samples are very high in TDS content where arsenicosis/hepatitis is reported (Table 2). The occurrence of oxbow lake and sewage water ponds seem responsible for high TDS content in the groundwater.

3.2.3. Tando Ghulam Hyder

Skin irritation and gastro related diseases are relatively less common in Tando Ghulam Hyder Taluka as compared to other two areas. It may be due to thin population in Tando Ghulam Hyder Taluka. Moreover, this part of study area is away from surface water bodies (river and canals) which are polluted and increase groundwater contamination through inter mixing. Sample TMK-104 is fresh water containing elevated arsenic content (30 µg/L) while other sample (TMK-208) collected at very shallow depth (5 m) show nil arsenic but high salinity (Table 3). Both these wells are installed near canal suggesting that pollution is induced from the surface water body (Azizullah et al., 2011) due to hydraulic connection with shallow aquifer (Nickson et al., 2004).

Table 2. Relationship between prevalent diseases/disorders and arsenic in Bhulri Shah Karim Taluka

No	Sample Code	Well depth (m)	As (µg/L)	TDS (mg/L)	Disease/Disorder	Remarks
1	TMK-25	21.33	*BDL	2208	Skin lesion common both in children and adults	Canal present near the well site
2	TMK-26	10.66	5	1160	Skin lesion common both in children and adults	Canal present near the well site
3	TMK-27	13.71	*BDL	1266	Skin irritation and lesion, common in children	Indus river present near village
4	TMK-28	15.24	*BDL	3411	Hepatitis, skin irritation and lesion (20-25 years old)	Sugarcane cropped field
5	TMK-29	10.66	150	3104	Hepatitis C, skin irritation common in children	City area
6	TMK-30	6.7	*BDL	881	Skin irritation common in both children and adults	OGDCL oil field present which has changed the groundwater quality after its installation
7	TMK-31	18.28	250	1574	Skin irritation and lesion common both in children and adults	Semi-urban area with channeled sewerage lines drained into nearby ponds and ditches
8	TMK-32	12.19	200	746	Skin irritation and lesion common both in children and adults	Sugar Mill present near well site
9	TMK-33	15.24	*BDL	1862	Skin irritation common both in children and adults	Seam Nala present near the well site
10	TMK-34	6.62	*BDL	5312	Skin irritation and Hepatitis both in children and adults	Unlined sanitation common
11	TMK-35	9.14	25	737	Skin problem prevalent both in children and adults	Oxbow lake occurs where sewage water is dumped due to lack of available sanitation facility

*Note: *BDL: Below Detection Limit*

Table 3. Relationship between diseases and As in Tando Ghulam Hyder Taluka

No	Sample Code	Well depth (m)	As µg/L	TDS mg/L	Disease/Disorder	Remarks
1	TMK-36	9	30	482	Gastro problem, hepatitis, skin irritation, tongue cancer	Canal present near the well site
2	TMK-37	5	*BDL	876	Skin irritation in children	Canal present near the well site

3.3. Mitigation Options

It is essential to remediate arsenic contaminated groundwater for providing healthy drinking water to public. A large number of treatment methods have been devised to remove arsenic from groundwater for drinking purpose. These include coagulation, flocculation, sedimentation, filtration, adsorption, chemical precipitation, membrane separation, and anion exchange (Shen, 1973; Gupta and Cheng, 1978; Cheng et al., 1998; Bhattacharya et al., 1997; Wang et al., 2009). However, in developing countries like Pakistan it is not possible to introduce such technologies due to the fact that water problem is mainly confined to rural areas where affordability is the main concern due to low income.

Moreover, applications of these methods are limited due to high cost of material, high energy requirements, generation of sludge and disposal constraints. Tando Muhammad Khan district revealed the occurrence of high arsenic (10-600 µg/L) in groundwater (Khan and Husain, 2019a) which induced health problems through drinking. It is therefore necessary to adopt mitigation options on urgent basis to cope with the current situation. Following are the suggested mitigation options which can be adopted to get rid of arsenic calamity at local level.

- All the groundwater wells with as concentration > 10µg/L must be abandoned and should be painted red.
- Arsenic free wells or with concentration < 10 µg/L should be painted green.
- Public should be informed to use wells with green paint and discourage water withdrawal from the red painted wells.
- Arsenic disaster can be alleviated by adopting rainwater harvesting.
- Solar oxidation technique should be introduced because one third of total arsenic concentrations occurring in the groundwater can be removed through this simple method which is a viable solution in low-income areas like Tando Muhammad Khan district.
- Government should provide specific drugs for helping recovery and/or averting disease progression caused by arsenic ingestion.
- Symptomatic and supportive treatment should be given to reduce the increasing severity of arsenic affected patients.
- A clinical survey should be carried out under the supervision of epidemiologists and nutritionists to collect data about health status and prevalence of arsenic borne diseases.

- Arsenic free wells should be monitored regularly in order to make sure the availability of arsenic safe water in future.
- Future groundwater should be exploited at deeper aquifers (> 150 m) which are usually rich in dissolved oxygen and lack organic matter occurrence (Kohnhorst, 2005; Islam and Bernuth, 2005).
- Mass awareness about the severity and consequences of drinking high as groundwater should be made through posters, banners and media (print and electronic) campaigns.
- Proper sewage disposal system should also be introduced in order to minimize the impact of sewage on arsenic release into the groundwater.
- Early detection of arsenic induced skin and bladder cancer is easily cured. Surveillance program should be made to register arsenic induced cancer in those areas where chronic as is reported in order to prevent cancer related deaths.
- Research group comprising geologists, hydrogeologists, geochemist, public health experts, water supply and environmental engineers should be established to carry out detailed investigation on the sources and causes of arsenic contamination in groundwater.
- A national groundwater resource management policy should be established in order to limit the indiscriminate abstraction of groundwater.
- A regulatory body should be made which should check the well being drilled for arsenic occurrence and then permit or inhibit for its installation and commissioning.
- Canals and their minors also contribute a part of contaminants to local groundwater. Side walls and channel base of these water bodies should be cemented to inhibit hydraulic connection with aquifers.

Arsenic removal plant should be installed which must be connected with groundwater and be supplied through piped based water system. It is possible if technical and scientific community work positively with large international organizations such as World Bank, UNICEF and WHO which have sufficient capital to use for mitigation.

4. Conclusion

It is concluded that whole district is badly affected by groundwater arsenic contamination where the toxicity is more prevalent in semi-urban parts of Tando Muhammad Khan district. Residents are affected by the arsenicosis using high arsenic groundwater for drinking. Morbidity stage is early to mild arsenicosis which may advance to cancer in next few years if the arsenic contaminated water is continuously consumed by the affected community in study area. A detailed epidemiological study is needed to clinically correlate the ingestion of arsenic through drinking groundwater with symptomatic skin manifestations of arsenicosis.

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