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# Contaminants Exposure and Impacts on Drinking Water of Johi Subdivision of Sindh, Pakistan

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**Abstract**
This study was conducted in the area of Taluka Johi, district Dadu, Sindh, Pakistan and 46 drinking water samples were collected from hand pumps. In the present study, different physicochemical parameters, including pH, electric conductance (EC), total dissolved solids (TDS), turbidity and arsenic level, microbial parameter such as *Escherichia coli* colony forming units (CFU) and health quotient of dermal, chronic and carcinogenic risks were determined. The physicochemical characteristics results varied within the ranges, pH 7.4-8.4, EC 1160-7125 µS/cm, TDS 743-4560 mg/l, turbidity 1.6-34 nephelometric turbidity unit (NTU) and arsenic 0-250 ppb, and microbial characteristic revealed 0-100 CFU/100ml *E. coli* bacterial colonies. Health quotient (HQ) (chronic) irrespective to 15 kg and 70 kg bodyweight was found more than the normal limit and HQ (carcinogenic) was also observed more than the limit from the identified arsenic contaminated water samples which shows the seriousness of the contamination level and its health impacts on local residents of Johi, Sindh, Pakistan.
**Keywords** Carcinogenic, drinking water, exposure, health quotient, Johi, Sindh.

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## Introduction

The most important basic necessity for the human life is water. Groundwater is an important source of drinking water throughout the world and currently, the quality of ground water is most commonly affected by chemical and microbial contamination [1, 2]. The main source of drinking water in Pakistan is ground water. In Sindh province of Pakistan, most of the people consume water without filtration or water-treatment so it poses serious concerns to the residents such as water-based diseases. Access to safe drinking water is the basic right of humans and also a basic need for good health. Chemical and microbial contaminants are the main factors responsible alone or in combination for several public health issues. The physicochemical and microbial characteristics represent the quality of drinking water [3, 4]. The main physicochemical parameters that affect the water quality are pH, turbidity, dissolved oxygen, temperature, total dissolved salts, alkalinity, etc. [5]. The major sources of microbial contamination are microorganisms from human or animal excreta, which reach humans through contaminated groundwater from wastewater, landfills, or waste water treatment stations, causing serious health problems. In Pakistan, bacterial contamination has been considered a major drinking water problem [6].

Arsenic has been identified in ground water sources of a number of countries and they are facing human health hazards due to the consumption of arsenic contaminated drinking water [7, 8]. In Sindh province of Pakistan, around 36% of the population has been exposed to arsenic contamination above World Health Organization (WHO) limits [9]. In recent investigations, groundwater arsenic concentration has reached up to 1100 µg/l in the province of Sindh, which is much higher than WHO limits of 10 µg/l [10]. A total of 37% water samples were positive for more than 50 µg/L of arsenic and 15% samples were positive for very high level of 250 µg/L of arsenic in underground water of Matiari and Khairpur districts [11]. Arsenic contaminated drinking water is one of the major causes of arsenicosis. Arsenicosis is the effect of arsenic poisoning, usually over a long period, such as from 5 to 20 years. The ingestion of arsenic contaminated drinking water can cause serious health issues, including melanosis, cancer, hyperkeratosis, gangrene, restrictive lung disease, hypertension and

peripheral vascular disease [12, 13], carcinogenic effect on lungs and skin [14] as well as skin lesions [15]. The presence of arsenic in drinking water has been used to evaluate potential health risk assessment: chronic and carcinogenic effects like hazard quotient (HQ), average daily dose (ADD) and carcinogenic risk (CR) [16, 17]. The objectives of the present study were to analyze physico-chemical and biological parameters of drinking water samples collected from Johi Tehsil, Dadu District, Sindh, Pakistan to assess health risk of exposure of arsenic via oral ingestion and absorption through the skin.

## Materials and methods

### Study area

The present study was conducted in Johi (Taluka / Tehsil / sub-district / administrative subdivision), district Dadu, Sindh province of Pakistan. The area of Taluka Johi is 3509 km², situated at 26°41′ N (latitude) and 67°36′ E (longitude), population 16311 according to the Geo Names geographical database.

### Water sampling and storage

The sampling network was planned to cover a wide range of determinants of the whole Tehsil. In the present study, 46 water samples were collected from hand pumps. The water samples were collected by using sterilized Van Dorn plastic bottles (1.5 L capacity) and were reserved in well-stoppered polyethylene plastic bottles earlier soaked in 10% $HNO_3$ for 24 h and rinsed with ultrapure water. All water samples were kept in insulated coolers containing ice and delivered on the same sampling day to the laboratory for examination.

### Water analysis

Appearance, color and odor were identified by the senses. Electric conductance (EC), total dissolved salts/solids (TDS) and pH were determined by the conductivity (Orion 115) and pH meter (Hanna Instruments), respectively. Turbidity was measured by turbidity meter (Model: PC Chekit Lovibond Germany), which showed clearness of water. A portable water testing kit (DelAgua Kit) was used to check the contamination of water by the detection of *Escherichia coli.* Briefly, each water sample of 100 ml passed through a filtration membrane (Millipore) with 0.45 µm pore size and 47 mm diameter. The bacteria present in the water sample retained on the surface of filtration membrane. Membrane lauryl sulfate broth (MLSB) was used as medium for bacterial growth and was poured on absorbent pads and then filtered membrane was placed on absorbent pads in petri plates. The plates were incubated at 44°C in the kit's incubator for the 18 hours. After the incubation period, yellowish *E. coli* colonies were counted and the results were expressed as colony-forming units per 100 ml of water (CFU/100ml).

Arsenic was determined by HACH Arsenic kit (EZ arsenic test kit 2822800) Hach Company USA for 0.01-0.5 mg/L. This test generates arsenic hydride, which reacts with the mercury bromide present in the analytical strip to form a yellow-brown miscellaneous arsenic mercury halogenide. The concentration of arsenic was analyzed through visual assessment of the reaction region of the analytical test strip with scales of fields of color [18].

### Exposure and risk assessment

Equation 1, adapted from the US Environmental Protection Agency [19] was used to calculate the chronic daily intake (CDI, µg/kg/d).

$$CDI = C \times DI / BW \quad \text{eq. 1}$$

Where
C = Contaminant concentration (ppb)
DI = Daily intake of drinking water (L/day)
BW = Body weight (kg)

The HQ for non-carcinogenic (chronic) risk can be calculated by the following equation 2 [20].

$$HQ = CDI / RfD \quad \text{eq. 2}$$

Where according to US EPA, the oral toxicity RfD value is 0.0003 mg/kg/day for arsenic [21].

Cancer hazard (HQ carcinogenic) linked to intake contact was calculated by means of the subsequent formula [22]:

$$R = CDI \times SF \quad \text{eq. 3}$$

R = Surplus possibility of upward cancer overall lifetime as a consequence of contact to a contaminant (or carcinogenic risk)
SF = 1500 µg/kg for arsenic.

According to the US EPA risk (R) standards, larger than one in a million ($10^{-6}$) are normally considered intolerable. On the other hand, along with national standards and environmental policies this acceptable level could change and possibly as elevated as $10^{-4}$ [23, 24, 25]. The SF and RfD standards engaged in this learning were obtained from IRIS [26]. When the HQ values are >1 the health risk is generally occurs [27].
The Eq. 4 adapted from the US Environmental Protection Agency [28, 29, 30] was used to calculate the chronic daily intake through dermal absorption pathways [31].

$$CDI\ (dermal) = CW \times SA \times Kp \times ABS \times ET \times EF \times ED \times CF / BW \times AT \quad \text{eq. 4}$$

**Table 1** Different parameters used to calculate the chronic daily intake (CDI).

| Parameters | Units | Values | References |
|---|---|---|---|
| Concentration of trace metals in water (CW) | µg/L | 0-250 | This study |
| Body weight (BW) | Kg | 70 | [31] |
| Exposure frequency (EF) | Events/year | 365 | [30] |
| Average time (AT) | Days | 25,550 | [31] |
| Skin-surface area (SA) | $cm^2$ | 18000 | [31] |
| Conversion factor (CF) | $L/cm^3$ | 1/1,000 | [30] |
| Permeability coefficient (Kp) | cm/hr | 1.00E-3 (As) | [31] |
| Dermal absorption factor (ABS) | - | 0.03 (As) | [32] |
| Exposure Time (ET) | - | 1 | [31] |
| Exposure Duration (ED) | - | 70 | [31] |

## Results and discussion

### Physical parameters

#### *Color, taste and smell*

Pure water is colorless, odorless and tasteless. Drinking water must have an acceptable taste and have an appropriate temperature and free of harmful microbes. Descriptive statistics of all 8 parameters of 46 water samples collected from Taluka Johi are shown in the Table 2. In the present study, all water samples were colorless and odorless due to the ground nature of water samples and depth of boring. All water samples were saline. It may due to the naturally occurring salt contents. The physical parameters observed in this study were in conformity with the results of a previous study in which ground water samples were observed colorless, odorless but were slightly saline [33]. The drinking water for human consumption should be colorless, odorless and tasteless, according to the WHO standards for drinking water.

#### *pH*

The pH of water shows the acidic or alkaline nature of water. The pH value of all water samples was found within the WHO limit which is 6.5 to 8.5. The results of the present study showed that all water samples were slightly alkaline to moderately alkaline and within the permissible limit. The highest pH was 8.4 and the lowest was 7.4.

#### *Electric conductance*

Electric conductance (EC) of water is a measurement of the amount of salts dissolved in water and thus EC indicates concentration of total dissolved solids that makes water conductor of heat. The normal WHO value of electric conductance is 1562 µS/cm. In this study, 96% of the water samples showed an EC level above the normal range and the rest of the samples were within permissible limits. The maximum EC value was 7125 µS/cm and minimum was 1160 µS/cm. The results indicate that drinking water samples were highly ionized due to excessive dissolve solids and other impurities. The similar results were previously reported for ground water samples from Bahawalpur City, Pakistan [34].

#### *Total dissolved solids*

Total Dissolved solids (TDS) refer to the amount of inorganic substances suspended or dissolved in water. The normal permissible value for TDS in drinking water is 1000 mg/L. In the present study area, 96% of the samples showed TDS concentration higher than the permissible value and the rest of the samples were in normal range. The maximum concentration of TDS was 4560 mg/l and minimum concentration was 743 mg/l. These results were in accordance with the results previously reported for ground water sources from district Matiari, Sindh [35]. Like EC, TDS concentration was above the permissible value and elevated TDS concentration make the drinking water unsuitable for human consumption. In addition, increased TDS concentration also affects the individuals suffering from heart and kidney problems. High TDS values also affect skin and cause rashes, and disturb body hair as well. TDS did not play a direct role in health risks, but high salt contained water's extended utilization (above 500 ppm) can cause stiffness of the joints, kidney stones, gallstones, and hardening of arteries [16]. The elevated level of TDS decreases the tastiness and causes gastrointestinal irritations in human and laxative effect mainly upon transits as reported by Khaiwal [37].

**Table 2** Descriptive statistics of six parameters of drinking water samples.

| Variable | Mean±SD | Min | Max | WHO limits |
|---|---|---|---|---|
| pH | 7.98±0.22 | 7.4 | 8.4 | 6.5-8.5 |
| EC | 2.86±1.21 | 1.16 | 7.12 | 1562µS/cm |
| TDS | 1832±778 | 743 | 4560 | 1000 mg/L |
| Turbidity | 9.73±8.84 | 1.6 | 34 | < 5 NTU |
| *E.coli* | 22.56±27.98 | 0 | 100 | 0 CFU |
| Arsenic | 24.78±50.74 | 0 | 250 | 10 ppb |

WHO = World health organization; TDS = Total dissolved salts; EC = Electrical conductivity; NTU = Nephelometric turbidity unit; CFU = Colony forming units.

#### *Turbidity*

Turbidity is a measure of the cloudiness of water and it was used to express the water quality. The normal WHO turbidity limit in water is <5 nephelometric turbidity unit (NTU). In this

investigation, 63% of the water samples were turbid beyond the suggested limit by WHO and 37% of the water samples were in normal range. The maximum turbidity value of water samples was 34 NTU and minimum value was 1.6 NTU. The present study indicated that water samples were not highly turbid and it may be the reason that water samples were odorless. Turbidity is a good analytical parameter to analyze water quality, but it is not a good indicator for the detection of microbial contamination. In the present study, water samples with higher turbidity value may be due to the old bore hand pumps, non-functioning of filters or big pore size. The turbid water provides shelter to the microorganisms like *E. coli*, dysentery and other chronic disease causing microbes and indirectly constitutes a health issue.

## Chemical parameters

### *Arsenic*

Arsenic in drinking water is recognized as a big threat to public health in many countries like Pakistan, Bangladesh, India, China, Vietnam, Nepal and Myanmar. The Pakistan Environmental Protection Agency (EPA) and WHO recommended permissible concentrations for arsenic in drinking water are 50 µg/L and 10 µg/L, respectively. In the present study area, arsenic was detected in 33 % (15) water samples and 24% (11) water samples showed arsenic concentration above the permissible WHO limit. The maximum concentration of arsenic in drinking water was 250 ppb. These results are in accordance with the results previously reported from Matiari Sindh [35] and Dighri, Sindh (un-published data). The drinking of lower arsenic contaminated water can cause nausea and vomiting, decreased production of red and white blood cells while higher concentration of inorganic arsenic ingestion can cause reproductive disorders and various types of cancers such as skin, kidney, lung and bladder [22, 23].

## Biological parameters

### *E. coli colonies counts*

The detection of *E. coli* bacteria in water used as a sign of microbial contamination. Guidelines for drinking water WHO (2011) and quality drinking water standards for Pakistan QDWSP (2007) suggested that water intended for drinking must not be contaminated with *E. coli* bacteria. In the present work, 65% water samples were contaminated with bacteria and 35% samples were not contaminated. The maximum colonies of *E. coli* in water samples were counted 100 CFU/100ml. In the present study, water samples were contaminated due to improper management, such as bad sewerage system surrounding the hand pumps, open defection and seepage of waste water into bore and other waste managements. *E. coli* mostly causes dysentery, but it may lead to hemorrhagic dysentery which creates a fatal condition, especially in newborn babies and children. It has been reported in a study that potential source of an outbreak of waterborne diseases in Pakistan is untreated waste water [38].

## Arsenic health risk assessment

Health Quotient is a probabilistic chronic measurement of heavy metals like arsenic by certain formula that shows health impact on the consumer of contaminated water. HQ of 15 kg revealed that all values were more than normal range (HQ <1) and may cause chronic health concern might be due to the less lean body mass, age and consuming duration of drinking water. HQ 70 kg showed that all samples were beyond the normal range (HQ <1) except two samples (Table 3). Factor R called as risk factor measured by certain formulas indicate carcinogenic effect of arsenic.

**Table 3** Identified values of chronic health quotients (HQ).

| HQ (15 kg) | Risk factor (R) | HQ (70 kg) | HQ (dermal) |
|---|---|---|---|
| 4.44E+00 | 4.29E-04 | 9.52E-01 | 6.61E-06 |
| 4.44E+00 | 4.29E-04 | 9.52E-01 | 6.61E-06 |
| 4.44E+01 | 4.29E-03 | 9.52E+00 | 6.61E-05 |
| 4.44E+01 | 4.29E-03 | 9.52E+00 | 6.61E-05 |
| 4.44E+01 | 4.29E-03 | 9.52E+00 | 6.61E-05 |
| 4.44E+01 | 4.29E-03 | 9.52E+00 | 6.61E-05 |
| 4.44E+01 | 4.29E-03 | 9.52E+00 | 6.61E-05 |
| 4.44E+00 | 4.29E-04 | 9.52E-01 | 6.61E-06 |
| 4.44E+01 | 4.29E-03 | 9.52E+00 | 6.61E-05 |
| 4.44E+00 | 4.29E-04 | 9.52E-01 | 6.61E-06 |
| 1.11E+01 | 1.07E-03 | 2.38E+00 | 1.65E-05 |
| 1.11E+02 | 1.07E-02 | 2.38E+01 | 1.65E-04 |
| 4.44E+01 | 4.29E-03 | 9.52E+00 | 6.61E-05 |
| 4.44E+01 | 4.29E-03 | 9.52E+00 | 6.61E-05 |
| 1.11E+01 | 1.07E-03 | 2.38E+00 | 1.65E-05 |

The present study revealed that all water samples in which arsenic was identified have positive carcinogenic risk factor except four samples which were within the normal range. HQ dermal found in normal range in all samples. The findings of this study are found in agreement with the studies reported previously that HQ dermal found lower than the HQ oral, and HQ dermal of trace metals in drinking water were lower than unity, suggesting that these pollutants could pose a minimum hazard to

local residents in Nanjing, China and Karachi, Pakistan [30, 39].

## Conclusions

In the present study area, all water samples were colorless, odorless and saline in taste. The pH values of water samples were within WHO range. EC and TDS values observed above the WHO limit shows elevated concentration of dissolved solids and other impurities. More than half (63%) of water samples were turbid suggesting choline disinfection. The arsenic was detected in 11 out of 46 water samples above the WHO limit, which may cause health hazards including cancer. More than half water samples were *E. coli* contaminated. Arsenic health risk assessment studies showed that HQ (chronic and carcinogenic) of arsenic contaminated samples were more than the normal limit irrespective to 70 kg or 15 kg body weight which reflects the seriousness of drinking water contamination for the consumers. At last, it can be concluded that the drinking water of the Taluka Johi, Pakistan may pose potential health risks to the residents and drinking of such water may lead to waterborne disease.

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