Desalination and Water Treatment
www.deswater.com
doi: 10.1080/19443994.2012.760109

51 (2013) 5701–5709
August

Taylor & Francis
Taylor & Francis Group

Assessment of arsenic in drinking water samples in south-western districts of Punjab—India

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Received 20 September 2012; Accepted 13 December 2012

ABSTRACT

The present study involves the investigation of drinking water taken from existing hand pumps/submersible pumps, tube-wells, dug wells (underground water), and municipal water supply from the south-western districts of Punjab for the presence of arsenic. Many of the samples analyzed were found to have high Total Dissolved Solids (TDS), pH, electrical conductivity, hardness, and high content of arsenic beyond their permissible limits set by WHO along with high variability, which is a matter of great concern. The study has revealed that 80% of the total samples analyzed were having arsenic concentration above the safe limit (10 μg/L). Out of all the districts analyzed, Faridkot showed maximum contamination of 92% followed by Sangrur 88%, Bathinda 86%, Ferozepur 74%, and Muktsar 60%. The mean arsenic level in water samples obtained from municipal water supply of Ferozepur, Faridkot, Bathinda, Muktsar, and Sangrur is 14.14, 25.171, 23.75, 21.86, and 21.21 with SD 5.177, 5.976, 5.30, and 7.59. The mean arsenic concentration in water samples obtained from public hand pumps is 15.36. An attempt to correlate the physical parameters like pH, TDS, and bore depth of water source was also made. A positive correlation between pH and As concentration was observed with $r^2 = 0.94$. The present study suggests the regular monitoring of arsenic content and the seasonal variation, if any, in future.

Keywords: Arsenic; Analysis and surveying; Global positioning system

1. Introduction

Alarming information has emerged in recent decades about the widespread presence of arsenic in groundwater used to supply drinking water in many countries on all continents. Millions of people, mostly in developing countries, daily use drinking water with arsenic concentrations several times higher than the permissible limit (10 μg/L) set by WHO (World Health Organization) [1]. It has been reported that approximately 42 million people are exposed to As containing potable water having concentration more than 50 μg/L and more than 100 million people worldwide are affected by As contaminated water with a concentration of more than 10 μg/L [2,3]. The occurrence of arsenic in ground water was first reported in 1976 in Chandigarh and in 1980 in West Bengal in India, where 79 blocks in 8 districts have been found contaminated with arsenic beyond the permissible limit of 0.01 mg/L [4,5]. Apart from this, arsenic contamination in ground water has been found in the states of Bihar, Chhattisgarh, Madhya

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Pradesh, Uttar Pradesh, parts of Rajasthan, Assam, Tripura, Manipur, Nagaland, and Arunachal Pradesh [6,7]. Recently, the occurrence of high concentration of arsenic has also been reported in many districts of Punjab. It has been known to cause serious health hazards in the above quoted areas [8].

Arsenic is an ubiquitous element with the atomic number 33, which persists in the environment through rocks, soil, water, air, and biota. It occurs as a constituent in more than 200 minerals, including elemental arsenic, arsenides, sulfides, oxides and arsenates [9]. The greatest threat to public health arises from arsenic in drinking water caused by the weathering and dissolution of arsenic-bearing rocks, minerals, and ores. Total arsenic is the sum of both particulate arsenic and soluble arsenic, which occurs in two primary forms: inorganic and organic. Organic arsenic species are abundant in seafood, and include such forms as monomethyl arsenic acid (MMAA), dimethyl arsenic acid (DMAA), and arseno-sugars, which are less harmful to health, and are readily eliminated by the body.

Arsenic toxicity strongly depends on the form in which arsenic is present. Inorganic arsenic forms, typical in drinking water, are much more toxic than organic ones. Inorganic arsenic compounds in which arsenic is present in trivalent form are known to be the most toxic and four to ten times more soluble in water than pentavalent arsenic. The acute toxicity of a number of arsenic compounds is given in Table 1 [10]. Toxicity is expressed as the number of milligrams of the compound per kilogram of body weight that will result within a few days in the death of half of those who ingest it in a single dose. This concentration is known as LD_{50}. Table 1 shows the amount of various arsenic compounds per kg of body weight required to reach LD_{50} (higher the number, lesser is the toxicity of the compound. Exposure to such high levels of acute arsenic poisoning is very unlikely. However, long-term exposure to very low arsenic concentrations in drinking water is also a health hazard.

Arsenic is a redox-sensitive element. Its occurrence, distribution, mobility, and forms rely on the interplay of several geochemical factors, such as pH conditions, reduction–oxidation reactions, distribution of other ionic species, aquatic chemistry, and microbial activity [11]. Anoxic conditions in subsurface environments enhance arsenic mobility, which renders groundwater more vulnerable than surface water to arsenic contamination [12–16]. As(V) exists in four forms in aqueous solution based on pH: H_3AsO_4, $H_2AsO_4^-$, $HAsO_4^{2-}$, and AsO_4^{3-}. Similarly, As(III) exists in five forms: $H_4AsO_3^+$, H_3AsO_3, $H_2AsO_3^-$, $HAsO_3^{2-}$, and AsO_3^{3-}. The ionic forms of As(V) dominate at $pH > 3$, and As(III) is neutral at $pH < 9$ and ionic at $pH > 9$. The valency and speciation analysis of soluble arsenic have significant effect on developing an arsenic removal strategy [17].

Table 1
Amount of various arsenic compounds per kilogram of body weight

Arsenic form	Oral LD_{50} (mg/kg body weight)
Sodium arsenite	15–40
Arsenic trioxide	34
Calcium arsenate	20–800
Arsenobetane	>10,000

The present study involves investigation of drinking water samples obtained from south-western districts of Punjab namely Ferozepur, Faridkot, Bathinda, Muktsar, and Sangrur for the presence of arsenic. These areas are selected on the basis of their geographical locations and increasing incidences of cancer mortality due to consumption of poor quality drinking water. Most of the experts feel that heavy metals like chromium, nickel, lead, cadmium, and other contaminants like arsenic in groundwater used over the years might be the real cause of such deaths in the Malwa region of Punjab [8].

The major objectives of the study is to measure arsenic concentration in drinking water taken from existing/working hand water-pumps and tube-wells situated in the Malwa region of Punjab and to identify the areas where concentration of arsenic is more than the permissible limits, so that people can avoid using the drinking water from the affected areas. The study also aims to find correlation between effects of various variable parameters viz; pH, total dissolved solids (TDS), electrical conductivity and depth etc. on the concentration of arsenic in underground water.

1.1. Study area

Punjab State covers an area of about $50,362\,km^2$ and is located in the northern part of India. The geographical coordinates of the surveyed area are determined with the help of global positioning system (Garmin GPS 60, Sr No. 1DG048032) and is shown in Table 2. The entire study area lies between latitudes of 29° 43′ 25′′ and 31° 10′ 58′′ North, and longitudes of 73° 52′ 33′′ and 76° 12′ 40′′ East.

2. Materials and methods

2.1. Sampling

Field visits were carried out to collect the samples from surface and underground sources of water

Table 2
Geographical positions of the studied areas

District	Latitude	Longitude
Sangrur	29° 43′ 25″ and 30° 41′ 41″ North	75° 33′ 09″ and 76° 12′ 40″ East
Ferozepur	29° 55′ 36 ″ and 31° 10′ 58″ North	73° 52′ 33″ and 75° 09′ 19″ East
Faridkot	30° 21′ 30 ″ and 30° 50′ 49″ North	74° 28′ 15″ and 75° 03′ 20″ East
Muktsar	29° 53′ 31 ″ and 30° 40′ 43″ North	74° 15′ 03″ and 74° 49′ 32″ East
Bathinda	29° 46′ 11 ″ and 30° 35′ 08″ North	74° 37′ 49″ and 75° 22′ 54″ East

(Hand pump/submersible pump, public tube-wells and Municipal water supply). Samples were collected in duplicates from randomly selected sites. Almost equal numbers of samples were taken from rural as well as urban areas of each district (Table 3).

2.2. Storage and preservation

The collected samples were stored in polyethylene bottles of about 100 ml capacity and preserved by addition of two drops of HNO_3 until pH 2 is obtained [18,9]. The acidification with HNO_3 helps in stabilization of As(III) and As(V) species in water.

2.3. Instrumentation and analysis

Most of the samples were collected and simultaneously tested at the sampling sites using Arsenic Field Testing Kit (Product No. 1.17927.0001, Merck, Germany), which works on the principle of treating the water sample with a reducing agent (e.g. zinc) that separates the arsenic by transforming arsenic compounds in the water into arsenic trihydride (arsine gas; AsH_3) in the reaction bottle. Arsenic trihydride diffuses out of the sample where it is exposed to a paper impregnated with mercuric bromide. Reaction with the paper produces a colored compound (AsH_2HgBr) ranging from yellow to brown. By comparing the color of the test strip to a color scale provided with the kit, the amount of arsenic in a sample is estimated in the range of 5–500 μg/L [19].

Experiments were carried out at calibrated temperature of the strip i.e 25°C. The analysis was performed in a closed reaction bottle with a predefined volume of the sample, i.e. 60 ml. After 20 min of reduction reaction, mercuric bromide strip (test strip) was removed and its color was matched to standardized color chart.

The field test kit method is more qualitative but semi-quantitative in nature. In order to validate the results obtained through field test kit, some samples were cross analyzed at Central Testing Laboratory in the department of soils, Punjab Agricultural University (PAU), Ludhiana, using inductively coupled plasma with atomic emission spectrometer (ICP-AES). The results obtained were in accordance with the colorimetric method with little variation.

Besides the arsenic content, other physico-chemical parameters viz; pH, TDS, and electrical conductivity were also determined by digital pH meter, TDS meter, and conductivity meter, respectively.

3. Results and discussion

Most of the drinking water samples analyzed from the Malwa region of Punjab were found to have high TDS, pH, electrical conductivity, and high content of arsenic. The summary of water quality parameters of surveyed districts is given in Table 3.

The maximum TDS of more than 10,000 ppm was found in the samples taken from the hand pumps situated in villages viz. Arianwala, Tehna, Chehna, Jaito of Faridkot district and few sites of Jawahar wala village of district Sangrur. Study showed that pH in most of the groundwater was in the range of 7.5–8.5. WHO guidelines for ground water quality are: pH = 6.5–8.5, TDS = < 500 ppm, Conductivity = 4.7–5.8 μS/cm, Arsenic Conc. = 10 μg/L.

Table 3
Water quality parameters of the studied area

Name of city	pH	TDS (ppm)	Conductivity (μS/cm)	As Conc. (μg/L)
Bathinda	7.3–8.4	455–1,870	555.1	05–50
Faridkot	6.9–8.8*	564–10,000*	1,997.5	10–100
Ferozepur	7.5–8.6	489–1,200	724.2	10–50
Muktsar	7.5–8.6	396–2,080	1,580.6	05–50
Sangrur	7.5–8.5	854–4,000	1,341.1	05–50

*Out of detection limit.
WHO guidelines for ground water quality are: pH = 6.5–8.5, TDS = < 500 ppm, Conductivity = 4.7–5.8 μS/cm, Arsenic Conc. = 10 μg/L.

Table 4
The level of arsenic contamination of southwestern districts of Punjab

Name of district	Total number of samples Tested	Samples with arsenic concentrations (in μg/L)				Maximum concentration detected (μg/L)	% age of samples having arsenic conc. more than permissible limit (%)
		⩽10	10–25	25–50	⩾50		
Bathinda	50	07	15	26	02	50	86
Faridkot	50	04	24	17	07	100	92
Ferozepur	50	13	23	17	Nil	38	74
Muktsar	50	20	12	10	08	50	60
Sangrur	50	06	23	18	03	50	88

The result of the study showed that out of total 250 water samples tested for arsenic, 149 samples exceeded value of 10 μg/L, with 26 of them showing a concentration level higher than 50 μg/L that is the interim national drinking water standard for arsenic in India are not fit for consumption. The level of arsenic contamination of southwestern districts is shown in Table 4.

Study has revealed that 80% of the total samples analyzed exceeded the recommended level of 10 μg/L in drinking water supplies of Malwa region. In 8% of samples, arsenic level was exceeding the mandatory limit of 50 μg/L.

The comparative study of samples of all the districts analyzed showed that district Faridkot has maximum contamination of 92% followed by district Sangrur 88%, Bathinda 86%, Ferozepur 74%, and Muktsar 60%, respectively (Fig. 1).

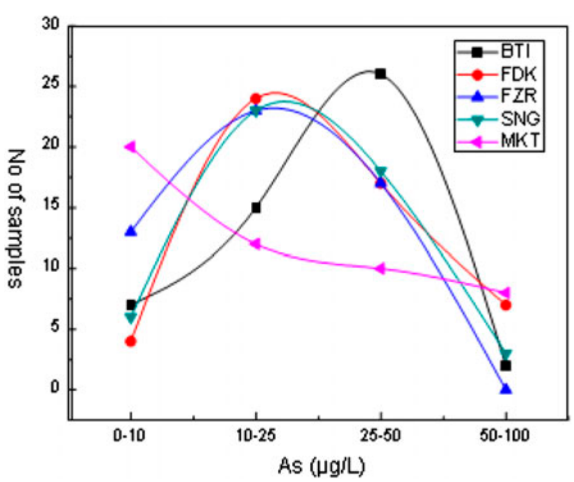

Fig. 1. Level of arsenic contamination in southwestern districts of Punjab.

In Faridkot alone, 46 samples were found to have arsenic more than the safe limit. Twenty-four samples were in the range of 10–25 μg/L and 17 samples indicated arsenic in the range of 25–50 μg/L. The maximum arsenic concentration of 100 μg/L was observed at 30° 39′ 54.11′′ N and 74° 45′ 30.89′′ E (Dogar Basti, Faridkot) and 30° 41′ 3.73′′ N and 74° 44′ 56.02′′ E (Guru Nanak Colony) in Faridkot district.

In Ferozepur, 74% of the samples taken from central city, cantonment area and adjoining villages were found to have arsenic beyond the safe limit. The water sample taken from public water supply tube-well located at 30° 57′ 12.20′′ N and 74° 37′ 30.14′′ E coordinates providing supply to nearly 250 houses in the region was found to have arsenic in the range of 25–50 μg/L.

In Muktsar, a total of 50 samples were tested, 16% of the tested samples were found having arsenic content five times higher than the WHO permissible limit. Areas with 30° 28′′ 42.16′′ N and 74° 32′′ 28.09′′ E showed maximum contamination with mean arsenic value 46.5, SD = 5.09, and SEM = 1.60.

The detailed examination of physico-chemical parameters of samples of surveyed districts of Malwa region is given in Table 5.

The mean arsenic level detected in water samples obtained from municipal water supply of Ferozepur district was 14.14 (SD = 5.17, SEM = 0.73), marginally higher than WHO/EPA recommended value of 10 μg/L, while the mean arsenic level detected in samples of district Faridkot was 25.17 (SD = 5.97 and SEM = 0.84), which is 2.5 times the WHO recommended limit. The mean arsenic value of district Sangrur 21.21(SD = 7.59, SEM = 1.07), Bathinda 23.75 (SD = 5.50, SEM = 0.77), and Muktsar 21.86 (SD = 5.30, SEM = 0.74) were also found more than double the 10 μg/L recommended limit.

The mean arsenic concentration in underground water samples obtained from public hand-pumps/

Table 5
Physico-chemical parameters of drinking water along with their statistical analysis

Sample no.	Location	No. of samples	pH	TDS	EC	Arsenic level			
						Range	Mean	S.D	S.E.M
District Ferozepur									
1	30° 57′ 12.20′′ N 74° 37′ 30.14′′ E	10	7.6–8.0	656–880	426.4–572	40	17.50	5.88	1.85
2.	30° 57′ 20.21′′ N 74° 37′ 29.57′′ E	10	7.6–8.2	560–895	364–581.75	40	32.50	8.39	2.653
3.	30°57′58.06′′N 74° 36′ 17.92′′ E	10	7.9–8.4	526–1,200	341.9–780	15	16.75	2.24	0.708
4.	30°57′20.18′′ N 74° 37′ 2.46′′ E	06	7.7–8.6	560–780	364–507	15	18.25	4.57	1.87
5.	30°57′ 40.72′′ N 74° 36′ 24.88′′ E	06	7.6–8.1	802–865	521.3–562.25	15	16.25	2.03	0.83
6.	30° 56′ 40.70′′ N 74° 36′ 45.85′′ E	06	7.5–8.0	300–585	195–380.25	15	15.00	1.89	0.77
7.	30° 57′ 36.00′′ N 74° 36′ 36.00′′ E	02	7.6–7.7	656–880	426.4–572	15	17.50	5.82	4.11
District Faridkot							*14.14*	*5.17*	*0.73*
1.	30° 43′ 31.12′′ N 74° 42′ 11.25′′ E	07	6.9–8.2	109–10,000*	70.85–6,500*	40	21.07	12.73	4.18
2.	30° 41′ 31.27′′ N 74° 47′ 47.79′′ E	06	7.4–8.8	264–10,000*	171.6–6,500*	15	17.5	6.12	2.50
3.	30° 27′ 3.74′′ N 74° 53′ 22.24′′ E	05	7.4–8.6	132–3,070	85.8–1995.5	7.5	21.00	3.80	1.69
4.	30° 25′ 18.88′′ N 74° 50′ 25.73′′ E	06	7.5–8.2	193–10,000*	125.45–6,500*	7.5	18.76	2.98	1.22
5.	30° 39′ 54.11′′ N 74° 45′ 30.89′′ E	06	7.4–7.9	250–889	162.5–577.85	50	50.00	0.00	–
6.	30° 41′ 3.73′′ N 74° 44′ 56.02′′ E	05	7.7–7.9	295–560	191.75–364	25	37.5	5.00	1.89
7.	30° 39′ 54.84′′ N 74° 44′ 50.92′′ E	05	7.7–7.8	545–890	354.25–578.5	7.50	19.00	3.00	1.13
8.	30° 41′ 24.97′′ N 74° 39′ 53.74′′ E	03	7.6–8.4	NA	–	7.5	20.00	3.53	2.04
9.	30° 40′ 24.34′′ N 74° 44′ 29.06′′ E	03	7.6–8.3	440–674	286–438.1	7.5	20	3.53	2.04

(*Continued*)

Table 5 (*Continued*)

Sample no.	Location	No. of samples	pH	TDS	EC	Arsenic level			
						Range	Mean	S.D	S.E.M
10.	30° 35′ 16.32″ N 74° 49′ 6.81″ E	04	8.1–8.7	330–1,270	214.5–825.5	7.5	21.50	3.75	1.87
District Bathinda							*25.17*	*5.97*	*0.84*
1.	30° 12′ 39.58″ N 74° 56′ 43.71″ E	10	7.4–7.8	267–825	173.55–536.25	7.5	19.00	3.00	0.94
2.	30° 13′ 20.47″ N 74° 56′ 2.76″ E	10	7.3–8.1	190–702	123.5–456.3	7.5	23.50	2.60	0.82
3.	30° 13′ 16.37″ N 74° 57′ 43.77″ E	10	7.4–8.1	442–965	287.3–627.25	7.5	22.00	3.67	1.16
4.	30° 13′ 2.75″ N 74° 57′ 4.50″ E	10	7.5–8.4	314–774	204.1–503.1	7.5	27.50	7.50	2.37
5.	30° 13′ 33.46″ N 74° 56′ 51.10″ E	10	7.5–8.3	280–792	182–514.8	32.5	26.75	8.06	2.54
1.	30° 12′ 39.58″ N 74° 56′ 43.71″ E	10	7.4–7.8	267–825	173.55–536.25	7.5	19.00	3.00	0.94
2.	30° 13′ 20.47″ N 74° 56′ 2.76″ E	10	7.3–8.1	190–702	123.5–456.3	7.5	23.50	2.60	0.82
3.	30° 13′ 16.37″ N 74° 57′ 43.77″ E	10	7.4–8.1	442–965	287.3–627.25	7.5	22.00	3.67	1.16
4.	30° 13′ 2.75″ N 74° 57′ 4.50″ E	10	7.5–8.4	314–774	204.1–503.1	7.5	27.50	7.50	2.37
5.	30° 13′ 33.46″ N 74° 56′ 51.10″ E	10	7.5–8.3	280–792	182–514.8	32.5	26.75	8.06	2.54
District Sangrur						*23.75*	*5.50*	*0.77*	
1.	30° 14′ 51.31″ N 75° 50′ 37.55″ E	10	7.5–8.3	384–856	249.6–556.4	7.5	24.25	2.25	0.71
2.	30° 15′ 20.37″ N 75° 51′ 29.34″ E	10	7.5–8.5	227–766	147.55–497.9	32.5	27.05	11.5	3.63
3.	30° 14′ 59.34″ N 75° 50′ 21.13″ E	10	7.7–8.3	960–2,580	624–1,677	40	20.00	11.2	3.54
4.	30° 15′ 2.13″ N 75° 51′ 35.63″ E	10	7.6–7.9	770–1,688	500.5–1097.2	15	16.50	4.04	1.27
5.	29° 56′ 6.31″ N 75° 48′ 44.69″ E	10	7.8–8.3	1,180–4,000	767–2,600	7.5	18.25	2.25	0.71
District Muktsar						*21.21*	*7.59*	*1.07*	
1.	30° 28′ 42.16″ N	10	7.7–8.6	349–2080	226.85–1,352	12.5	46.5	5.09	1.60

(*Continued*)

Table 5 (*Continued*)

Sample no.	Location	No. of samples	pH	TDS	EC	Arsenic level			
						Range	Mean	S.D	S.E.M
	74° 32′ 4.09″ E								
2	30° 28′ 37.77″ N 74° 31′ 3.53″ E	10	7.5–8.3	1,160–3,027	754–1967.55	15	20.05	6.47	2.04
3	30° 27′ 39.97″ N 74° 31′ 36.43″ E	10	7.5–7.9	880–2,560	572–1,664	15	13.75	5.03	1.59
4	30° 28′ 9.27″ N 74° 30′ 32.16″ E	10	7.5–7.8	774–2,856	503.2–1856.4	15	12.25	4.46	1.41
5	31° 49′ 42.70″ N 70° 53′ 28.14″ E	10	7.6–8.1	652–1,470	423.8–955.5	15	16.75	5.25	1.66
		250					*21.86*	*5.30*	*0.74*

Table 6
Variation in concentration of arsenic w.r.t depth of well/hand pumps

S. no.	Global position	Depth	Arsenic conc. (μg/l)
1.	30° 43′ 49.58″ N 74° 43′ 50.81″ E	110 feet	Nil
2.	30° 41′ 23.73″ N 74° 39′ 53.21″ E	40 feet	25
3.	30° 41′ 10.49″ N 74° 44′ 59.12″ E	45 feet	17
4.	30° 43′ 52.36″ N 74° 42′ 33.35″ E	90 feet	17.5
5.	30° 43′ 31.52″ N 74° 42′ 9.32″ E	25 feet	Nil
6.	30° 43′ 31.52″ N 74° 42′ 9.32″ E	33 feet	Nil
7.	30° 41′ 31.27″ N 74° 47′ 47.79″ E	60 feet	25
8.	30° 25′ 18.89″ N 74° 50′ 25.72″ E	40 feet	20
9.	30° 25′ 13.72″ N 74° 50′ 29.73″ E	90 feet	Nil
10.	30° 25′ 18.89″ N 74° 50′ 25.72″ E	35 feet	Nil
11.	30° 43′ 31.52″ N 74° 42′ 9.32″ E	35 feet	50
12.	30° 43′ 31.52″ N 74° 42′ 9.32″ E	100 feet	Nil
13.	30° 43′ 31.52″ N 74° 42′ 9.32″ E	40 feet	25
14.	30° 41′ 32.37″ N 74° 47′ 52.61″ E	100 feet	10
15.	30° 41′ 33.03″ N 74° 47′ 54.77″ E	50 feet	25
16.	30° 27′ 4.81″ N 74° 53′ 10.95″ E	45 feet	50
17.	30° 25′ 11.86″ N 74° 50′ 29.12″ E	100 feet	5
19.	30° 13′ 26.64″ N 74° 59′ 54.03″ E	95 feet	5
20.	30° 12′ 39.58″ N 74° 56′ 43.71″ E	90 feet	Nil
21.	30° 34′ 9.61″ N 74° 55′ 20.42″ E	35 feet	50
22.	30° 57′ 7.90″ N 74° 37′ 9.12″ E	140 feet	10
23.	30° 57′ 23.37″ N 74° 37′ 28.82″ E	180 feet	Nil

submersible pumps and tube-wells installed at a depth ranging from 25 to 110 feet is 15.17 (Table 6).

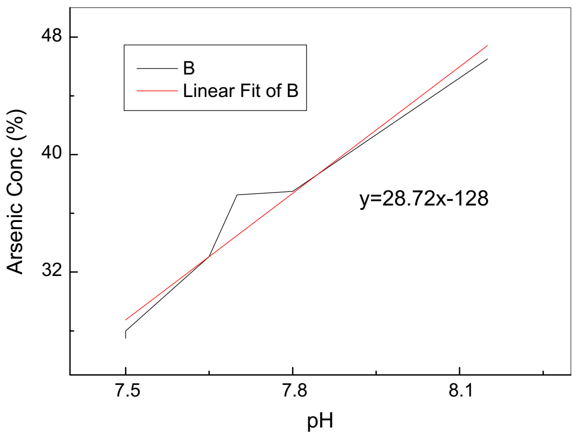

Fig. 2. Linear fit between pH and arsenic concentration.

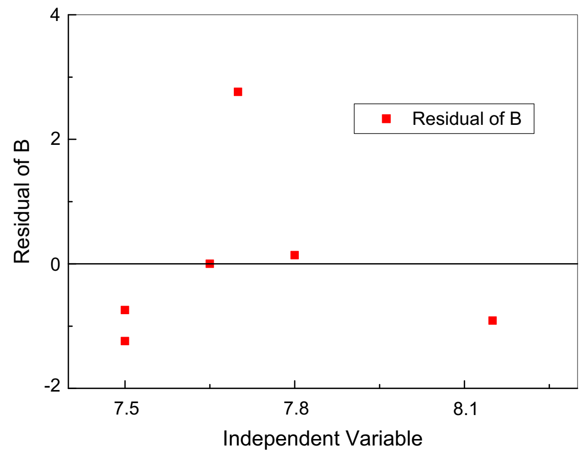

Fig. 3. Figure showing residual effect of independent variables.

It has been observed that 34% samples showed arsenic contamination beyond the permissible limit. Most of the contamination has been observed in depth range 25–60 feet and no significant contamination has been seen in the ground water samples obtained from deep i.e. above 90 feet.

Most of the samples having high TDS/electrical conductivity and high pH also showed high arsenic content (Table). A positive correlation between pH and arsenic concentration was observed with $r^2 = 0.9474$.

4. Statistical analysis

An effort has been made to correlate the effect of pH on the concentration of As in the underground source of water. Origin 9.0 (Origin lab, USA) software has been used to evaluate the correlation between the pH on the concentration of As (Fig. 2) and study showed that there is a positive correlation between pH and arsenic concentration. The linear correlation lines with high coefficient of variation ($r^2 = 0.94$) implies that increase in pH level leads possibility of higher concentration of As content in water samples. Analysis of Variance (ANOVA) with F value < 0.006 also implies that the model is highly significant (Table 7).

Fig. 3 shows the residual effect of independent variables like pH. Data shows that all the points are either on the line or are almost in the proximity of mean value, which again favors linear correlation between dependent and independent variables.

5. Conclusion

Present study reveals the status of drinking water quality of Malwa region of Punjab regarding the presence of arsenic. The foregoing discussion concludes that water quality in the Punjab is fast deteriorating and the situation calls for urgent and effective measures before the situation becomes irretrievable. Both urban and rural water supplies across the southwestern districts of Punjab are largely contaminated due to anthropogenic and natural geochemical activities. The results showed high content of TDS, pH, electrical conductivity, and arsenic along with high variability, which is a matter of great concern and thus leading to adverse effects on the people residing in the study area. The study has revealed that 80% of the total samples analyzed were having arsenic concentration more than the permissible limit of 10 μg/L, even 8% of them showed arsenic concentration more than five times higher than the safe limit. Findings also showed that 34% samples with mean arsenic concentration 15.17, collected from public hand pumps/submersible pumps were not fit for human consumption. A

Table 7
ANOVA showing linear fitness of data

	DF	Sum of squares	Mean square	F-value	Prob > F-value	Adjusted R^2
Model	1	242.02728	242.02728	91.49454	0.0064	0.94764
Model	4	10.58106	2.64526			
Error	5	252.60833				

positive correlation between pH and arsenic level has also been observed.

Acknowledgments

This study was supported by financial assistance provided by the Department of Science and Technology, New Delhi, Government of India and Adesh Institute of Engineering and Technology, Faridkot, for providing the necessary support and laboratory to carry out the study.

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