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Groundwater Arsenic Contamination and its Implications: A Case Study of Shahpur Block of Bhojpur District, Bihar

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Abstract: *Bhojpur district is one of the 36th districts in Bihar composed of 14 blocks. Out of 14 blocks, 06 blocks namely Ara, Barhara, Bihia, Koilwar, Shahpur and Udwant Nagar, situated along the bank of Ganga river are severely affected by ground water arsenic contamination. In the present study, Shahpur block has taken into consideration for assessment of groundwater arsenic contamination, impact of arsenic on grain quality and human health, average daily consumption of arsenic by inhabitants of affected villages and total agricultural area affected due to irrigation through arsenic contaminated groundwater. Shahpur block is composed of 86 revenue villages. Out of 86 revenue villages, 30 villages were selected for assessment of arsenic contamination in groundwater. Study findings reveals that out of total 30 selected revenue villages, 27 villages are severely affected by groundwater arsenic contamination. Maximum concentration of arsenic findings was obtained in hand pump of village Karnamepur where the level of arsenic was 598 ppb. Out of 30 revenue villages, only three villages namely Harkhi Pipra, Suhiya and Domariya were arsenic free. Study findings shows that 2137.11 hectares irrigated agricultural land (43.76 % of blocks irrigated land) of 27 revenue villages in Shahpur block is irrigated by arsenic contaminated groundwater. These agricultural land and crops cultivated in the affected area are vulnerable to assimilation of groundwater arsenic through irrigation. The elevated level of arsenic in food grains may result since crops receiving arsenic contaminated groundwater as a source of irrigation can uptake arsenic during the phyto-extraction process and bio-accumulate in different degrees in different parts of plants. The present study findings also reveals that the average per capita consumption of arsenic by children, young person, adults and old persons are 0.227 mg/L, 0.489 mg/L, 0.559 mg/L and 0.568 mg/L respectively. The identified per capita arsenic consumption in arsenic affected villages has exceeded the maximum allowable limit of arsenic consumption through water and food.*

Key words: *agricultural field, groundwater arsenic, irrigation, arsenic in food grains*

I. Introduction

Arsenic (As) is a metalloid element (atomic number 33) with one naturally occurring isotope of atomic mass 75, and four oxidation states (-3, 0, +3, and +5) [1]. In the aqueous environment, the +3 and +5 oxidation states are most prevalent, as the oxyanions arsenite (H_3AsO_3 or $H_2AsO_3^-$ at pH ~9-11) and arsenate ($H_2AsO_4^-$ and $HAsO_4^{2-}$ at pH ~4-10) [1]. In soils, arsine gases (containing As_3^-) may be generated by fungi and other organisms [2].

There are about 24 As-bearing minerals that are commonly found in hydrothermal veins, ore deposits, and rocks. Most primary As minerals are sulfides, of which arsenopyrite is the most common [3]. Secondary minerals tend to be less common arsenates and oxides. Arsenic in crustal rocks also has an affinity for, and is associated with, pyrite or Fe hydroxides and oxides [4] for which chemical formulas are FeS_2, FeOOH, Fe_2O_3, and Fe_3O_4, respectively.

High As concentrations have been found in both surface waters and shallow groundwater from the area around the mining activity as a result of natural oxidation of arsenopyrite, mining activity and release following post-mining groundwater rebound [5]. It is reported that concentrations of As in the surface waters reaching up to 580 µg/L. [6].

There is no proof regarding the natural emission of As in the Ganga–Brahmaputra plains so far. However, the release of As, by the natural processes in groundwater, has been recognized, from the Holocene sediments comprising sand, silt and clay [7,8] in parts of the Bengal Delta Plains (BDP), West Bengal and in the Gangetic plains of Bihar. Several isolated geological sources of As have been recognized, viz. Gondwana coal seams in Rajmahal basin (200 mg/kg of As), Bihar mica-belt (0.08–0.12% of As), pyrite-bearing shale from the

Proterozoic Vindhyan range (0.26% of As), Son valley gold belt (2.8% of As) and Darjeeling Himalayas belt (0.8% of As) [9,10,11,12]. The contaminated aquifers are of Quaternary age and comprise micaceous sand, silt and clay derived from the Himalayas and basement complexes of eastern India. These are sharply bound by the River Bhagirathi-Hooghly (distributaries of the River Ganges) [13] in the west, the rivers, Ganges and Padma in the north, the flood plain of the River Meghna (tributary of the River Padma), and the River Yamuna in the northeast [14].

The actual source of groundwater arsenic contamination, in the Ganga–Brahmaputra basin, is yet to be established. The sources of arsenic are natural or may partly stem from anthropogenic activities like intense exploitation of groundwater, application of fertilizers, burning of coal and leaching of metals from coal-ash tailings. The hypotheses about the sources of arsenic in the BDP are as follows:

(i) Arsenic, transported by the River Ganges and its tributaries from the Gondwana coal seams in the Rajmahal trap area located at the west of the basin can be of the order of 200 ppm. [15].

(ii) Arsenic is transported by the north Bengal tributaries of Bhagirathi and Padma from near the Gorubathan base-metal deposits in the eastern Himalayas [16].

(iii) Arsenic is transported with the fluvial sediments from the Himalayas [8]. This is the most accepted hypothesis at present.

Several studies suggested that the groundwater arsenic contamination is mostly restricted to the alluvial aquifers of the Ganges delta comprising sediments carried from the sulphide-rich mineralized areas of Bihar and elsewhere surrounding the basin of deposition [17].

The first case of arsenic in India was reported in 1976 from Chandigarh [18]. Since then widespread arsenic contamination has been reported in groundwater from many parts of India including West Bengal, Bihar, Chhattisgarh, Jharkhand, Uttar Pradesh and Assam and other regions of Punjab, Haryana, and Himachal Pradesh, surroundings of New Delhi, the union territory of Chandigarh, and the state of Rajasthan [19]. Among them, the most severely contaminated state is West Bengal where 12 districts and 26,00,000 people are affected [18,19,20].

In West Bengal, India, cases of arsenic poisoning were first noted in 1983-84 [21], although in the year of 1978 arsenicosis (skin lesions) and groundwater contamination were first noticed in West Bengal [22]. Since the 1980s, extensive sampling of well water in West Bengal has revealed levels of As that exceed 50 μg/L concentrations in some samples exceeding 1000 μg/L [21]. In 1983-84, several patients treated for arsenicosis in West Bengal came from neighbouring Bangladesh. Sampling in Bangladesh during the early 1990s from tube wells (installed two decades earlier to provide what was thought to be safe, pathogen-free drinking water) revealed elevated concentrations of As [23].

In the recent study on assessment of arsenic contamination in groundwater of Bihar a number of districts of Bihar namely Begusarai, Bhagalpur, Bhojpur, Buxar, Darbhanga, Katihar, Khagaria, Kishanganj, Lakhiserai, Munger, Patna, Purnea, Samastipur, Saran, Vaishali are arsenic effected districts [24].

In Bhojpur district, out of total 14 blocks, 06 blocks namely Ara, Barhara, Behea, Koilwar, Shahpur and Udwant Nagar, situated along the Ganga river bank are affected by groundwater arsenic contamination. In the present study, out of 86 revenue villages of Shahpur block, 30 revenue villages were selected for assessment of arsenic contamination in groundwater. Out of 30 selected revenue village of block, only three villages namely Harkhi Pipra, Suhiya and Domariya are free from groundwater arsenic contamination. Further, 27 revenue village of block having 73,775 people and 11,792 (15.98%) children (0-6 years) are vulnerable by consuming arsenic contaminated groundwater (50 and over 50 ppb). The concentration of groundwater arsenic consuming by the villagers is much higher than the World Health Organisation (WHO) limit (10 ppb).

II. Study Area

Shahpur is one of the 14th blocks of Bhojpur district situated on the bank of river Gnaga and located at $25^0$35.972'N latitude and $84^0$24.108'E longitude. The block is approximately 27.5 km (aerial distance) away from the Ara town (distract headquarter) of Bhojpur. The block is composed of 23 panchayats, 86 villages and 99 habitations. The study area in the block is spread over a 10 km. belt running roughly parallel to the river Ganga. Most of the selected villages and their tolas in the study area are known as flood affected area. The main sources of livelihood of the area are agriculture and livestock.

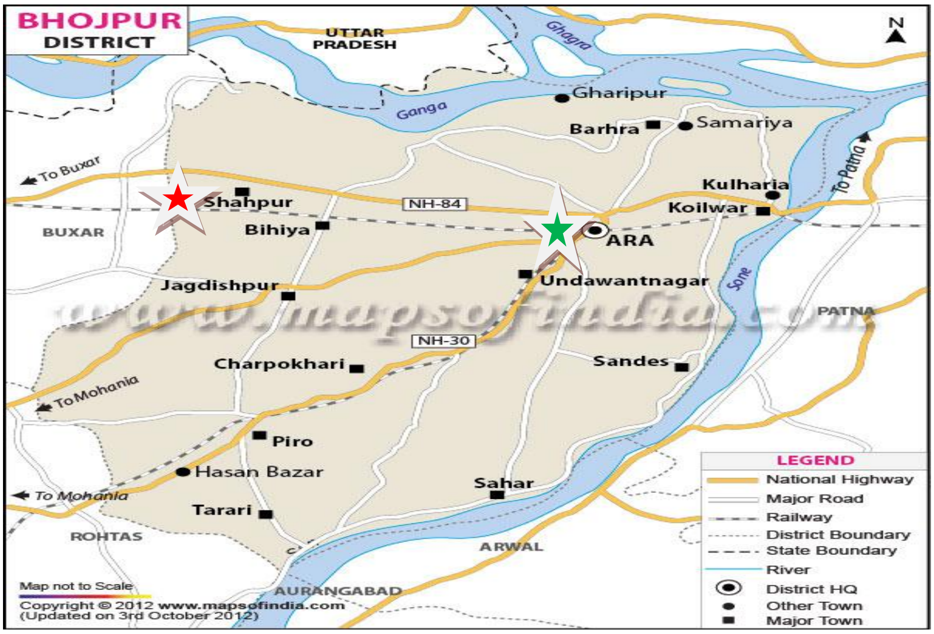

Fig.1.1: Map of Bhojpur district showing location of Ara and Shahpur block

In the present study, 27 revenue villages of the block were selected to assess the extent of groundwater arsenic contamination, area of agricultural field irrigated by arsenic contaminated groundwater, quality of food grains and vegetables cultivated in the area and also to identify the daily consumption of arsenic by the villagers from various sources. The assumptions about food grains and vegetables containing arsenic which are grown in the arsenic affected area is based on the previous study undertaken by the researchers.

III. Materials And Methods

In the present study, testing of groundwater samples of the study area has done by reliable laboratory-based testing methods i.e., UV/VIS Spectrophotometry and Atomic Absorption Spectrophotometry (AAS) methods. However, Field Test Kits [FTKs] are essential for quick preliminary survey, and met the immediate priority of identifying the most contaminated groundwater sources. All the hand pumps of the villages under study were tested for Arsenic content by FTKs. 10% of random verification of FTK results was done by UV (Ultra Violet) Spectrophotometer. Thereafter, all the results above 40 µg/L were retested using Atomic Absorption Spectrophotometer (AAS).

IV. Results And Discussions

Arsenic Contaminated Hand Pumps in Bhojpur District

In Bhojpur district total 5,917 water samples of public hand pumps were assessed by FTK (Field Test Kit) to know the approximate level of arsenic content in the groundwater. Out of total 5,917 water samples of public hand pumps, 2,806 (47.42%) samples were contaminated with arsenic. Taking into account the permissible limit of 10 µg/L set by WHO 1993 [25], Table 1.1 shows the percentage of arsenic contaminated groundwater in selected bocks of Bhojpur districts. However, the selected blocks in the district show considerable number of safe or below detectable limit (BDL) marked hand pumps. Comparing to all selected blocks of the district, maximum number of contaminated hand pumps were identified in Barhara block (Table 1.1).

Table 1.1: Percentage arsenic affected blocks of Bhojpur district (FTK Readings)

Sl. No.	Name of Block	Arsenic Concentration 11 ppb and above
1	Barhara	55.35 %
2	Shahpur	37.97 %
3	Bihia	33.37 %
4	Udwant Nagar	55.69 %
5	Ara	15.23 %
6	Koilwar	26.12 %

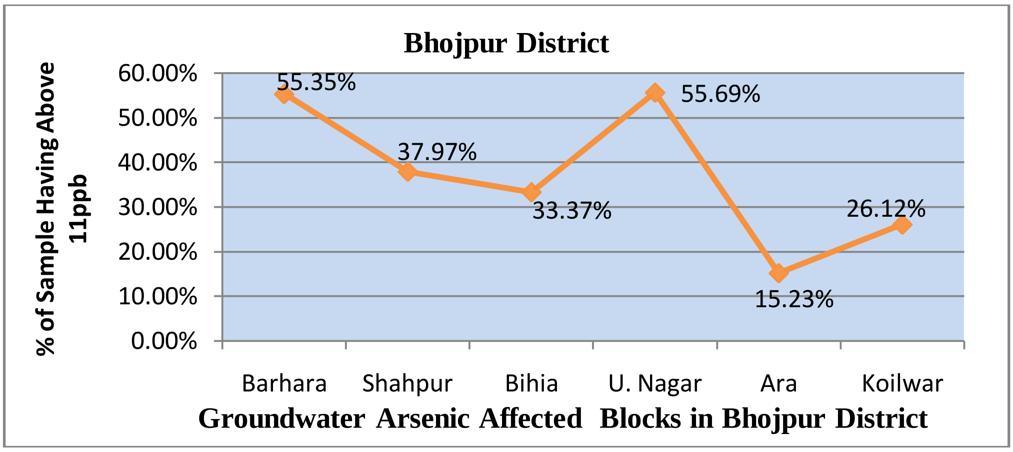

Fig.1.2: Status of percentage arsenic contaminated blocks of Bhojpur district

A base map of arsenic hot spots (block-wise) in the district was prepared on the basis of FTK data of 5,917 groundwater samples. In the base map, red coloured dots (>101 µg/L arsenic) showing alarming level of arsenic contamination in affected revenue villages and their tolas of the blocks. The Global Positioning System (GPS) data were used during preparation of the base map of arsenic affected areas (Fig. 1.3).

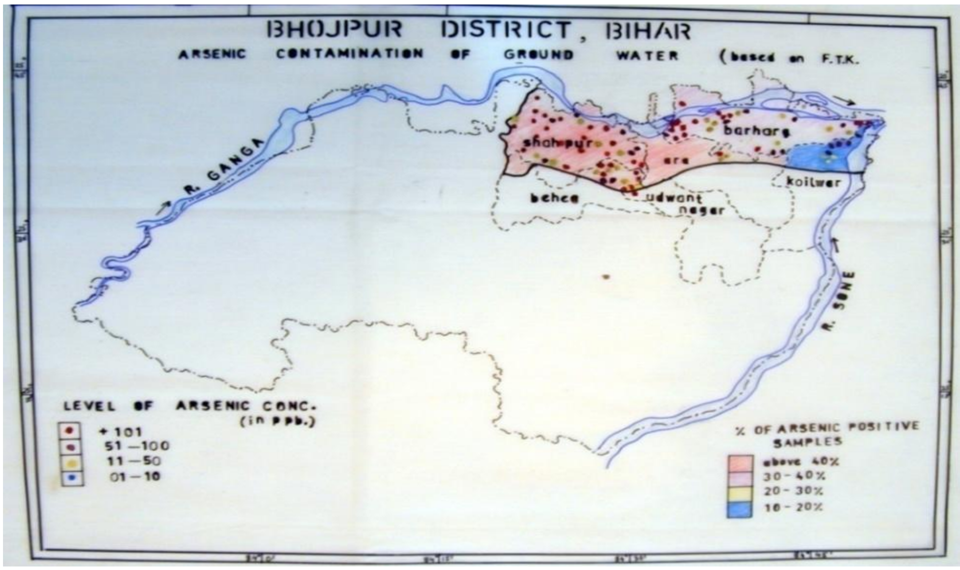

Fig. 1.3: Arsenic contaminated blocks of Bhojpur district, based on FTK data & GPS fixes

Arsenic Affected Villages in Shahpur Block

In Shahpur block of Bhojpur district total revenue villages are 86. Out of 86 revenue villages, 30 revenue villages were selected for assessment of arsenic contamination in groundwater. All selected villages of the block are located along the southern boundary of Ganga river distanced up to 10 km from the bank.

The study findings reveals that out of 30 selected revenue villages, only three villages namely Harkhi Pipra, Suhiya and Domariya are free from groundwater arsenic contamination. Remaining 27 revenue villages towards the southern part from the bank of the Ganga river were identified as arsenic contaminated villages. The details of groundwater arsenic contaminated revenue villages with population are shown in Table 1.2.

Table 1.2: Groundwater arsenic contaminated villages of Shahpur block

S. No.	Block	Arsenic Affected Revenue Villages (50 and over 50 ppb by FTK)	Total Population	Population (0-6 Years)
1	Shahpur	Parsonda	1,967	292
2	Shahpur	Ramdatahi	3,131	473
3	Shahpur	Sonbarsa	3,070	526
4	Shahpur	Sarna	5,568	844
5	Shahpur	Isharpura	4,254	628
6	Shahpur	Milki Gopalpur	1,254	194

7	Shahpur	Karnamenpur	4,402	710
8	Shahpur	Chakki Nauranga Ojhwalia Diara	836	112
9	Shahpur	Ram Karhi (Ditto)	629	141
10	Shahpur	Mirchaiya Ka Dera (Ditto)	1,328	174
11	Shahpur	Misrauliya	759	104
12	Shahpur	Gashainpur	834	141
13	Shahpur	Bishunpur	317	71
14	Shahpur	Dudh Ghat	1,285	261
15	Shahpur	Nargada	1,226	136
16	Shahpur	Barsaun	8,586	1,338
17	Shahpur	Semariya Palti Ojha	5,788	976
18	Shahpur	Bahoranpur Dakhinwar	2,326	411
19	Shahpur	Karja	3,453	519
20	Shahpur	Paharpur	1,822	345
21	Shahpur	Jhaua	11,459	1,995
22	Shahpur	Dhauri	1,724	246
23	Shahpur	Pakri	1,645	236
24	Shahpur	Dumariya	3,265	460
25	Shahpur	Abatana	346	51
26	Shahpur	Dewaich Kundi	1,281	223
27	Shahpur	Bansipur	1,220	185
Total			**73,775**	**11,792**

Source: Census 2011

In Shahpur block, total 1,018 groundwater samples of public hand pumps were tested through (FTK). Out of total 1,018 groundwater samples of public hand pumps, 102 samples shown arsenic concentration in between 01 to 10 ppb, 386 samples shown arsenic concentration in between 11 to 50 ppb and remaining 530 samples shown arsenic concentration in between 51 to 110 ppb respectively (Table 1.3).

Table 1.3: Number of F.T.K tested drinking water samples in Shahpur block

Sl. No.	Arsenic contamination (in ppb)	No. of samples
1	01 to 10 ppb.	102
2	11 to 50 ppb.	386
3	51 to 110 ppb.	530
Total		**1,018**

A base map of arsenic affected areas (village-wise) in the block was prepared on the basis of FTK data of 1,018 groundwater samples. In the base map, red coloured dots (over 50 µg/L arsenic) showing alarming level of arsenic contamination in affected villages of the block. The GPS data were used during preparation of base map of As affected villages (Fig. 1.4).

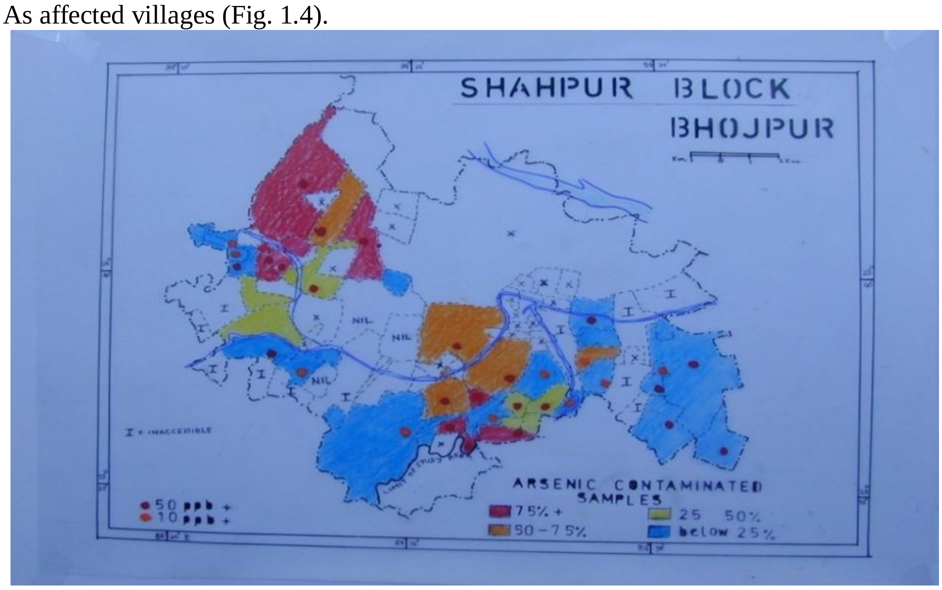

Fig. 1.4: Arsenic contaminated village of Shahpur block, based on FTK data & GPS

Further, out of total 1,018 groundwater samples of public hand pumps, 308 samples were tested through AAS-HG by Sriram Institute of Industrial Research (SIIR), New Delhi. The selected 308 groundwater samples has already shown the high arsenic content during FTK testing in the field environment were sent to the SIIR for final confirmation and data base. Maximum concentration of arsenic findings was obtained in hand pump of village Karnamepur where the level of arsenic was 598 ppb. The details of the arsenic content (range-wise) in 308 groundwater samples of selected 27 revenue villages of Shahpur block are shown in Table 1.4.

Table 1.4: Number of ASS-HG tested drinking water samples in Shahpur block

Sl. No	Arsenic content (µg/L)	No. of samples containing arsenic in a specific range
1	BDL	50
2	1-9	23
3	10-49	69
4	50-99	70
5	100-199	61
6	200-299	20
7	300-399	07
8	400-499	05
9	500-599	03
Total		**308**

Out of 1,018 hand pumps surveyed in the block, 166 hand pumps in various villages of block shows more than 50 ppb concentration of groundwater arsenic. The villages which show more than 50 ppb concentration of arsenic were Karnamenpur, Isharpura, Ram Karhi, Sonbarsa, Mirchaiya Ka Dera, Milki Gopalpur, Chakki Nauranga Ojhwalia Diara, Bansipur, Sarna, Parsonda and Ramdatahi.

Based on 308 tested and identified groundwater samples of public hand pumps by AAS-Hg in Shahpur block, Table 1.4 shows the specific number of samples having specific range of arsenic concentration. Out of total 308 groundwater sample of the study area, 50 samples shown the arsenic content Below Detectable Limit (BDL) and 01 sample shown the highest arsenic level of 598 ppb (Karnamepur village).

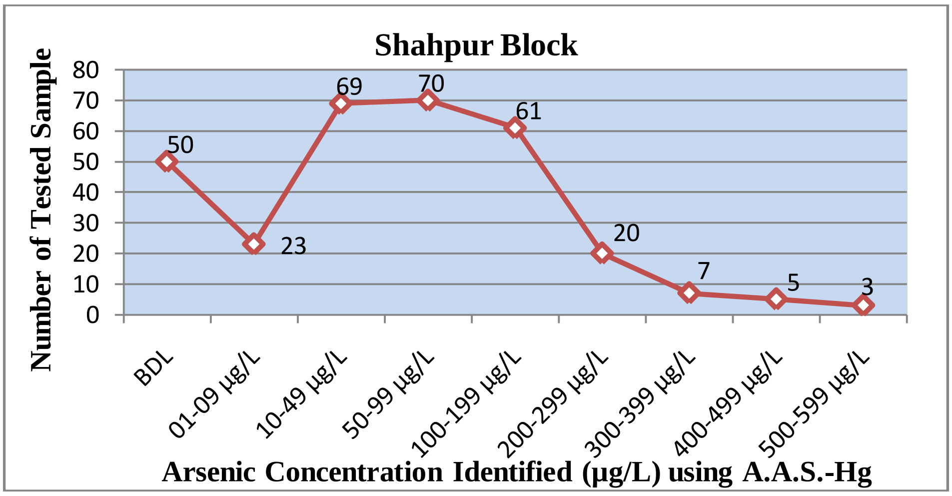

Fig. 1.5: Status of ASS-HG tested drinking water samples in Shahpur block

Arsenic Content in Food Grains

Arsenic concentration in uncontaminated soils in some Bangladesh districts ranged between 0.10 and 2.75 mg/kg. In contrast, in areas where irrigation is carried out with contaminated groundwater, the soil As level is reported to be up to 81 mg/kg [26, 27]. The elevated level of As in soil has resulted in elevated concentrations of As in food since crops receiving arsenic contaminated irrigated water can uptake As during the phyto-extraction process and bio-accumulated in different degrees in different parts of plants (e.g. roots, stems, and grains). Several research studies have found high concentrations of arsenic in vegetables and rice in areas where concentrations of arsenic in soil and water are also high.

Higher concentrations of arsenic were also reported in rice plants (*boro* rice) in the following orders: rice roots > rice stem > rice leaf > rice grain > rice husk [26]. It is therefore evident that, the food chain could be a significant pathway of As ingestion by the people of Bangladesh [28]. The arsenic-contaminated irrigation water (0.318– 0.643 mg/L) and soil (5.70–9.71 mg/ kg) considerably influenced in the accumulation of arsenic in rice, pulses, and vegetables in West Bengal, India [29].

In previous study, for identification of arsenic content in food grains, seeds of wheat, maize, rice, lentils and rice husk were selected. The samples of seeds and rice husk were taken from village Rampur Diarra of Maner block in Patna district. The village is well known arsenic hot spot of the block. For assessing arsenic content in food grains, the hybrid variety of wheat, maize and rice were Ub-2338, K-H-101 and Sonam. For lentil, locally available lentil seeds were selected. Besides, the food grains, rice husk of Sonam variety was selected for estimation of arsenic contents for comparing its concentration with rice grain [30].

Laboratory findings showed that selected food grains and rice husk have substantial concentration of arsenic contents. The highest value of arsenic contents was shown in wheat grain and minimum in maize seeds. Rice husk has shown comparatively more arsenic content than the rice grain. In comparison with the Australian Food Standard (AFS) i.e., 0.1 mg/kg, the arsenic value in different food grains were within the limit but cumulative effect of arsenic along with arsenic contaminated drinking water significantly affects human health. Details of the exact arsenic concentration in each selected food samples are shown in Table 1.5.

Table 1.5: Arsenic in food samples (Maner block, Patna)

S. No.	Sample Id	Village	Food Item	Variety	As(mg/kg)
1	10/28/0001/900/PMRDF001	Rampur Diara	Wheat	Ub-2338	0.024
2	10/28/0001/900/PMRDF002	Rampur Diara	Maize	K-H-101	0.011
3	10/28/0001/900/PMRDF004	Rampur Diara	Rice	Sonam	0.019
4	10/28/0001/900/PMRDF004	Rampur Diara	Rice husk	Sonam	0.022
5	10/28/0001/900/PMRDF005	Rampur Diara	Lentil	N.A	0.015

Source: Singh, K.S. & Ghosh, K.A. 2011

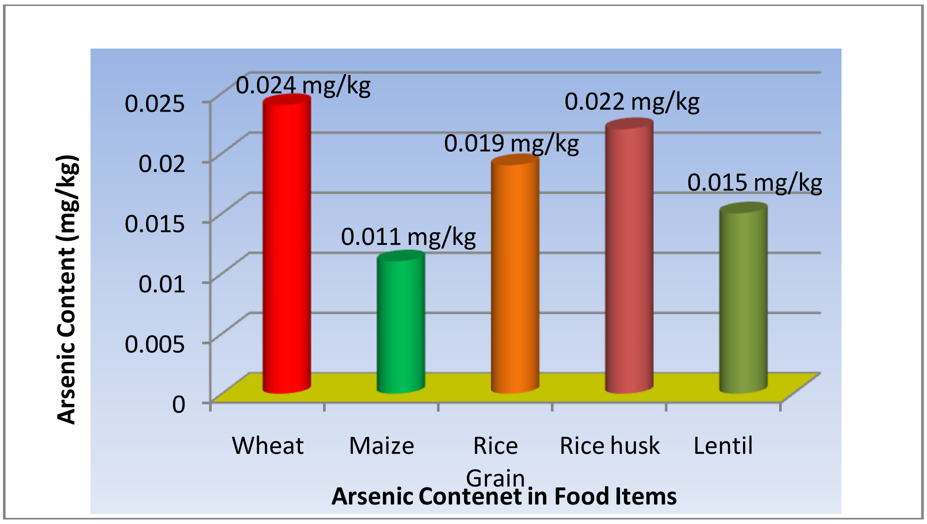

Fig. 1.6: Arsenic in food samples, Maner, Patna (Singh, K.S. & Ghosh, K.A. 2011)

Findings of the above mentioned study carried out in Maner block of Patna district further correlates strongly with chances of findings of substantial amount of arsenic in food grains cultivated in arsenic affected villages of Brahara block.

Daily Consumption of Arsenic

To assess per capita average daily consumption of arsenic from various sources such as drinkable water, cooked foods (rice, pulses, chapatti and vegetables), a survey study was conducted in selected revenue villages (27 village) of Shahpur block (20% sample survey). The average per capita consumption of arsenic from various sources by children, young person, adults and old persons are 0.227mg/L, 0.489 mg/L, 0.559 mg/L and 0.568 mg/L respectively (Table 1.6).

The above findings reveals that per capita arsenic consumption in arsenic affected villages of Shahpur block has exceeded the maximum allowable limit of arsenic consumption through water and food (0.2 mg/kg/day). Hence, the cumulative effect of high arsenic consumption for long duration would be fatal for the habitants of arsenic affected villages.

Table 1.6: Consumption of arsenic from various sources

Village	Type of Person	Consumption of Water					Consumption of Water/Day (Lit.)	Avg. As in Water (mg/L)	Intake of As/Day (mg/L)
		Drinking Water (Lit.)	Rice (Lit.)	Pulse(Lit.)	Chapati (Lit.)	Veg. (Lit.)			
26 selected revenue villages	Children	2.25	0.180	0.095	0.035	0.025	2.585	0.088	0.227
	Young	4.85	0.355	0.150	0.090	0.115	5.56	0.088	0.489
	Adult	5.70	0.300	0.155	0.090	0.110	6.355	0.088	0.559
	Old	5.90	0.280	0.130	0.055	0.100	6.465	0.088	0.568

Source: Field Survey

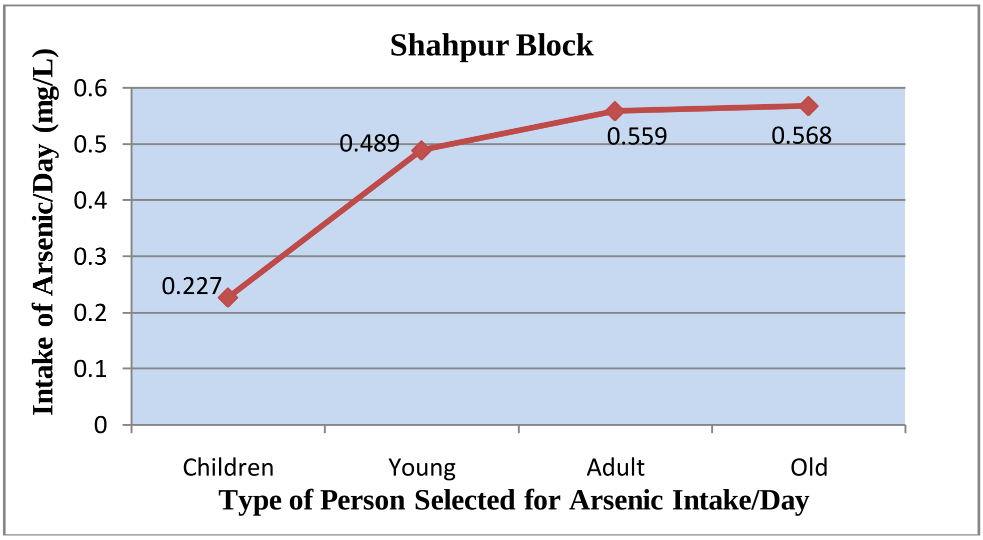

Fig. 1.7: Daily consumption of arsenic from various sources in Shahpur block

Vulnerability of Agricultural Land and Crops Due to Groundwater Arsenic

In Shahpur block, agriculture is the main economic activity of the people, and major crops are wheat, maize, rice, marua, arhar, mung, massor, urad, khesari, mustered, ground nut, lentil, turmeric, zinger, potato, sweet patato, bringal, ladiys finger, beans, tomato, cauliflower, cabbage, onion etc.

The total agricultural land of Shahpur block is 10,722.57 hectare. Total agriculture land of arsenic contaminated villages (27 villages) in block is 5,648.39 hectares which constitute 52.67 % of block's agricultural land, out of this, irrigated and un-irrigated land is 2,137.11 and 3,511.28 hectares which constitute 19.93 % and 32.74 % of total agricultural land respectively (Table 1.7).

Table 1.7: Land use pattern in arsenic contaminated villages (in hectares)

Village	Forest Land	Agricultural Land			Cultivable Waste Land	Area Not Available for Cultivation	Total
		Irrigated	Un-irrigated	Total			
Parsonda	0.00	246.00	5.00	251	1.33	1.00	253.33
Ramdatahi	0.00	10.10	2.83	12.93	0.00	5.28	18.21
Sonbarsa	0.00	220.24	20.26	240.5	22.06	45.00	307.56
Sarna	0.00	278.00	208.00	486	9.00	18.54	513.54
Isharpura	0.00	0.00	1,061.48	1,061.48	0.00	0.00	1,061.48
Milki Gopalpur	0.00	8.09	3.14	11.23	5.26	1.72	18.21
Karnamenpur	0.00	20.00	40.05	60.05	2.02	3.08	65.15
Chakki Nauranga Ojhwalia Diara	0.00	0.00	0.00	0	0.00	0.00	0
Ram Karhi (Ditto)	0.00	0.00	0.00	0	0.00	0.00	0
Mirchaiya Ka Dera	0.00	0.00	0.00	0	0.00	0.00	0
Misrauliya	0.00	28.32	5.67	33.99	10.12	4.05	48.16

Gashainpur	0.00	25.60	44.45	70.05	9.25	3.25	82.55
Bishunpur	0.00	13.96	0.00	13.96	24.89	7.28	46.13
Dudh Ghat	0.00	15.56	39.94	55.5	2.35	2.45	60.3
Nargada	0.00	21.65	43.95	65.6	15.35	18.20	99.15
Barsaun	0.00	49.05	304.38	353.43	12.00	0.00	365.43
Semariya Palti Ojha	0.00	0.00	164.98	164.98	8.23	81.74	254.95
Bahoranpur Dakhinwar	0.00	100.30	504.00	604.3	0.00	10.00	614.3
Karja	0.00	236.74	0.00	236.74	0.00	0.00	236.74
Paharpur	0.00	195.00	5.00	200	0.00	6.79	206.79
Jhaua	0.00	267.45	578.65	846.1	25.25	10.45	881.8
Dhauri	0.00	20.45	39.56	60.01	0.75	0.35	61.11
Pakri	0.00	115.45	156.23	271.68	11.30	5.15	288.13
Dumariya	0.00	165.35	177.25	342.6	12.15	4.20	358.95
Abatana	0.00	44.35	38.00	82.35	16.00	10.10	108.45
Dewaich Kundi	0.00	15.35	30.14	45.49	15.45	16.35	77.29
Bansipur	0.00	40.10	38.32	78.42	3.28	2.88	84.58
Total	**0.00**	**2,137.11**	**3,511.28**	**5,648.39**	**206.04**	**257.86**	**6,112.29**
Block Total	**15.30**	**4,883.23**	**5,839.34**	**10,722.5**	**1,083.43**	**881.63**	**23,425.5**

Source: Census of India-2001, Village Directory

Based on the Census of India, 2001, 2137.11 hectares (43.76 % of blocks irrigated land) of agricultural land in Shahpur block is irrigated by arsenic contaminated groundwater. These agricultural land and the cultivable crops are vulnerable due to assimilation of arsenic through plant roots by irrigation of arsenic contaminated groundwater. Previous laboratory findings supports that the samples of food grains collected from Rampur Diara village of Maner block in Patna district have substantial amount of arsenic. This study strongly supports the hypothesis that if the crops area irrigated by the arsenic contaminated groundwater, a substantial amount of arsenic will be assimilated by the crop plants and will be available in food gains also.

V. Impact of Arsenic on Human Health

Arsenic is a global health concern due to its toxicity and the fact that it occurs at unhealthful levels in water supplies, particularly groundwater, in more than 70 countries [31] of six continents. Chronic exposure to As can cause harm to the human cardiovascular, dermal, gastrointestinal, hepatic, neurological, pulmonary, renal and respiratory systems [32] and reproductive system [33]. The different forms of As have different toxicities, with arsine gas being the most toxic form. Of the inorganic oxyanions, arsenite is considered more toxic than arsenate, and the organic (methylated) arsenic forms are considered least toxic [33].

Inorganic arsenic is one of the few substances that have been shown to cause cancer in humans through consumption of drinking-water. Cancer usually takes more than 10 years to develop. Arsenic can cause cancers of the skin, bladder and lungs, and there is limited evidence that it may also cause cancers of the kidney, liver and prostate [34]. The International Agency for Research on Cancer (IARC) has classified arsenic and arsenic compounds as carcinogenic to humans (Group 1), which means that there is sufficient evidence for their carcinogenicity in humans [35]. The organic arsenic compounds monomethylarsonic acid and dimethylarsinic acid are the active ingredients of some herbicides and are metabolites of inorganic arsenic. On the basis of sufficient evidences of cancer in experimental animals and because monomethylarsonic acid is extensively metabolized to dimethylarsinic acid, both compounds are classified as possibly carcinogenic to humans (Group 2B). Arsenobetaine and other organic compounds that are not metabolized in humans are not classifiable as to their carcinogenicity (Group 3) [34]. Furthermore, IARC has stated that arsenic in drinking-water is carcinogenic to humans (Group 1) [36].

Arsenic exposure from contaminated drinking water of more than 50µg/l is a significant cancer risk. The exposure of human to arsenic contaminated water and foods can lead to some physical changes on the skin such as the appearance of small black or white marks (melanosis), then thickening of the skin on the palms and the feet (keratosis), followed by skin lesions and eventually skin cancer. The development of internal cancer in humans may take 10 years to develop and is often the result of long term exposure to arsenic. The long term ingestion or exposure (10-15 years) of arsenic can lead to a disease called 'Arseniasis, arsenicosis, and arsenicism' [28]. Chronic exposure to arsenic has been linked to carcinogenic effects in both humans and animals. These include cancer of the various skin and various internal organs (lung, bladder, liver and kidney) reproductive and developmental effects; cardiovascular disease; reduced intellectual function in children and mortality. Non-cancer endpoints include hyper-pigmentation, hypo-pigmentation, keratosis of skin, peripheral vascular disease (black foot disease), cardiovascular disease, hypertension and neurotoxicity. There are some claims that chronic exposure of arsenic may also cause diabetes development and prostate cancer [37, 38, 39].

Considering the above facts and figures, the population of selected 27 revenue villages of Shahpur block is critically vulnerable to high arsenic exposure. Out of total population, 15.98 % children (below 06 years age), 13.01 % SC, 1.57 % ST and 85.40 % other category population is vulnerable to arsenic exposure (Table 1.8).

Table 1.8: Population vulnerable to arsenic exposure in selected villages of Shahpur block

S. N.	Particulars	Male	Female	Total
1	**Population Distribution and Sex Ratio**			
2	Population	38,247 (100)	34,879 (100)	73,775 (100)
3	Children below 6 yrs	6,142 (16.05)	5,650 (16.19)	11,792 (15.98)
5	**Caste Distribution**			
6	Schedule Caste	5,038 (13.17)	4,564 (13.08)	9,602 (13.01)
7	Schedule Tribes	630 (1.64)	534 (1.53)	1,164 (1.57)
8	Others	32,579 (85.18)	29,781 (85.38)	63,009 (85.40)
9	**Total population**	**38,247 (100)**	**34,879 (100)**	**73,775 (100)**

Source: Census of India 2001, Figures within parentheses are in percentage

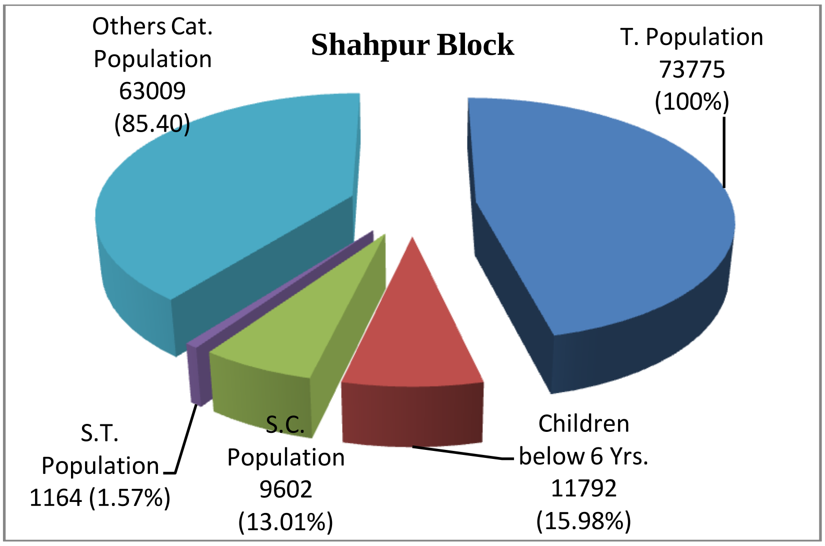

Fig: 1.8: Population vulnerable to arsenic exposure in selected villages of Shahpur block

VI. Food Safety And Security

In the present study, the most well-known concern is entering of arsenic in food chain, affecting food safety. This poses a potential dietary risk to human health in addition to the risk from drinking of contaminated groundwater. Less well known but potentially more serious is the risk of arsenic to crop production. Continuous build up of arsenic in the soil from arsenic contaminated groundwater irrigation reduces crop yields in the long term.

Impact of green revolution resulted in installation of numerous shallow tube wells in the study area over the last three decades. This has caused in a sharp increase of groundwater extraction for irrigation. Based on census 2001, 2,137.11 hectares irrigated agricultural land (43.76 % of blocks irrigated land) in selected 27 revenue village of block is irrigated by arsenic contaminated groundwater especially for cultivation of Rabi and Zaid crops. These agricultural land and the cultivable crops are vulnerable due to assimilation of arsenic through the plant roots by irrigation of arsenic contaminated groundwater. In addition, widespread use of arsenic contaminated irrigation water ultimately leads to issues of food security, food safety and degradation of the environment.

In contrast, based on the general discussions among the villagers of the arsenic affected villages, they says that "even though the villages are suffering from groundwater arsenic contamination but the productivity of various crops are very good and almost equal in comparison of other nearby villages which are free from groundwater arsenic contamination. Further, it is recommended that the assessment of arsenic content in various crops and vegetables grown in the present study area should be undertaken immediately to identify the exact concentration of arsenic content in various food grains and vegetables.

VII. Conclusion

On the basis of overall findings of the present study it is observed that out of total 30 selected revenue villages of Shahpur block in Bhojpur district, 27 revenue villages situated along the bank of the Ganga river are severely affected by groundwater arsenic contamination. Maximum concentration of arsenic findings was obtained in hand pump of village Karnamepur where the level of arsenic was 598 ppb. In selected 27 revenue villages, arsenic free revenue villages were Harkhi Pipra, Suhiya and Domariya only. Present study findings reveals that average per capita consumption of arsenic from all sources i.e., from drinking water, rice, pulses, chapatti and vegetable by children, young person, adults and old persons are 0.227 mg/L, 0.489 mg/L, 0.559 mg/L and 0.568 mg/L respectively. The identified per capita arsenic consumption in arsenic affected villages has exceeded the maximum allowable limit of arsenic consumption through water and food (0.2 mg/kg/day).

Consumption of arsenic greater than its permissible limit though drinking water and foods is fatal for human health. Chronic exposure to arsenic can cause harm to the human cardiovascular, dermal, gastrointestinal, hepatic, neurological, pulmonary, renal and respiratory systems and reproductive system. The exposure of human to arsenic contaminated water and foods can lead to some physical changes on the skin such as the appearance of small black or white marks (melanosis), then thickening of the skin on the palms and the feet (keratosis), followed by skin lesions and eventually skin cancer. The long term ingestion or exposure (10-15 years) of arsenic can lead to a disease called 'arseniasis, arsenicosis, and arsenicism'. Non-cancer endpoints include hyper-pigmentation, hypo-pigmentation, keratosis of skin, peripheral vascular disease (black foot disease), cardiovascular disease, hypertension and neurotoxicity. Most of the symptoms of above mentioned diseases were observed in the field during the study. In the present study out of total population, 15.98% children (below 06 years age), 13.01% SC, 1.57% ST and 85.40% other category population is vulnerable to arsenic exposure.

In addition, 2,137.11 hectares agricultural land (43.76 % block's irrigated land) of 27 revenue villages in Shahpur block is irrigated by arsenic contaminated groundwater. These agricultural land and the cultivable crops are vulnerable due to assimilation of arsenic through plant roots by irrigation of arsenic contaminated groundwater. The justification in support of the vulnerability of agricultural land and the cultivable crops towards arsenic assimilation is the previous study undertaken in village Rampur Diarra of Maner block in Patna district. Study findings of the previous study shows that food grains such as seeds of wheat, maize, rice, lentils and rice husk containing substantial amount of arsenic (Maner block is declared as arsenic hotspot). The elevated level of arsenic in food grains resulted since crops receiving arsenic contaminated groundwater as a source of irrigation can uptake arsenic during the phyto-extraction process and bio-accumulated in different degrees in different parts of plants.

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