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Arsenic transport in canal water and across rice fields in district Badin

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Abstract

Background/Objectives: Irrigation water at Phuleli and Akram canals carry the waste of Hyderabad city and other places on the way to rice fields at lower part of Indus Plain. The long term use of arsenic contaminated irrigation water can accumulate arsenic in rice soils. This study evaluated total arsenic in irrigation water and transported load to rice sites, in addition to the arsenic concentration in main canals and waste sites on the way to Badin. **Methods:** Atomic absorption spectrophotometer equipped with hydride vapor assembly was used to analyze the arsenic concentrations in irrigation water. **Findings:** Currently, the irrigation water quality was generally within the permissible limits of FAO for rice. All types of wastes (14.62-37.2 μg L^{-1}) entering the Phuleli and Akram canals (7.08 μg L^{-1}) on the way contributed to total arsenic (6.30-57.12 μg L^{-1}) in irrigation water at the entrance of rice sites. However, higher arsenic contamination in irrigation water was due to sugar industry waste (37.2 μg L^{-1}) and lowest due to city waste of Badin (14.62 μg L^{-1}). The data indicated that mean total arsenic concentration from irrigation water would load 0.12 and 0.14 mg kg^{-1} of arsenic annually in soils on the basis of net 1000 and 1300 mm a^{-1} water application to rice, respectively. **Applications/Improvements:** The results clearly indicated that waste added from different sources may aggravate the arsenic contamination of canal water and yet the accumulation in rice fields will keep on increasing. It is suggested that waste must be treated before releasing to prevent contamination of rice field.

Keywords: Arsenic load; City waste; Contamination; Industrial waste

1 Introduction

District Badin (24°13' to 25°12' N and 68°21' to 69°20' E) is part of Lower Indus plain, formed by alluvial deposits of the Indus River through ancient Hakra, Nullah and Gungra water courses. Rice is widely grown (115340 ha) along with many other crops. The main sources of irrigation in the area are Phuleli and Akram canals, emerging from

Kotri Barrage, carrying water from the left bank of River Indus. When these canals pass through Hyderabad city, they receive more than 60 million gallons of toxic runoff of industries and about 1.5 million gallons sewerage on daily basis[1,2]. Moving from Hyderabad to Badin, the canals additionally receive wastewater of laundries, animal farms, plastic factories, sugar industries and domestic sewage[3].

The canal water mixed with untreated wastewater and its continuous use on agricultural lands, particularly on rice fields under flooding conditions can accumulate significant quantities of arsenic in rice soils[4,5]. In general, the arsenic concentration of water is in the range of 3.5-1800 μg L^{-1} for many South East Asian countries like Bangladesh, China, India, Taiwan, Nepal and even Pakistan, however, the degree of arsenic contamination is severe in first three countries[6]. The arsenic concentration in some water samples of district Badin was greater than 50 μg L^{-1}, while majority of samples indicated (1.5-50 μg L^{-1}) no contamination[7]. Surface water of district Jamshoro also had more or less similar (3.0-50.0 μg L^{-1}) arsenic concentration[8].

Arsenic can easily get transported to soil through irrigation water[9,10]. The arsenic transported load from irrigation water to soil will vary according to the amount of arsenic present in irrigation water, amount coming from each source of waste on the way, and also on the amount of water used for irrigation of rice in the area. Local studies related to surface water arsenic are scarce[8]. Most of them are either related to drinking[11–13] or ground water[14–16] arsenic. The studies highlighting arsenic transport in irrigation water from each possible point of contamination and prediction of arsenic load transported to rice fields is of significant importance, before it becomes part of food chain above the permissible limits.

2 Material and Methods

Selection of the study area is based on the fact that, the irrigation canals (Phuleli and Akram canals) responsible for irrigating the rice fields at lower Indus Plain (i.e. district Badin) receive huge quantities of wastewater on the way. There is possibility that this waste may contaminate the canal irrigation water with arsenic before it gets to the rice fields. The climate of the area is moderate, hot in summer and cold in winter. The mean lowest annual temperature is 4°C and the highest is 46°C with annual rainfall ranging from 200-300 mm. A total of 120 irrigation water samples were collected at the entrance of each of the 24 rice sites at district Badin. In addition to that, 8 canal water samples were collected from each Phuleli and Akram canals at Kotri Barrage and 28 from 7 individual waste sites entering into Phuleli and Akram canals on the way to Badin Figure 1.

The samples were collected in Van Dorn plastic bottles (1.5 L) at low flow rate. The bottles were already soaked for 24 h in 10% HNO_3 and rinsed with deionized water[17]. Temperature, pH, EC and TDS were measured on the spot (HI-9813-5, Hanna Instrument, USA). The samples were kept in ice box, stored in the dark and transported on the same day to be preserved at 4 °C[18].

Total arsenic in water samples was determined as outlined for waste water[19]. For this, 70 ml of water sample was digested in 10 M hydrochloric acid at 70°C for 30 minutes. The contents were filtered using 0.45μ filter paper. The final solution was used for the determination of total arsenic using atomic absorption spectrometer (Shimadzu AA-6300, Japan) equipped with hydride vapor generation assembly (Shimadzu HGV-1, Japan). A hollow cathode lamp of arsenic was used as a radiation source (193.7 nm wavelength) and spectral slit width of 0.7 nm. The carrier solution for the hydride generation module was 10% HCl at a flow rate of 10 ml m^{-1} and the reducing solutions were 0.5% $NaBH_4$ (Alfa Aesar) in 0.05% NaOH (Riedel-de-Haens) at the flow rate of 5 ml m^{-1}. The mean arsenic concentration in the irrigation water was used to calculate arsenic load transported from water to soil. The arsenic load was calculated separately from net irrigation water (1000-1300 mm a^{-1}) quantity for rice crop in Pakistan[20]. The calculations were done as per details under Current Pollution Report[21]. The data was used to run descriptive statistics (range, mean +standard deviation, skewness and kurtosis) and arsenic concentration at the entrance of rice sites was correlated with pH, EC and TDS by using Statistix 8.1. Arsenic concentration in irrigation water was compared with the permissible limits[22] for rice crop and other parameters were compared with the allowable limits[13] as given by FAO.

3 Results and Discussion

3.1 Arsenic transport from waste sites to canal water

Amount of arsenic transported in canal irrigation water at each waste point starting from Kotri Barrage to Badin (Figure 2) depicted that total arsenic concentration at Phuleli (6.55) and Akram (7.6 μg L^{-1}) canals was more or less similar. However, the waste from animal farms was relatively more and added 28.71 μg L^{-1} of arsenic to these canals. About same quantity of arsenic was coming from the city waste of Hyderabad (28.78 μg L^{-1}). The industrial area having textile mills and cement factory was adding even more (32.56 μg L^{-1}) arsenic. Highest amount of arsenic (37.2 μg L^{-1}) came from sugar industries. While, the waste Drain of Khoski at Tando Bago and Pangrio (21.3 μg L^{-1}) and waste of Badin city (14.62 μg L^{-1}) also added significant quantities of arsenic. Nonetheless, total arsenic concentration of all the effluents, entering the sub-distributary irrigation canals

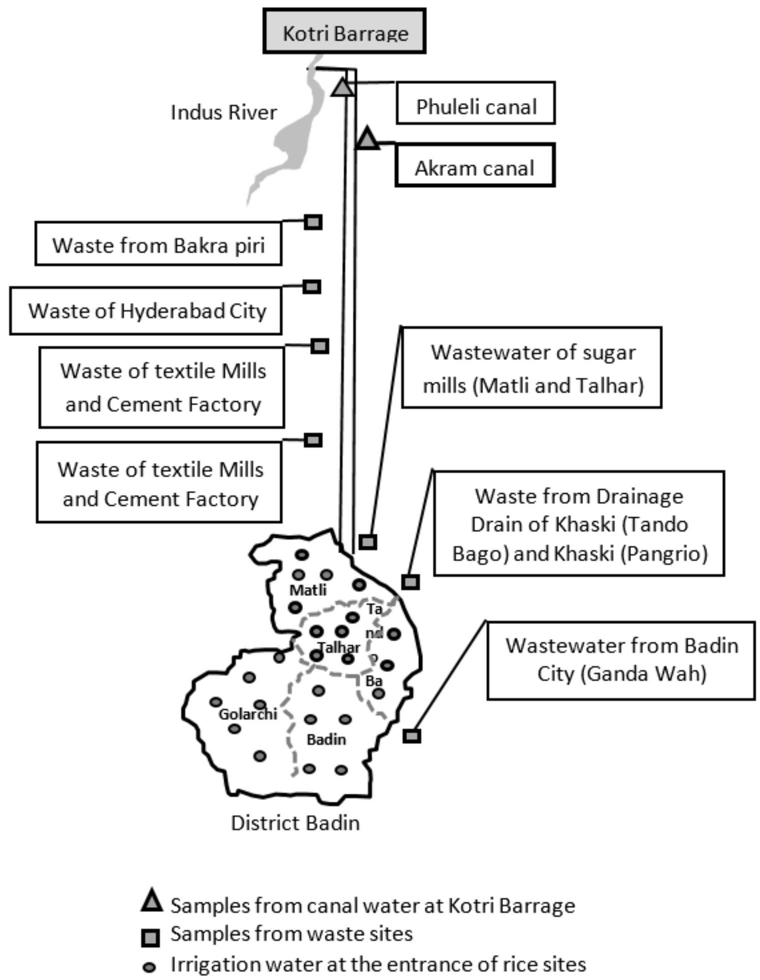

Fig 1. Schematic diagram of the study area

were below the permissible limit of 50 μg L^{-1} for irrigation of rice [22]. The studies on Phuleli canal water [23] also reported lower arsenic concentration (10.0 μg L^{-1}) at the entrance of canal, and increased values (17.00-380 μg L^{-1}) from RD-30 to RD-130, as the effluents of city and different mills were added to it. Other studies also reported similar concentrations of arsenic (up to 30 μg L^{-1}) as a result of urban and industrial waste, particularly from sewage [24] in river waters. The arsenic concentration of sugar mill effluent obtained in this study was way too low, compared to the quantity of arsenic (200 μg L^{-1}) reported [25] from sugar mill of Madurai, India. The earlier studies [26] reported even higher arsenic (1100 μgL^{-1}) in Sugar Creek of South Carolina.

3.2 Arsenic and other properties of irrigation water at the entrance rice field

The total arsenic was in the range of 6.30-57.12 μg L^{-1} (Table 1) and the average values at each rice site are presented in Figure 3. This was in line with the studies carried out for Chinese rice [27]. The inferences of the data showed that only 8% (2) sites were above the permissible limit of 50 μg L^{-1} for irrigating rice [22]. The arsenic concentration in irrigation water of rice fields cannot be compared to other studies, as none of the studies have attempted to determine the arsenic contamination from individual rice fields. Also, the average values of any study are misleading; it should be majority of the samples having a particular range. Comparing the 10 years back data of arsenic (3-17 μg L^{-1}) for 91% surface water samples of Jamshoro [8] (not particular for rice soils), the arsenic concentration was much lower than those obtained in this study (10-30 μg L^{-1}). Badin is situated at the lower part, compared to Jamshoro (middle part) of Indus River plain; therefore, maximum effluent is carried out into the study area. This is also in line with the results for Hyderabad city [2]. Results of this study are evident that anthropogenic activities have been adding more and more arsenic with the passage of time.

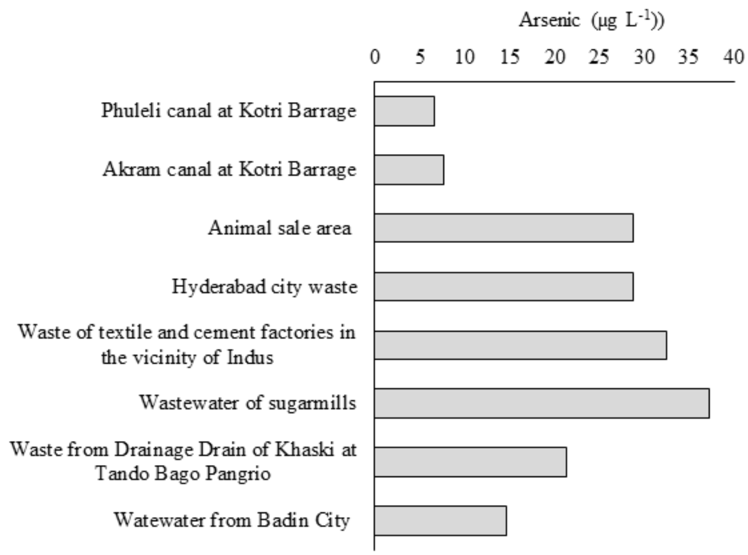

Fig 2. Arsenic concentration in canal water at Kotri Barrage and wastewater sites all the way to Badin

Table 1. Properties of irrigation water at the entrance of rice sites of Badin

Parameters	Range	Mean± Standard Deviation	Skewness	Kurtosis	Permissible limits for irrigation water [20,21]	Contamination (%)
Temperature (°C)	31.10-32.62	32.52±0.42	-3.01	7.13	-	-
pH	7.75-8.30	8.05±0.14	-0.00	-0.61	6.50-8.40	-
EC (dS m-1)	0.22-1.69	0.87±0.38	0.28	-0.80	0-3	-
TDS (mg L-1)	111-798	433±184	0.34	-0.68	<750	8
Total arsenic (μg L-1)	6.30-57.12	20.83±12.40	1.69	2.59	50	8

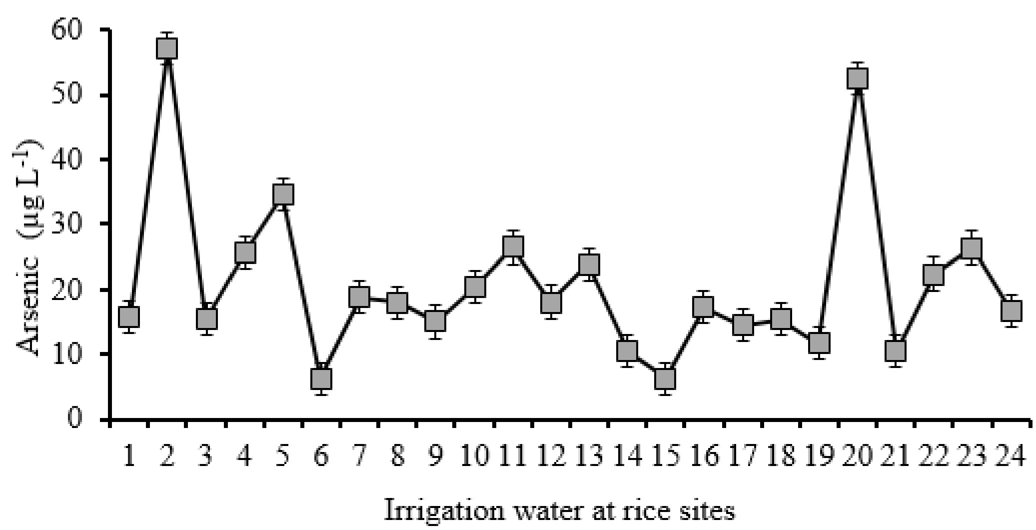

Fig 3. Total arsenic in irrigation water at associated rice sites

EC (0.221-1.69 dS m^{-1}), pH (7.75-8.30) and TDS (111-798 mg L^{-1}) values varied widely, but were within the permissible limits for irrigation water guidelines [13], except the TDS of 8% sites (Table 1). The TDS of these rice irrigating sites were slightly above the safe limit of 750 mg L^{-1}. The moderately alkaline conditions suggested that irrigation water has great potential to dissolve the salts and minerals. Generally, the skewness and kurtosis values indicated the flatness of physico-chemical parameters in the area. The pH and TDS values of the study area were higher than the reported values of pH 7.1-7.8 and 180-250 mg kg^{-1} [8] for canal irrigation water of Jamshoro. This is because the irrigation water samples described here were collected only from rice fields, rather than the overall collection of water samples as in case of Jamshoro. Secondly, the Phuleli and Akram canals at lower end, receive all the effluents coming from city waste of both Hyderabad and Badin including, the waste of sugar mills, cement factories and other industries. The study relating to Pinyari canal contamination [2] also confirmed the same. The arsenic concentrations of irrigation water entering the rice fields were regressed with relevant parameters i.e. pH (0.78), EC (0.63) and TDS (0.62), depicting positive relationship (Table 2). Our results were in line and in confirmation with results by different scientists [28–30].

Table 2. Relationship of each pH, EC, and TDS with total Arsenic in irrigation water of rice sites

Parameter	Coefficient of correlation (r)	Coefficient of determination (R2)	Regression equation (Y=bx+a)
pH	0.78	0.61	Y=69.1x-535.7
EC	0.63	0.40	Y=20.61x+2.82
TDS	0.62	0.39	Y=0.042x+2.56

3.3 Arsenic load transported from irrigation water to rice sites

Continuous use of contaminated water for irrigation can contribute to arsenic loading in rice soils. The data indicated that mean total arsenic concentration from irrigation water would load 0.12 and 0.14 mg kg^{-1} of arsenic annually in soils on the basis of net 1000 and 1300 mm a^{-1} water application, respectively. This way, there will be 0.72-0.84 mg kg^{-1} arsenic loaded after 6 years' time (Figure 4).

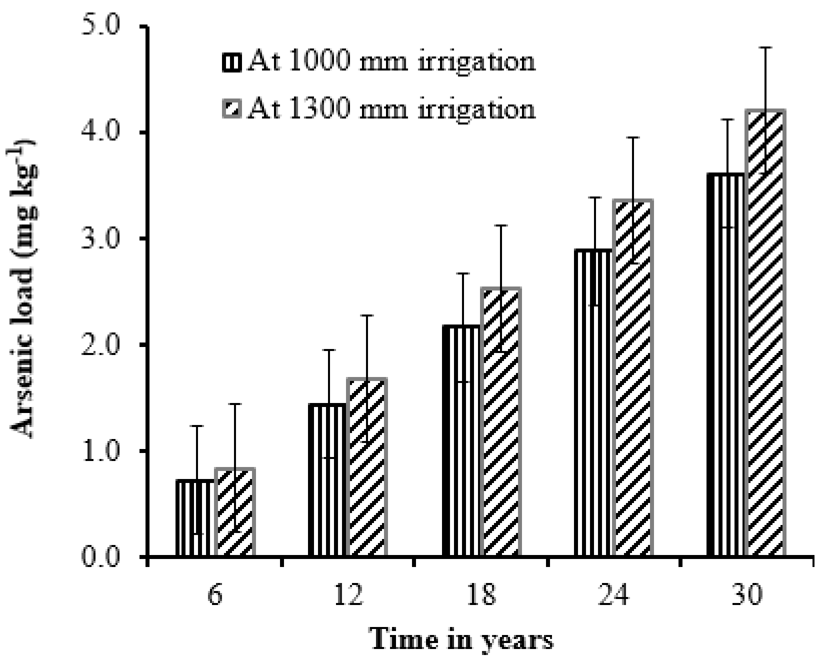

Fig 4. Arsenic load transported from canal water to rice sites over the years

Likewise, considerable amount of arsenic will be transferred (i.e. 3.6-4.2 mg kg^{-1} in 30 years) to the rice soils with time. Research [31] reported similar results to this study. The predicted arsenic concentration in soil is currently below the permissible limits of 50 mg kg^{-1} [22]. However, the amount of arsenic currently (i.e. 0.12-0.14 mg kg^{-1}) entering the rice soils may change, as it depends on the amount of arsenic present in irrigation water. The average arsenic concentration (100 $\mu g\ L^{-1}$) of irrigation water in Bangladesh has been loading more arsenic to agricultural soils [23]. Other than groundwater [31,32], arsenic contaminated irrigation water has also been loading arsenic to rice fields.

4 Conclusion

The results of this study depicted that the canal water itself is not contaminated but it is the anthropogenic activities (different types of waste) which keep on adding arsenic to this water and ultimately to rice fields in Badin. Significant arsenic is being added from sugar, textile, cement industries, animal sale area and the waste from Hyderabad city and relatively low arsenic from Badin city waste itself. Majority of the sites (22 sites) were within the permissible limits, nonetheless, annual arsenic transfer of 0.12-0.14 mg kg^{-1} will accumulate more arsenic with time and quantity of irrigation water to rice fields of Badin. In order to keep record and minimize the contamination level arsenic waste sources, irrigation water quality and quantity should be monitored on regular basis.

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