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# Depth wise distribution of Arsenic in soils of ambagarh chowki block of Rajnandgaon district, Chhattisgarh

**Satyendra Patley, SS Sengar, Neelam Baghel and Pragya Keshri**

**Abstract**
A micro level investigation was conducted in the Arsenic affected 10 villages of Ambagarh chowki block, Rajnandgaon district, Chhattisgarh, India, to determine the depth wise distribution of arsenic in soil. After analysing 120 samples of different soil depth and 40 plant samples from different villages, it is revealed that during pre-monsoon season, in 0-20 cm soil depth, arsenic content varied from 3.36 to 6.15 mg $kg^{-1}$ with an average of 5.30±0.867 mg $kg^{-1}$. In 20-40 cm soil depth, it varied from 3.12 to 5.89 mg $kg^{-1}$ with an average of 4.84±0.965 mg $kg^{1}$. At 40-60 cm soil depth, arsenic content varied from 1.65 to 5.12 mg $kg^{-1}$ with an average of
3.36±1.227 mg $kg^{-1}$. In post-monsoon season, in 0-20 cm soil depth, arsenic content varied from 3.01 to 5.95 mg $kg^{-1}$ with an average of 4.86±0.896 mg $kg^{-1}$. In 20-40 cm soil depth, it varied from 2.91 to 5.49 mg $kg^{-1}$ with an average of 4.40±0.933 mg $kg^{-1}$. At 40-60 cm soil depth, arsenic content varied from 1.01 to 5.12 mg $kg^{-1}$ with an average of 3.36±1.227 mg $kg^{-1}$. In the soils of studied area, arsenic content was below 10 mg $kg^{-1}$, which is lower than the global average of soil arsenic 10 mg $kg^{-1}$ and also less than the soils permissible limit for arsenic 20 mg $kg^{-1}$ by environmental guideline. It was found that in surface soil, the concentration of arsenic was high as compared to sub-surface soil. Seasonal variation in arsenic content was also found and the concentration of arsenic in soil during pre-monsoon season is higher than in postmonsoon season.

**Keywords:** Arsenic, depth of soil, seasonal variation

## Introduction

Arsenic is an elusive element, with a mysterious ability to change colour, behaviour, reactivity, and toxicity. For example, two arsenic sulphide minerals, red-colour realgar ($As_4S_4$) and bright yellow orpiment ($As_2S_3$), were described by the ancient Greeks, but they considered them to be two entirely different substances (Irgolic 1992) [7]. Arsenic has a long history with humans, having been used as both a poison and a curative, in metallurgy, for decoration and pigmentation, and in pyrotechnics and warfare (Miller *et al*. 2002; Nriagu 2002) [9, 10]. Arsenic trioxide ($As_2O_3$), for example, is a tasteless, odourless, white powder. Arsenic a metalloid, thirdrow, group 15$^{th}$ element, arsenic is seated beneath nitrogen and phosphorus in the periodic table and thus has an excess of electrons and unfilled orbital's that stabilize formal oxidation states from +5 to –3. The electron configuration for neutral arsenic is [Ar] $3d^{10}4s^24px^1$ $4py^14pz^1$, a state that supplies up to five valence electrons for participation in chemical bonding and empty porbital's for electron occupation.

Arsenic (As) is a toxic metalloid found in rocks, soil, water, sediments and air. It enters into the soil and water ecosystem through natural process and as a result of anthropogenic activities. Elevated concentration of arsenic in the biosphere pose a significant threat to humankind. Arsenic contamination of surface and ground water's occurs worldwide and has become a socio-political issue in several parts of the globe.

The behavior of arsenic is distinctly different under flooded (anaerobic) and non-flooded (aerobic) soil conditions, with flooded conditions being likely the most hazardous in terms of uptake by plant and toxicity. (Banejad *et al*. 2011) [2]. Arsenic exsist in the environment in various organic and inorganic forms (species). The most inorganic species are arsenate (As V) and arsenite (As III). Monomethylarsenic acid (MMA) and dimethylarsenic acid (DMA) are the most common organic species in the soil, but there natural presence is low copared to inorganic arsenic (Abedin *et al*. 2002, Fitz and Wenzels, 2002) [1]. Speciation of inorganic arsenic in the soil is largely controlled by reduction and oxidation processes (redox). Under aerobic (oxidizing) conditions arsenate (As V) predominates, whereas arsenite (As III) predominates under anaerobic (reducing) conditions (Fitz and Wenzel, 2002; Takahashi *et al*. 2004) [12]. Microbial activity can influence arsenic speciation *via* various mechanisms such as redox reaction with iron (Fe) and arsenic (As) and *via* (de) methylation of arsenic species. (Banejad *et al*. 2011) [2].

## Materials and Methods

### Studied area

The studied area (Ambagarh chowki block of Rajnandgaon district Chhattisgarh, India) is contaminated with arsenic. 10 villages of Ambagarh chowki block of Rajnandgaon district (Kaudikasa, Biharikala, Atargaon, Dhadutola, Jadutola, Joratarai, Mangatola, Sangali, Sonsaytola and Telitola) have been chosen for the present study. In all these areas, the level of arsenic in ground water is frequently exceeding World Health Organization (0.01 mg $l^{-1}$) permissible water limits (WHO 1992).

### Sample collection

Soil samples were collected by composite sampling from the fields irrigated with the arsenic contaminated water and transferred to airtight polyethylene bags. Soil samples were collected from different depths i.e 0-20 cm, 20-40 cm, 40-60 cm with the help of auger during pre-monsoon and post-monsoon season.

### Sample treatment

Soil samples were immediately sun dried after collection and later dried in the Hot Air Oven at 60 $^0$C for 72 h. The dried soil samples were then ground and passed through 2.0 mm pore sized sieve to get homogenized powder.

### Sample Digestion

Soil sample, root, straw, husk, and grian portions of the rice sample were digested separately following heating block digestion procedure (Rahman *et al*. 2007). About 0.5 g of the sample was taken into clean dry digestion tube and 5ml of concentrated $HNO_3$ was added to it. The mixture was allowed to stand overnight under fume hood. In the following day, the digestion tubes were placed on a heating block and heated at 60 $^0$C for 2 h. The tubes were then allowed to cool at room temperature. About 2 ml of concentrated $HClO_4$ was added to the plant samples. For the soil samples 3 ml of concentrated $H_2SO_4$ was added in addition to 2 ml of concentrated $HClO_4$. Then the tubes were heated at 160 $^0$C for about 4-5 h. The heating was stopped when the dense white fume of $HClO_4$ was emitted. The content was then cooled, diluted to 50ml with de-ionized water and filtered through Whatman No. 42 filter paper for soil samples and Whatman No. 41 for plant samples and finally stored in polyethylene bottles. Prior to sample digestion all glass good were washed with 2% $HNO_3$ followed by rinsing with de-ionized water and drying.

### Sample analysis

The total arsenic of the digested soil samples were analyzed by the flow injection hydride generation atomic absorption spectrophotometer (FI-HG-AAS, Perkin Elmer PinAAcle 900F) using external calibration through arsenate as standard (Welsch *et al*. 1990). The optimum HCl concentration was 10% v/v and 0.4% $NaBH_4$ produced the maximum sensitivity. For each sample three replicates were taken and the mean values were obtained on the basis of calculation of those three replicates.

## Results and Discussion

After analysing the samples of Pre-monsoon and Post-monsoon season. The results indicated that, during pre-monsoon season at 0-20 cm soil depth the total arsenic (As) content varied from 3.36 to 6.15 mg $kg^{-1}$ with an average of 5.30±0.867 mg $kg^{-1}$. The maximum arsenic content in surface soil was recorded in Joratari1 (6.15 mg $kg^{-1}$) followed by Sonsaytola1 (6.07 mg $kg^{-1}$) and the minimum arsenic content was recorded in Biharikala1 (3.36 mg $kg^{-1}$). In 20-40 cm soil depth, total arsenic content varied from 3.12 to 5.89 mg $kg^{-1}$ with an average of 4.84±0.965 mg $kg^{-1}$. However, the maximum arsenic content in 20-40 cm was recorded in Mangatola1 (5.89 mg $kg^{-1}$) followed by Kaudikasa1 (5.82 mg $kg^{-1}$) and the minimum arsenic content was recorded in Biharikala1 (3.12 mg $kg^{-1}$). At 40-60 cm soil depth, the total arsenic(As) content varied from 1.65 to 5.59 mg $kg^{-1}$ with an average of 3.79±1.076 mg $kg^{-1}$ and the maximum arsenic content in 40-60 cm was recorded in Joratari1 (5.59 mg $kg^{-1}$) followed by Mangatola2 (4.99 mg $kg^{-1}$) and the minimum arsenic content was recorded in Atargaon1 (1.65 mg $kg^{-1}$). (Table 1) and (Fig 1).

In post-monsoon season at 0-20 cm soil depth, the total arsenic (As) content varied from 3.01 to 5.95 mg $kg^{-1}$ with an average of 4.86±0.896 mg $kg^{-1}$. The maximum arsenic content in surface soil was recorded in Sonsaytola1 (5.95 mg $kg^{-1}$) followed by Kaudikasa1 (5.87 mg $kg^{-1}$) and the minimum arsenic content was recorded in Biharikala1 (3.01 mg $kg^{-1}$). In 20-40 cm soil depth, total arsenic (As) content varied from 2.91 to 5.49 mg $kg^{-1}$ with an average of 4.40±0.933 mg $kg^{-1}$. However, the maximum arsenic content in 20-40 cm was found in Mangatola1 (5.49 mg $kg^{-1}$) followed by Sonsaytola1 (5.37 mg $kg^{-1}$) and the minimum arsenic content was recorded in Biharikala1 (2.91 mg $kg^{-1}$). At 40-60 cm depth, the total arsenic (As) content varied from 1.01 to 5.12 mg $kg^{-1}$ with an average of 3.36±1.227 mg $kg^{-1}$, and the maximum arsenic content in 40-60 cm was recorded in Mangatola1 (5.12 mg $kg^{-1}$) followed by Joratari1 (5.10 mg $kg^{-1}$) and the minimum arsenic content was recorded in Atargaon1 (1.01 mg $kg^{-1}$). (Table 1) and (Fig 2)

In general, most of the soils contained <10 mg $kg^{-1}$ of arsenic and, as such, met the guidelines for residential soils of 100 mg $kg^{-1}$ as required by the australian health and 20 mg $kg^{-1}$ as required by the environmental guidelines and below then the global average concentration of arsenic (10 mg $kg^{-1}$). (Huq *et al*. 2006) [4]. (Table 1), (Fig 1) and (Fig 2).

Moreover, concentration of arsenic in surface (0-20 cm) soils typically exceeded as compared with sub-surface layer (20-40 cm) and (40-60 cm). (Table 1), (Fig 1) and (Fig 2). The concentration of arsenic depends on the clay content and metal oxide content of soil, adsorption of arsenic is high in soils having high clay content and clay content decreases with depth of soil so, the concentration of arsenic in soil decreased with soil depth. Similar finding were also observed by the Huq *et al*. (2003, 2006) [3, 4] and Samal *et al*. (2010) [11].

Seasonal variations in arsenic concentration showed that the concentration of arsenic in soil during pre-monsoon season is higher as compared to post-monsoon season. (Table 1) and (Fig 3). Seasonal variations of arsenic concentration is due to various reasons such as, arsenic desorbs to the standing water and is then removed laterally, the top layer may be eroded and run off during heavy rainfall, volatilization of arsenic during prolonged periods of flooding and leaching of standing water desorbing and transporting arsenic from the top soil to deeper layer. (Islam *et al*. 2005) [8]. Similar finding were also observed by the Samal *et al*. (2010) [11] and Islam *et al*. (2005)

[8]. Similar seasonal variations in arsenic content was also found by Hussain *et al.* (2014) [5, 6] in ground water of Bolaram and Patancheru Industrial Area, Andra Pradesh, India and Samal *et al.* (2010) [11] in ground water of Nadia district of West Bengal.

**Table 1:** Spatial, depth wise distribution and seasonal variations of arsenic in soils of different villages of Ambagarh chowki block.

| **Village** | **Pre-monsoon arsenic in soil (mg kg$^{-1}$)** | | | **Post-monsoon arsenic in soil (mg kg$^{-1}$)** | | |
|---|---|---|---|---|---|---|
| | 0-20 cm | 20-40 cm | 40-60 cm | 0-20 cm | 20-40 cm | 40-60 cm |
| Kaudikasa1 | 6.03 | 5.82 | 2.90 | 5.87 | 4.98 | 2.01 |
| Kaudikasa2 | 5.82 | 4.94 | 3.52 | 5.13 | 4.36 | 3.12 |
| Bihrikala1 | 3.36 | 3.12 | 3.00 | 3.01 | 2.91 | 1.36 |
| Bihrikala2 | 4.12 | 3.64 | 2.34 | 3.98 | 3.12 | 2.12 |
| Dadhutol1 | 5.60 | 3.90 | 3.84 | 4.95 | 3.69 | 3.54 |
| Dadhutol2 | 4.98 | 3.75 | 3.35 | 4.16 | 3.13 | 3.01 |
| Sonsaytol1 | 6.07 | 5.78 | 4.59 | 5.95 | 5.37 | 4.36 |
| Sonsaytol2 | 5.92 | 5.12 | 4.13 | 5.17 | 4.92 | 3.91 |
| Telitola1 | 5.91 | 5.80 | 4.31 | 5.41 | 5.30 | 4.01 |
| Telitola2 | 5.87 | 5.62 | 4.79 | 5.61 | 5.12 | 4.14 |
| Joratari1 | 6.15 | 5.76 | 5.59 | 5.85 | 5.36 | 5.10 |
| Joratari2 | 6.02 | 5.63 | 5.13 | 5.67 | 5.23 | 4.98 |
| Mangatol1 | 5.84 | 5.89 | 5.32 | 5.73 | 5.49 | 5.12 |
| Mangatol2 | 5.94 | 5.72 | 4.99 | 5.49 | 5.27 | 4.31 |
| Atargaon1 | 4.18 | 3.57 | 1.65 | 4.01 | 3.21 | 1.01 |
| Atargaon2 | 4.63 | 4.70 | 2.87 | 4.23 | 3.92 | 2.37 |
| Sangali1 | 4.98 | 4.38 | 3.72 | 4.18 | 4.22 | 3.97 |
| Sangali2 | 3.82 | 3.35 | 2.65 | 3.17 | 3.01 | 2.16 |
| Jadutola1 | 5.92 | 5.42 | 4.18 | 5.03 | 5.13 | 3.98 |
| Jadutola2 | 4.92 | 5.01 | 3.08 | 4.61 | 4.37 | 2.75 |
| Range | 3.36-6.15 | 3.12-5.89 | 1.65-5.59 | 3.01-5.95 | 2.91-5.49 | 1.01-5.12 |
| Average | 5.30±0.86 | 4.84±0.96 | 3.79±1.07 | 4.80±0.89 | 4.40±0.93 | 3.36±1.22 |
| **Total** | 20 | 20 | 20 | 20 | 20 | 20 |

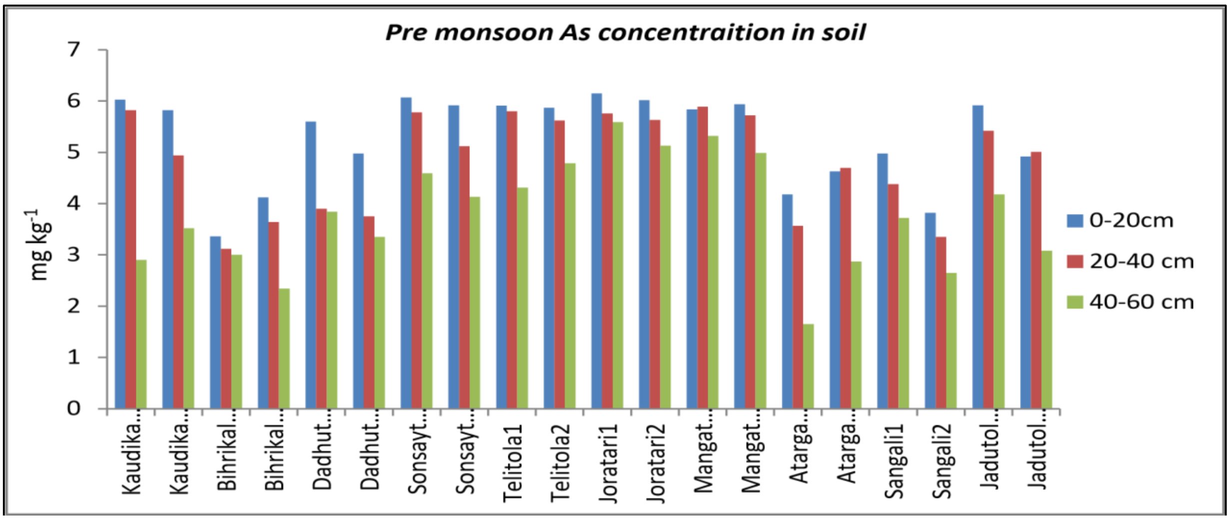


**Fig 1:** Spatial and depth wise distribution of arsenic in soils of different villages of Ambagarh chowki block during pre-monsoon season

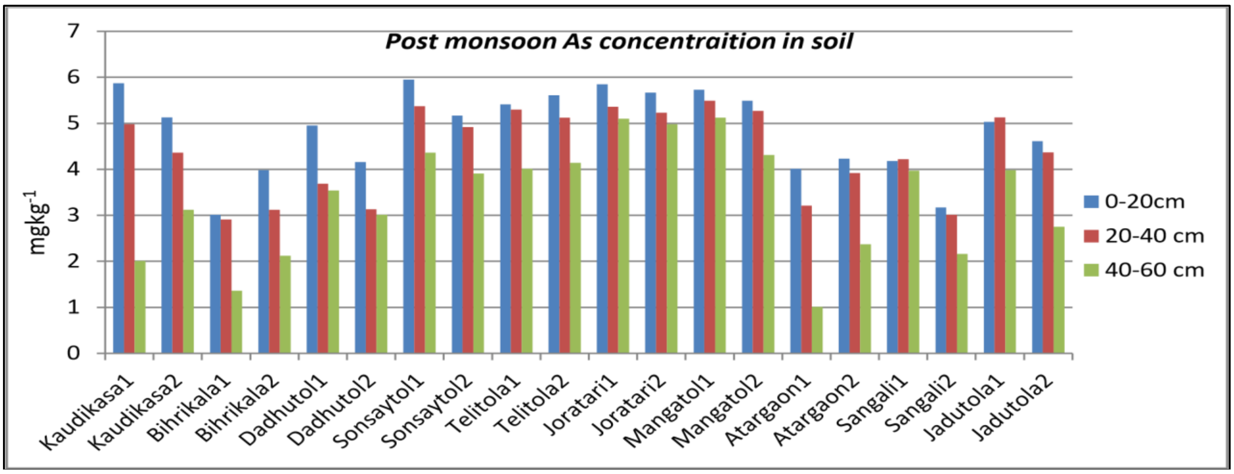


**Fig 2:** Spatial and depth wise distribution of arsenic in soils of different villages of Ambagarh chowki block during post-monsoon season

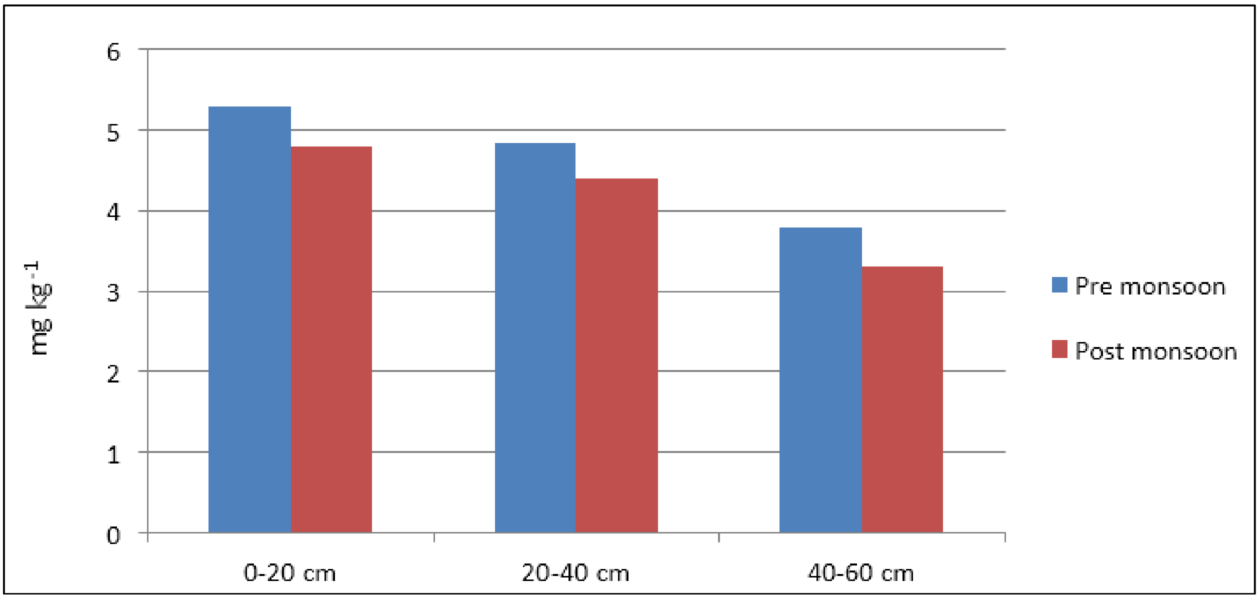


**Fig 3:** Seasonal variation of arsenic in different depth of soils in Ambagarh chowki block during pre and post monsoon season.

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