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Original Research

Study of Arsenic Concentration Levels in Pakistani Drinking Water

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Abstract

Arsenic contamination in drinking water is one of the major causes of arsenicosis, a clinical syndrome due to drinking arsenic-rich water. Data on arsenic concentration levels in drinking water is lacking in Pakistan. Knowledge of arsenic concentration in ground water used for drinking is essential to introduce a strategy to avoid arsenic contamination associated with health hazards. The present work deals with the assessment of arsenic concentration levels in ground water in eight provincial districts of Punjab, Pakistan. During a study conducted in 2001-03 by the provincial Local Government and Community Development department in the Punjab province, 4,547 drinking water samples were collected and analyzed using atomic absorption spectrometry technique. The results show that arsenic levels in drinking water varied from 6 to 12 ng ml^{-1} with a mean value of 8.5±1.6 ng ml^{-1}, which is below the recommended World Health Organization (WHO) guidelines of 10 ng ml^{-1} for drinking water. The data generated in this study will provide base line values for monitoring arsenic concentrations in drinking water in the surveyed area.

Keywords: arsenic, drinking water, arsenicosis, Punjab, atomic absorption spectrometry

Introduction

Arsenic is an element commonly found in water. It originates from geological surroundings and pollution of the environment. The geogenic content of arsenic therefore varies from a few tenths of ng ml^{-1} to tens of μg ml^{-1} [1]. Arsenic is the 12th most common element in nature. It is widely distributed throughout the earth's crust and commonly found in the atmosphere, soils, rocks, organisms and natural waters. The occurrence of arsenic in the environment is also associated with anthropogenic activities and it is estimated that about 60% of arsenic present in the environment is of anthropogenic origin [2]. Arsenic can combine with other elements to form inorganic and organic arsenic compounds.

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Inorganic arsenic appears in compounds with oxygen, sodium, potassium, copper, chlorine, iron and sulpher. Arsenic in plants and animals combines with carbon and hydrogen to form organic arsenic. Organic arsenic compounds that are found in foods are quite harmless and pass through the body quickly. Inorganic arsenic is more toxic and can have acute, sub-acute and chronic effects, which may be either local or systemic. It is deposited in the body, gets concentrated during long-term exposure and causes long-term damage. Arsenic is mobilized in the environment through a combination of natural processes such as weathering reaction, biological activities, volcanic emissions and anthropogenic activities [3]. In the recent past, many epidemiological studies [4-5] have indicated health hazards in humans due to inhalation and ingestion of arsenic-contaminated air, food and water. Arsenic concentration beyond permissible levels in drinking water poses a serious threat

to human health [2]. Monitoring of arsenic concentration in drinking water therefore becomes important to avoid health risks.

Data on arsenic contamination levels in drinking water is lacking in Pakistan. Knowledge of arsenic contamination levels in drinking water is essential to introduce a strategy to avoid arsenic contamination associated with health hazards. Knowledge of arsenic concentration levels in different areas in the country would enable establishing background values that could be used to distinguish additional contributions when a contamination event occurs. In Pakistan, most places use ground water for drinking purposes. Ground water is pumped out through wells by hand pumps and electric pumps. It was therefore considered imperative to measure the concentration levels of arsenic in drinking water pumped out from ground water in the Punjab province of Pakistan. At the first stage, this exercise was carried out in eleven districts of Punjab province. As the data on arsenic concentration in drinking water is lacking in Pakistan, the data generated in the present study may be helpful for environmental protection authorities in establishing the background levels in the country and detection of pollution sources, which may enable prevention and design of more efficient remediation systems on one hand and setting up the standards for safe drinking water for the general public on the other.

The Study Area

Punjab province is the most populace province of Pakistan (Fig. 1) with nearly 74 million inhibitants. Fig. 2 shows location of all districts of Punjab province, including eleven districts investigated for arsenic concentration in the drinking water in the present study. Geographically, Punjab lies between latitudes 28º to 34º north, and longitudes 69º to 75º east and covers an area of 205,344 km^2. The province is bordered in the east by India, in the northeast by Azad Jammu and Kashmir, in the north by the North West Frontier Province and federal capital Islamabad, in the southwest by Sindh Province and in the west by Baluchistan Province. Climatically, this area is warm, semi arid having average annual rainfall of 500 mm to 750 mm. However, the lower portion of the province is hot and arid, having average annual rainfall of 175 mm to 250 mm. Monsoon and westerlies are believed to be mainly responsible for rainfall in the study area. The Monsoon rainfall takes place during July to September, whereas the Eastern depressions cause rainfall from December to March. The intervening periods are dominated by thunderstorms. The word "Punjab" means five rivers, which includes the Indus, the Jhelum, the Chenab, the Ravi and the Satlug rivers flowing down through Punjab. This province has the world's best irrigation sys-

Fig. 1. Map of Pakistan showing location of the Punjab province.

tem through its network of canals. Punjab comprises a level plain formed by the Indus and its tributaries. The general slope of the land is from northeast to southwest. Geologically, the study area is part of the Indo-Gangetic plain formed in front of the rising Himalayas. This area falls in the territory of the vast Indus Plains which stretch south of the Himalayas. The Indus plains were formed by the alluvium laid down by the Indus and its tributaries. The swelling of the Indus and its tributaries during the summer season usually causes floods in the areas adjacent to riverbanks. Most of the cities of Punjab, as well as the irrigated agricultural land, have developed over the Indus Plain [6].

Materials and Methods

Water samples were randomly collected from underground wells using hand pumps in each district during 2001-03. Water samples were collected in half litre polyethylene bottles in accordance with the standard sampling protocol [7]. Total number of water samples collected from each district is shown in Table 1. Collected water samples were analyzed for arsenic (inorganic) concentration using atomic absorption spectrometry (AAS). For this purpose, AAS Vario 6 Analytik Jena AG, Mercury/ Hydride system HS55 and argon gas with 99.99% purity, arrangement system was employed.

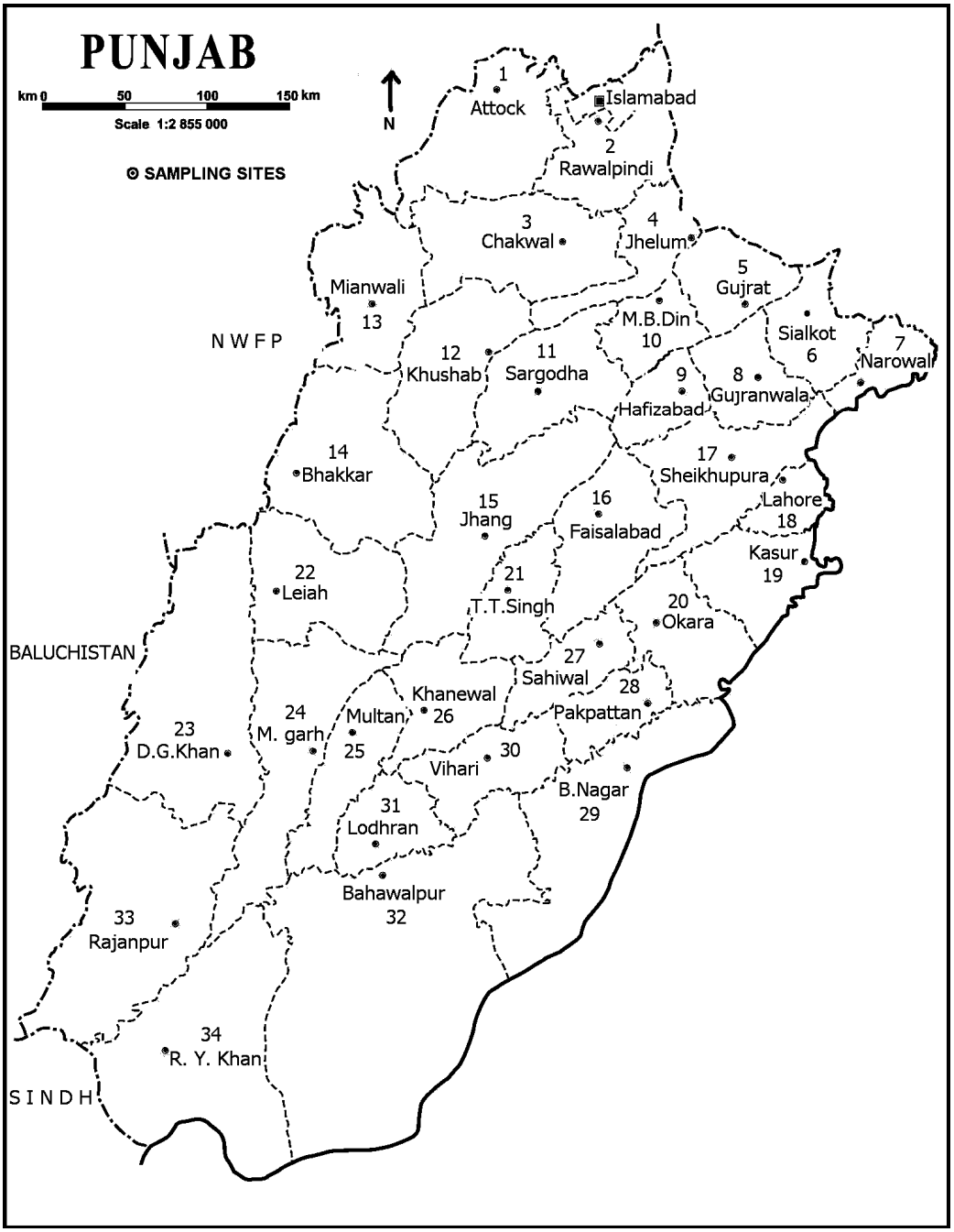

Fig. 2. Map of Punjab province showing location of districts.

Table 1. Measured concentrations of arsenic (As) in drinking water samples.

District	Number of samples	As concentration range (ng ml^{-1})	Values between 0-10 ng ml^{-1} (% samples)	Values between 10-50 ng ml^{-1} (% samples)	Values >50 ng ml^{-1} (% samples)	Average values (ng ml^{-1})
Bahawalpur	620	3-101	92	7.5	0.5	10
R. Y. Khan	580	3-103	86	10.5	3.5	9
Multan	590	2-107	66	33	1	12
D. G. Khan	304	5-83	92.5	7.5	0	9
Jhang	595	0-48	91.5	8.5	0	8
Leiah	198	4-62	88	11	1	10
Mianwali	301	0-37	98.5	1.5	0	7
Muzaffargarh	398	2-45	88	12	0	8
Rajanpur	172	4-39	98.5	1.5	0	7
T. T. Singh	388	2-30	97	3	0	8
Sargodha	401	0-28	98	2	0	6
					Min. value:	6
					Max. value:	12
					Mean value:	8.5±1.6

The system was calibrated with known multiple arsenic standards using the certified standard stock solution.

Results and Discussion

Measured values of arsenic concentration in water samples from each district are tabulated in Table 1. In district Bahawalpur, out of 620 total collected samples, arsenic concentrations in 92% of samples lies in the range from zero to 10 ng ml^{-1}, 7.5% of samples vary from 10 to 50 ng ml^{-1} and 0.5% of samples are found above 50 ng ml^{-1}. Arsenic concentrations in this district is in the range 3-101 ng ml^{-1} with an average value of 10 ng ml^{-1}.

In district R. Y. Khan, out of 580 total collected samples, arsenic concentrations in 86% of samples lies in the range zero to 10 ng ml^{-1}, 10.5% of samples vary from 10 to 50 ng ml^{-1} and 3.5% of samples are found above 50 ng ml^{-1}. Arsenic concentrations in this district is in the range 3-103 ng ml^{-1} with an average value of 9 ng ml^{-1}.

In district Multan, out of 590 total collected samples, arsenic concentration in 66% of samples lies in the range zero to 10 ng ml^{-1}, 33% of samples vary from 10 to 50 ng ml^{-1} and 1% of samples are found above 50 ng ml^{-1}. Arsenic concentrations in this district are in the range from 2-107 ng ml^{-1} and an overall average value of arsenic concentrations in district Multan is 12 ng ml^{-1}.

In district D. G. Khan, out of 304 total collected samples, arsenic concentrations in 92.5% of samples lies in the range from zero to 10 ng ml^{-1}, 7.5% of samples vary from 10 to 50 ng ml^{-1} and none of the collected samples shows value above 50 ng ml^{-1}. Arsenic concentrations in this district are in the range from 5-83 ng ml^{-1}, and the overall average value of arsenic concentrations in district D. G. Khan is 9 ng ml^{-1}.

In district Jhang, out of 595 total collected samples, arsenic concentrations in 91.5% of samples lies in the range from zero to 10 ng ml^{-1}, 8.5% of samples vary from 10 to 50 ng ml^{-1} and none of the collected samples shows a value above 50 ng ml^{-1}. Arsenic concentrations in this district are in the range 0-48 ng ml^{-1} with an average value of 8 ng ml^{-1}.

In district Leiah, out of 198 total collected samples, arsenic concentrations in 88% of samples lie in the range from zero to 10 ng ml^{-1}, 11% samples vary from 10 to 50 ng ml^{-1} and 1% shows value above 50 ng ml^{-1}. Arsenic concentration in this district is in the range 4-62 ng ml^{-1} and the overall average value of arsenic concentration in district Leiah is 10 ng ml^{-1}.

In district Mianwali, out of 301 total collected samples, arsenic concentrations in 98.5% lie range from zero to 10 ppb, 1.5% vary from 10 to 50 ng ml^{-1}, and none of the collected samples shows value above 50 ng ml^{-1}. Arsenic concentrations in this district are in the range 0-37 ng ml^{-1} and overall average value of arsenic concentration in district Mianwali is 7 ng ml^{-1}.

In district Muzaffargarh, out of 398 total collected samples, arsenic concentration in 88% range from zero to 10 ng ml^{-1}, 12% vary from 10 to 50 ng ml^{-1}, and none of the collected samples shows value above 50 ng ml^{-1}. Arsenic concentrations in this district is in the range 2-45 ng ml^{-1}, with an average value of 8 ng ml^{-1}.

Table 2. Admissible concentration of arsenic in drinking water [1].

Country	Concentration (ng ml^{-1})	Country	Concentration (ng ml^{-1})
Japan	50	Hungary	50
Russia	50	Poland	10
Austria	50	Germany	10
Czech Rep.	50	USA	50
WHO	10	EU	50

In district Rajanpur, out of 172 total collected samples, arsenic concentrations in 98.5% range from zero to 10 ng ml^{-1}, 1.5% samples vary from 10 to 50 ng ml^{-1}, and none of the collected samples shows value above 50 ng ml^{-1}. Arsenic concentrations in this district range 4-39 ng ml^{-1}, with an average value of 7 ng ml^{-1}.

In district T. T. Singh, out of 388 total collected samples, arsenic concentrations in 97% range from zero to 10 ng ml^{-1}, 3% vary from 10 to 50 ng ml^{-1} and none of the collected samples shows value above 50 ng ml^{-1}. Arsenic concentrations range 2-30 ng ml^{-1}, with an average value of 8 ng ml^{-1}.

In district Sargodha, out of 401 total collected samples, arsenic concentrations in 98% range from zero to 10 ng ml^{-1}, 2% vary from 10 to 50 ng ml^{-1}, and none of the collected samples indicates arsenic concentrations above 50 ng ml^{-1}. Arsenic concentrations in this district range 0-28 ng ml^{-1}, with an average value of 6 ng ml^{-1}. A comparison of measured arsenic concentration ranges and average values in water samples from all eleven districts is shown in Fig. 3.

Data of a total of 4,547 water samples given in Table 1 show that arsenic concentration in all eleven districts exists in the range 6-12 ng ml^{-1}, with a mean value of 8.5±1.6 ng ml^{-1}. The measured concentration range of arsenic is comparable with the permissible limits in many countries of the world like Japan, Russia, Austria, the Czech Republic, Hungary, Poland, Germany, USA and the European Union [1] as shown in Table 2. The World Health Organization [8] guidelines for drinking water have recommended a limit of 10 ng ml^{-1} for arsenic concentration in drinking water. The Pakistan Standards Quality Control Authority [9] has recommended a limit of 50 ng ml^{-1} for arsenic concentration in drinking water. Overall average concentration of 8.5±1.6 ng ml^{-1} from all eleven districts is found within the WHO recommended limit of 10 ng ml^{-1}, except the Multan district, where the average value of arsenic concentrations is 12 ng ml^{-1}. 10% of samples in all eleven districts show arsenic concentrations in the range 10-50 ng ml^{-1}, and only in Multan district, where 33% samples have predicted arsenic concentrations above this range. In four districts, namely Bahawalpur, R. Y. Khan, Multan and Leiah, some samples have shown arsenic concentrations in water samples even higher than the recommended limit of 50 ng ml^{-1} in Pakistan. At some places in districts Bahawalpur, R. Y. Khan and Multan, arsenic concentrations in water samples is found even higher than 100 ng ml^{-1}. However, the frequency of such samples is less than 1% of total samples analyzed.

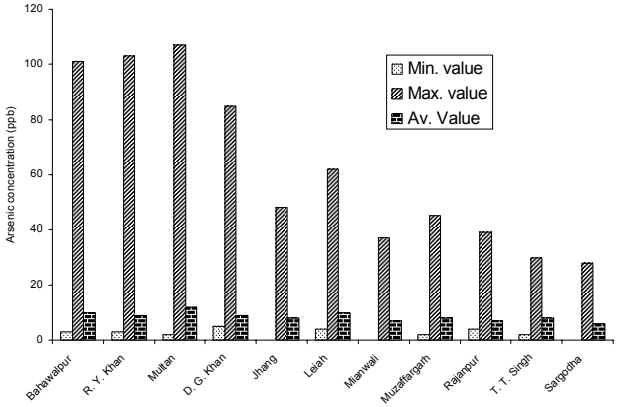

Fig. 3. A comparison of arsenic concentration range and mean values in eleven districts.

These results indicate that arsenic concentrations in water samples in different districts varies from place to place and is not uniform. Using the statistical technique, measured values of arsenic concentrations in water samples are drawn against water well depths from where ground water samples were collected in each district to see if any correlation exists between them. No significant correlations could be drawn between measured arsenic concentrations in water samples and depth of water wells, implying that arsenic concentrations in water samples is independent of water table depth and that there is no common source of release of arsenic in ground water in all districts.

The concentration levels of arsenic in ground water samples measured in this study may contribute to the database of this region. Such a database serves a vast gamut of environmental purposes and even offers a way to assess the relationship between concentrations of arsenic in ground water and health hazards in humans. Moreover, available data with regard to the measured arsenic concentration in ground water used for drinking purpose in Pakistan could be characterized better in terms of physical and chemical properties with increased sampling density to fully understand the extent of environmental endangerment.

Conclusions

Arsenic concentrations were measured in drinking water samples collected during 2001-03 from eleven districts in Punjab province of Pakistan. A wide range of variation in measured arsenic concentrations have been observed in these districts. Average arsenic concentrations from all eleven districts range 6-12 ng ml^{-1}, with an overall average value of 8.5±1.6 ng ml^{-1}. Average value of 8.5±1.6 ng ml^{-1} is found within the WHO recommended limit of 10 ng ml^{-1}. The results obtained in this study will provide base line data, which may help in improving the national water quality standards in the country. Further investigations for regular monitoring of water quality are desirable, especially for those areas showing abnormally higher arsenic concentrations, for

providing arsenic-free drinking water supplies to the general population.

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