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# Arsenic Contamination in Drinking Water of Some of the Gangetic Plain Villages of Katihar District, Bihar and Its Health Impacts on Human Beings

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***Abstract:*** *Drinking water deserves immediate attention from the point view of public health. This paper presents arsenic contamination in different drinking water sources of some of the villages of different blocks (Katihar, Manihari, Amdabad and Barari block) of Katihar district. A total of 1986 samples collected during March 2012 to Feb 2015 from different drinking water sources (Tubewell, Dugwell, Municipal supply, Railway supply and River Ganga) of different villages of Katihar dist. were analyzed for arsenic concentration. Of the total 1986 water sampes, only 63.69% samples had arsenic less than 10 $\mu gL^{-1}$ (WHO limit) and were safe for drinking. 25.13% samples had arsenic between 10 to 50 $\mu gL^{-1}$, 8.16% samples had arsenic between 51 to100 $\mu gL^{-1}$, 3.02% samples had arsenic between 101 to 500 $\mu gL^{-1}$. 43.73% tube well water, 6.48% dug well water and 14.06% samples of river Ganga water were contaminated with more than 10 $\mu gL^{-1}$ arsenic. Maximum arsenic contamination was recorded in tube well water and minimum in dug well water. Railway supply and municipal supply water were safe from arsenic contamination. All water resources of Katihar block were safe from arsenic problems. Arsenic contamination in drinking water may create a problem of arsenicosis. Many people were found with skin pigmentation, numbness and burning sensation, liver disorder, watery diarrhea, incidence of miscarriages,low birth weight, abdominal pain gastrointestinal symptom and diabetes. Some persons were also suffering from lung and liver cancer. The use of river Ganga, dug well and rain water may provide a permanent solution for arsenic free drinking water.*

***Key Word:*** *Arseniccontamination;Drinking water; Tube well; Dug wel;, Rriver Ganga; Railway supply; Municipal supply; Katihar district*

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## I. Introduction

Arsenic occurs naturally, being the 20th most abundant element in the earth's crust, and is a component of more than 245 minerals[1].It can be present in soil, air and water as a metalloid and as chemical compounds of both inorganic and organic forms[2]. It is one of the most toxic elements in the environment[3,4]. It is four times as poisonous as mercury. In water it has no color, smell and taste and can only be detected through a chemical test. Pollution of groundwater by arsenic is widespread throughout the globe[5]. Inorganic arsenic is naturally present at high level in drinking water of a number of countries. Very often, it is anthropogenic origin[6,7]. WHO has classified arsenic as one of 10 chemicals of public health concern[8].

**1.1 Occurrence of Arsenic in Groundwater**

Arsenic is important due to its association with environmental issues and health of human, animals and plants. It is important to point out that the consumption of groundwater in an attempt to replace polluted surface water supplies has resulted in widespread arsenic poisoning. Groundwater is far more likely to contain high level of arsenic than surface water. Arsenic concentration in surface water and groundwater is subject to seasonal variations in raw water input[9]. Inorganic arsenic, arsenate ($As^{5+}$) and arsenite ($As^{3+}$) in the form of $Na_2HAsO_4$ and $NaAsO_2$, respectively, are toxic to man and plants[10]. Arsenite is known to be more toxic and mobile than arsenate[11]. Another form of arsenic, namely organoarsenic, which is less toxic than both arsenate and arsenite and less harmful, is also found in the nature. Organoarsenic is present in various organisms like plants, fishes, crabs and even humans. In general, inorganic arsenic species is more mobile and toxic than organic forms to living organism including plants, animals and human[12]. At higher concentration, it interferes with the metabolic process of a plant and inhibits its growth. Very high concentration may lead to plant death[3]. Arsenic groundwater contamination has far reaching consequences, including its ingestions through food chain, which are in the form of social disorders, health hazards and socioeconomic dissolutions besides its sprawling with movement and exploitation of groundwater. The food crops grown using arsenic contaminated water are sold off to other places, including uncontaminated regions where the inhabitants may consume arsenic from the contaminated food. This may give rise to a new danger.

**1.2 Global Scenario**

Arsenic contamination of groundwater has now resulted in worldwide human health problems affecting millions of people across a large number of countries. At present, arsenic is estimated to affect more than 150 million people worldwide with its increasingly elevated concentrations in drinking water[13]. Arsenic pollution in ground water used for drinking purposes has been envisaged as a problem of global concern[14]. Arsenic contamination in drinking water has been reported from many countries like Taiwan, China, Argentina, Chile, Mexico, Cambodia, Thailand, Myanmar, Nepal, and USA[15]. The world's largest arsenic related health issues are reported from Bangladesh and India (West Bengal) due to contamination of drinking water aquifers, potentially affecting millions of people[16,17].

**1.3 Indian Scenario**

In India, arsenic contamination in drinking water was first reported in 1976 in Punjab, Haryana, Himachal Pradesh and Uttar Pradesh in Northern India[18]. The first case of arsenic poisoning was detected in 1983 in Calcutta, West Bengal, India[19,20]. The occurrences of arsenic in ground water have also been reported from Bihar, Jharkhand, Chhattisgarh, Uttar Pradesh and Assam[15]. The situation of arsenic toxicity in India is alarming. Various reports of severe health problems in states namely Jharkhand, Bihar, Uttar Pradesh (flood plain of the Ganga), Assam and Manipur (flood plain of the Brahmaputra and Imphal rivers) and Rajnandgaon village in Chattisgarh state have come to limelight[21,22,23].More recently, problems were reported in the state of Arunachal Pradesh, Nagaland, Mizoram and Tripura[22,24]. People in these affected states have been chronically exposed to arsenic contaminated hand tube well drinking water. All the arsenic affected river plains are from the rivers of Himalayan origin.

Groundwater arsenic contamination in Bihar was first surfaced in the year 2002 from Bhojpur district in the Middle Ganga Plain located in the flood-prone belt of Sone-Ganga[21,25]. About 48% of districts of Bihar have been reported with arsenic contamination in groundwater. This comprises more than 67 blocks from 18 districts and covering more than 1600 habitations across the state where arsenic contamination in groundwater exceeds BIS limits for safe drinking water of $50 \mu g l^{-1}$ and more[26]. More than 13.85 million people could be under the threat of contamination level above $10 \mu g l^{-1}$ out of which more than 9.6 million people could be above $50 \mu g l^{-1}$.

**1.4 Sources of Arsenic Contamination**

Arsenic can enter terrestrial and aquatic environment through geological (geogenic), human (anthropogenic) and biological (biogenic) sources. About one-third of the arsenic in the atmosphere comes from natural sources and two-thirds from manmade (anthropogenic) sources. Volcanic action is the most important natural resource of arsenic. Arsenic is introduced into soil and groundwater during weathering of rocks and minerals followed by subsequent leaching and run off[27,28]. It may be released to soil, surface water, groundwater and atmosphere from sulfide ores of other metals including Cu, Pb, Ag and Au[29].

Arsenic contamination in environment also occurs from anthropogenic activities like intense exploitation of groundwater, application of fertilizers and pesticides in agriculture and chemicals used for timber preservation[30]. The pumping of groundwater and intrusion of surface water led to the penetration of organic matter into the groundwater, which fueled biogeochemical processes, resulting in the dissolution of arsenic from the soil sediments[31,32]. Extensive use of lead arsenate and copper arsenite in pesticides called arsenicals and rodenticides can also be responsible for arsenic contamination[33]. There is a significant use of arsenic in the production of lead-acid batteries, gallium arsenide and other electronic applications[29]. About 70% of the world production of arsenic is used in timber treatment, 22% in agricultural chemicals and remainder in glass, pharmaceuticals and metallic alloys. However it is claimed that Ganga Brahmaputra basin is rather undisturbed by anthropogenic sources compared to industrialized countries where river basin are generally affected by industrialized activities

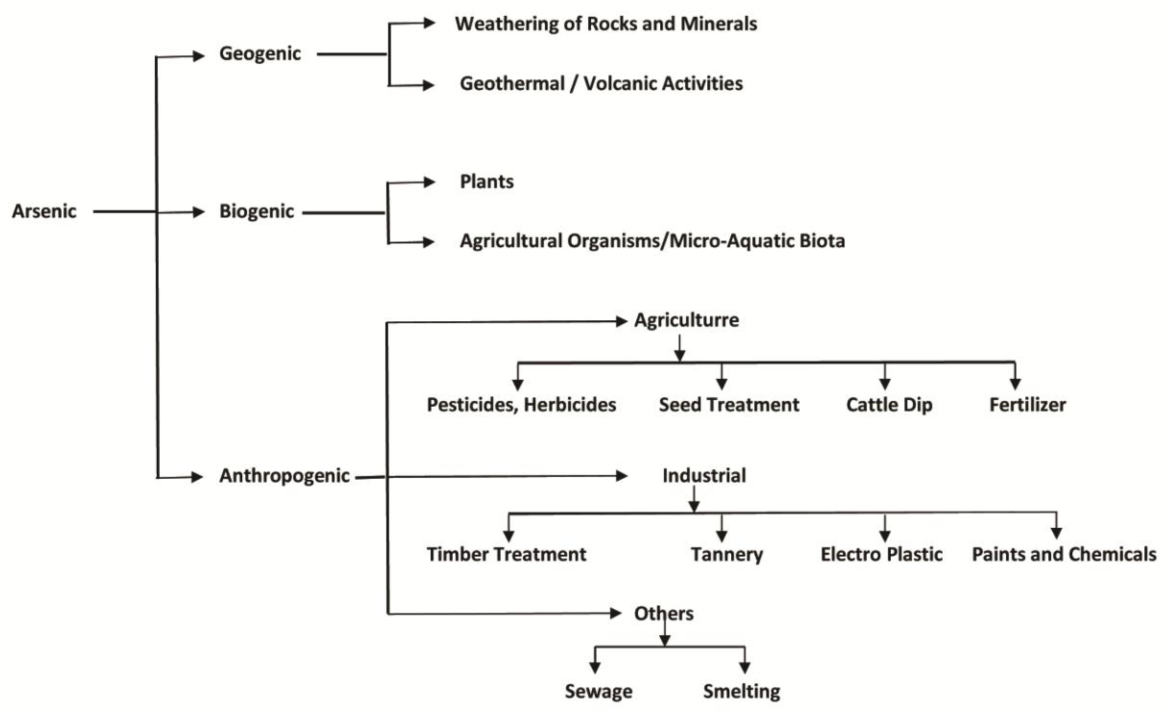



**Figure Showing the major sources and routes of arsenic in soil and aquatic ecosystem.**

**1.5 BENEFICIAL EFFECTS**

Arsenic has been used for many years for medicinal purposes. It is used as a cure for diseases such as syphilis and leukemia. Arsenicumsulfuratumflavum 1-X is used in homeopathic medicines (SOES report). Arsenic compounds are used in agriculture and industries in many ways. Arsenic is beneficial at low doses. It is important to note that the beneficial effects are for different medical outcomes than either the acute or chronic adverse effects or those both beneficial and adverse effects can be observed simultaneously.

1.6 **ADVERSE HEALTH EFFECTS**

Inorganic arsenic is a recognized toxicant and cancer causing substance (carcinogen). Drinking water having more than permissible arsenic levels of 10 ppb (WHO limit) increases the mortality rates as arsenic is a bio-accumulative toxin. Arsenic exerts its toxicity by inactivation of many important enzyme systems.Acute effect and short-term exposure of arsenic poisoning can cause nausea, vomiting, neurological effects such as numbness or burning sensation in the hands and feet, cardiovascular effects, profuse watery diarrhea, abdominal pain, excessive salivation and decreased production of red and white blood cells which may result in fatigue. Chronic effects are long term exposure of arsenic poisoning. It includes changes in skin coloration and skin thickening and small corn like growths that can develop especially on the palms of the hand and soles on the feet. Chronic exposure to arsenic is also associated with increased risk of skin, bladder, blood, liver and lung cancer. Arsenic harms the central and peripheral nervous systems as well as heart and blood vessels. There is also evidence that long-term exposure to arsenic can increase risks for kidney and prostate cancer. Arsenic may act as carcinogen and tumor promoter under certain circumstances. People drinking arsenic contaminated water have shown an increased risk of type 2 diabetes in areas with high levels of arsenic in Taiwan and Bangladesh[34].

To understand the magnitude of arsenic problem, an extensive survey of the affected area was done and the drinking water of many blocks of Katihar district was found contaminated with arsenic. The widespread arsenic contamination in drinking water was reportedly causing serious health problems for thousands of people in this area. Thus, it was thought necessary to know much more about the impact of arsenic problems in drinking water.

## II. MATERIALS AND METHODS

The study was undertaken in four blocks of Katihar district to analyse the arsenic contamination in different drinking water sources from March 2012 to February 2015. Altogether 21 villages from four blocks namely Katihar (village-Sahebpara, Dalan, Makhdumpur and Sirnia), Manihari (Village-Baghmara, Baullia, Kumaripur Hat, Krishna Nagar, Narayanpur and Katakoas,), Amdabad (Village-Karimullapur, Amdabad, Balrampur, Paharpur, Baluwa and LalBathani) and Barari (Village-Madheli, BhaisDiara, Gurumela, Kalkapur and Gurubajar) were selected for detailed study. Katihar, Manihari, Amdabad and Barari blocks were selected as Site-I, II III and IV respectively. The drinking water sources used by the people in these villages, *e.g.* tube wells, dug wells, railway supply, municipal supply and river Ganga were selected for detailed analyses.

The groundwater testing was done initially by field test kit (Colorimetrique avec bandle test) and then confirmed by U.V. Spectrophotometric method (Photo lab 6600 UV-VIS series).

## III. Results

**Table 1-13** illustrates the findings of arsenic contamination in drinking water based on the analyses of 1986 water samples from different drinking water sources (tube wells, dug wells, railway supply, municipal supply and river Ganga) at different sites of Katihar district. Correlation co-efficient between physico-chemical factors and arsenic of different drinking water sources at different sites is depicted in **Table-14.**

**Table -1: Comparative Study of Arsenic Contamination in Different Drinking Water Sources of Katihar District**

| Water sources | Number of water samples analyzed | Arsenic contaminated water samples( $\mu gl^{-1}$) | | | | Percentage of arsenic contaminated water samples ( >10 $\mu gl^{-1}$) |
|---|---|---|---|---|---|---|
| | | <10 | 10-50 | 51-100 | 101-500 | |
| **Tube well** | 1596 | 898<br>56.27% | 4813<br>0.14% | 159<br>9.96% | 58<br>3.63% | 43.73 |
| **Dug well** | 216 | 202<br>93.52% | 12<br>5.55% | 2<br>0.93% | 0 | 6.48 |
| **Railway supply** | 76 | 76<br>100% | 0 | 0 | 0 | 0 |
| **Municipal supply** | 34 | 34<br>100% | 0 | 0 | 0 | 0 |
| **River Ganga** | 64 | 55<br>85.94 | 6<br>9.38% | 1<br>1.56% | 2<br>3.12% | 14.06 |
| **Total** | 1986 | 1265<br>63.69% | 499<br>25.13% | 162<br>8.16% | 60<br>3.02% | 36.31 |

Table-1 shows the distribution of number and percentage of total water samples with different arsenic concentrations of different water sources of Katihar district. Of the total 1986 water samples 63.69% (1265) samples had arsenic concentration below 10$\mu gL^{-1}$ (WHO guideline value) and safe for drinking purposes, 25.13% (499) had arsenic between 10 to50 $\mu gL^{-1}$, 8.16% (162) had arsenic between 51 to100 $\mu gL^{-1}$ and 3.02% (60) had arsenic between 101 to 500 $\mu gL^{-1}$.

**Table -2: Arsenic Contamination in Tube Well Water at Different Sites of Katihar Dist.**

| Sites | Number of water samples analyzed | Arsenic contaminated water samples( $\mu gl^{-1}$) | | | | Percentage of arsenic contaminated water samples ( >10 $\mu gl^{-1}$) |
|---|---|---|---|---|---|---|
| | | <10 | 10-50 | 51-100 | 101-500 | |
| **I** | 62 | 62<br>100% | 0 | 0 | 0 | 0 |
| **II** | 565 | 291<br>51.50% | 182<br>32.21% | 68<br>12.04% | 24<br>4.25% | 48.5 |
| **III** | 581 | 313<br>53.87% | 192<br>33.05% | 56<br>9.64% | 20<br>3.44% | 46.13 |
| **IV** | 388 | 232<br>59.79% | 107<br>27.58% | 35<br>09.02% | 14<br>3.61% | 40.21 |
| **Total** | 1596 | 898<br>56.27% | 481<br>30.14% | 159<br>9.96% | 58<br>3.63% | 43.73 |

Table-2 shows the number and percentage of tube well water samples with different arsenic concentration found at different sites. Of the total 1596 tube well water samples, 56.27% (898) had arsenic below 10 µgL$^{-1}$ (WHO guideline value) and hence safe for drinking purposes. 30.14% (481), 9.96% (159) and 3.63% (58) water samples had arsenic in range of 10-50 µgL$^{-1}$, 51-100 µgL$^{-1}$ and 101-500 µgL$^{-1}$ respectively.

**Table – 3: Arsenic Contamination in Dug Well Water at Different Sites of Katihar Dist.**

| Sites | Number of water samples analyzed | Arsenic contaminated water samples( µgl$^{-1}$) | | | | Percentage of arsenic contaminated water samples ( >10 µgl$^{-1}$) |
|---|---|---|---|---|---|---|
| | | <10 | 10-50 | 51-100 | 101-500 | |
| I | 41 | 41<br>100% | 0 | 0 | 0 | 0 |
| II | 83 | 77<br>92.77% | 05<br>6.02% | 01<br>1.20% | 0 | 8.43 |
| III | 92 | 84<br>91.30% | 07<br>7.61% | 01<br>1.09% | 0 | 8.7 |
| IV | 216 | 202<br>93.52% | 12<br>5.55% | 02<br>0.93 | 0 | 6.48 |
| **Total** | | | | | | |

Table-3 shows the number and percentage distribution of arsenic contaminated dug well water samples with different arsenic concentration at different sites of Katihar district. Of the total 216 dug wells water, 93.52% (202) had arsenic below 10 µgL$^{-1}$ (WHO guideline value).5.55% (12) sample had arsenic between 10-50 µgL$^{-1}$and 0.93% (02) samples had arsenic between 51 to 100 µgL$^{-1}$. Not a single sample of dug well water was found with more than 100 µgL$^{-1}$ arsenic. Only 6.48% dug well water were arsenic contaminated and unsafe for drinking and domestic purposes.

**Table – 4: Arsenic Contamination in Railway Supply Water at Different Sites of Katihar Dist.**

| Sites | Number of water samples analyzed | Arsenic contaminated water samples( µgl$^{-1}$) | | | | Percentage of arsenic contaminated water samples ( >10 µgl$^{-1}$) |
|---|---|---|---|---|---|---|
| | | <10 | 10-50 | 51-100 | 101-500 | |
| I | 45 | 45 | 0 | 0 | 0 | 0 |
| II | 31 | 31 | 0 | 0 | 0 | 0 |
| Total | 76 | 76 | 0 | 0 | 0 | 0 |

**Table – 5: Arsenic Contamination in Municipal Supply Water at Different Sites of Katihar Dist.**

| Sites | Number of water samples analyzed | Arsenic contaminated water samples( µgl$^{-1}$) | | | | Percentage of arsenic contaminated water samples ( >10 µgl$^{-1}$) |
|---|---|---|---|---|---|---|
| | | <10 | 10-50 | 51-100 | 101-500 | |
| Site-II | 34 | 34 | 0 | 0 | 0 | 0 |
| TOTAL | 34 | 34 | 0 | 0 | 0 | 0 |

Table-4 & 5 show arsenic contaminations in railway supply and municipal supply water at different sites of Katihar district respectively. Of the total 76 railway supply and 34 municipal supply water samples, not a single sample was found contaminated with arsenic. It seems that railway supply and municipal supply water were totally free from arsenic and safe for drinking and domestic use.

**Table - 6: Arsenic Contamination in River Ganga Water at Different Sites of Katihar Dist.**

| Sites | Number of water samples analyzed | Arsenic contaminated water samples( $\mu gl^{-1}$) | | | | Percentage of arsenic contaminated water samples ( >10 $\mu gl^{-1}$) |
|---|---|---|---|---|---|---|
| | | <10 | 10-50 | 51-100 | 101-500 | |
| **II** | 35 | 29<br>82.86% | 04<br>11.43% | 01<br>2.86% | 1<br>2.86% | 17.14 |
| **IV** | 29 | 26<br>89.66% | 02<br>6.89% | 0 | 01<br>3.45% | 10.34 |
| **Total** | 64 | 55<br>85.94% | 6<br>9.38% | 1<br>1.56% | 2<br>3.12% | 14.09 |

Table-6 represents the number and percentage of river Ganga water with different concentrations of arsenic at different sites of Katihar district. Among 64 of the water samples, 85.94% (55) had arsenic less than 10 $\mu gL^{-1}$(WHO guideline value). 9.38% (06), 1.56% (01) and 3.12% (02) samples had arsenic in range of 10-50 $\mu gL^{-1}$, 51-100 $\mu gL^{-1}$ and 101-500 $\mu gL^{-1}$ respectively. Only 14.06% water samples of Ganga water were unsafe for drinking and domestic use.

Monthly and seasonal fluctuations in arsenic contamination of different water sources at different sites are depicted in Table- **7** to 13.

**Table – 7: Monthly and Seasonal Fluctuations in Arsenic Contamination of Tube Well Water of Katihar Dist.at Site-II**

| Seasons | Months | Number of water samples analyzed | Arsenic contaminated water samples( $\mu gl^{-1}$) | | | | Percentage of arsenic contaminated water samples ( >10 $\mu gl^{-1}$) |
|---|---|---|---|---|---|---|---|
| | | | <10 | 10-50 | 51-100 | 101-500 | |
| **Summer** | Mar | 56 | 37 | 14 | 4 | 1 | 33.93 |
| | Apr | 19 | 10 | 6 | 1 | 2 | 47.37 |
| | May | 67 | 42 | 17 | 7 | 1 | 37.31 |
| | Jun | 26 | 14 | 7 | 3 | 2 | 46.15 |
| | Total | 168 | 103 | 44 | 15 | 6 | 38.69 |
| **Rainy** | Jul | 67 | 26 | 28 | 11 | 2 | 61.19 |
| | Aug | 28 | 12 | 9 | 3 | 4 | 57.14 |
| | Sep | 60 | 28 | 20 | 9 | 3 | 53.53 |
| | Oct | 37 | 17 | 11 | 7 | 2 | 54.05 |
| | Total | 192 | 83 | 68 | 30 | 11 | 56.77 |
| **Winter** | Nov | 75 | 29 | 34 | 9 | 3 | 61.33 |
| | Dec | 36 | 22 | 7 | 6 | 1 | 38.88 |
| | Jan | 25 | 15 | 6 | 2 | 2 | 40 |
| | Feb | 69 | 39 | 23 | 6 | 1 | 43.48 |
| | Total | 205 | 105 | 70 | 23 | 7 | 48.78 |
| | **Sum Total** | **565** | **291<br>51.50%** | **182<br>32.21%** | **68<br>12.04%** | **24<br>4.25%** | **48.5** |

Table-7: shows monthly and seasonal variations in arsenic contaminations in tube well water at Site- II. Of the total 565 water samples, 51.50% had arsenic less than 10 $\mu gL^{-1}$ (WHO guideline value), 32.21% samples had arsenic between 10 to 50 $\mu gL^{-1}$, 12.04% samples had arsenic between 51 to 100 $\mu gL^{-1}$ and 4.25% samples had arsenic between 101 to 500 $\mu gL^{-1}$. There was evidence of seasonal variations in concentration of arsenic in tube well water with minimum percentage contaminated water sample occurring in the summer season (38.69%) and the maximum in the rainy season (56.77%).

**Table – 8: Monthly and Seasonal Fluctuations in Arsenic Contamination of Tube Well Water of Katihar Dist. at Site-III**

| Seasons | Months | Number of water samples analyzed | Arsenic contaminated water samples( μgl⁻¹) | | | | Percentage of arsenic contaminated water samples ( >10 μgl⁻¹) |
|---|---|---|---|---|---|---|---|
| | | | <10 | 10-50 | 51-100 | 101-500 | |
| **Summer** | Mar | 47 | 30 | 15 | 2 | 0 | 36.17 |
| | Apr | 78 | 42 | 30 | 5 | 1 | 46.15 |
| | May | 59 | 31 | 22 | 4 | 2 | 47.46 |
| | Jun | 41 | 25 | 13 | 3 | 0 | 39.02 |
| | Total | 225 | 128 | 80 | 14 | 3 | 43.11 |
| **Rainy** | Jul | 22 | 12 | 7 | 1 | 2 | 45.45 |
| | Aug | 38 | 15 | 14 | 5 | 4 | 60.53 |
| | Sep | 69 | 34 | 21 | 10 | 4 | 50.72 |
| | Oct | 45 | 22 | 15 | 7 | 1 | 51.11 |
| | Total | 174 | 83 | 57 | 23 | 11 | 52.30 |
| **Winter** | Nov | 81 | 46 | 26 | 7 | 2 | 43.21 |
| | Dec | 35 | 22 | 8 | 4 | 1 | 37.14 |
| | Jan | 45 | 24 | 14 | 5 | 2 | 46.67 |
| | Feb | 21 | 10 | 7 | 3 | 1 | 52.38 |
| | Total | 182 | 102 | 55 | 19 | 6 | 43.96 |
| | **Sum Total** | **581** | **313<br>53.87%** | **192<br>33.05%** | **56<br>9.64%** | **20<br>3.44%** | **46.13** |

Table- 8shows monthly and seasonal variations in arsenic contamination in tube well water at Site- III. Of the total 581 water samples, 53.87% samples had arsenic below 10 $\mu gL^{-1}$ (WHO guideline value), 33.05% samples had arsenic between 10 to 50 $\mu gL^{-1}$, 9.64% samples had arsenic between 51 to 100 $\mu gL^{-1}$ and 3.44% samples had arsenic between 101 to 500 $\mu gL^{-1}$. The percentage of arsenic contaminated tube well water samples was found minimum (43.11%) during summer and maximum (52.3%) during rainy season.

**Table - 9: Monthly and Seasonal Fluctuations in Arsenic Contamination of Tube Well Water of Katihar Dist. at Site-IV**

| Seasons | Months | Number of water samples analyzed | Arsenic contaminated water samples( μgl⁻¹) | | | | Percentage of arsenic contaminated water samples ( >10 μgl⁻¹) |
|---|---|---|---|---|---|---|---|
| | | | **<10** | **10-50** | **51-100** | **101-500** | |
| **Summer** | Mar | 36 | 21 | 12 | 2 | 1 | 41.67 |
| | Apr | 56 | 45 | 7 | 3 | 1 | 19.30 |
| | May | 32 | 26 | 5 | 1 | 0 | 18.75 |
| | Jun | 24 | 15 | 6 | 2 | 1 | 37.50 |
| | Total | 148 | 107 | 30 | 8 | 3 | 27.7 |
| **Rainy** | Jul | 35 | 14 | 12 | 6 | 3 | 60.00 |
| | Aug | 12 | 7 | 4 | 1 | 0 | 41.67 |
| | Sep | 29 | 13 | 9 | 5 | 2 | 55.17 |
| | Oct | 29 | 23 | 17 | 6 | 1 | 51.06 |
| | Total | 123 | 57 | 42 | 18 | 6 | 53.66 |
| **Winter** | Nov | 31 | 18 | 9 | 2 | 2 | 41.94 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Dec | 42 | 24 | 13 | 3 | 2 | 42.86 |
| | Jan | 26 | 16 | 8 | 1 | 2 | 38.46 |
| | Feb | 18 | 10 | 5 | 3 | 0 | 44.44 |
| | Total | 117 | 68 | 35 | 9 | 5 | 41.88 |
| | **Sum Total** | **388** | **232 59.79%** | **107 27.58%** | **35 09.02%** | **14 3.61%** | **40.21** |

Table-9 shows monthly and seasonal variations in arsenic contaminated tube well water at Site- IV. Of the total 388 water samples, 59.79% samples had arsenic less than 10µgL$^{-1}$ (WHO guideline value). 27.58%, 09.02% and 3.61% water sample had arsenic in range of 10to 50 µgL$^{-1}$, 51 to 100 µgL$^{-1}$and 101 to 500 µgL$^{-1}$ respectively. Seasonal variations were profoundly observed. The percentage of arsenic contaminated tube well water sample was found minimum (27.7%) in summer season and maximum (53.66%) in rainy season.

**Table – 10: Monthly and seasonal fluctuations in arsenic contamination of Dug well water of Katihar dist. at Site-II**

| Seasons | Months | Number of water samples analyzed | Arsenic contaminated water samples( µgl$^{-1}$) | | | | Percentage of arsenic contaminated water samples ( >10 µgl$^{-1}$) |
|---|---|---|---|---|---|---|---|
| | | | <10 | 10-50 | 51-100 | 101-500 | |
| **Summer** | Mar | 5 | 5 | 0 | 0 | 0 | 0.00 |
| | Apr | 6 | 6 | 0 | 0 | 0 | 0.00 |
| | May | 10 | 9 | 1 | 0 | 0 | 10.00 |
| | Jun | 8 | 7 | 1 | 0 | 0 | 12.50 |
| | Total | 29 | 27 | 2 | 0 | 0 | 6.9 |
| **Rainy** | Jul | 7 | 6 | 0 | 1 | 0 | 14.29 |
| | Aug | 10 | 9 | 1 | 0 | 0 | 10.00 |
| | Sep | 6 | 6 | 0 | 0 | 0 | 0.00 |
| | Oct | 9 | 9 | 0 | 0 | 0 | 0.00 |
| | Total | 32 | 30 | 1 | 1 | 0 | 6.25 |
| **Winter** | Nov | 5 | 5 | 0 | 0 | 0 | 0.00 |
| | Dec | 6 | 5 | 1 | 0 | 0 | 16.67 |
| | Jan | 3 | 3 | 0 | 0 | 0 | 0.00 |
| | Feb | 8 | 7 | 1 | 0 | 0 | 12.50 |
| | Total | 22 | 20 | 2 | 0 | 0 | 9.09 |
| | **SumTotal** | **83** | **77 92.77%** | **05 6.02%** | **01 1.20%** | **0** | **8.43** |

Table-10 illustrates the monthly and seasonal variations in arsenic contamination in dug well water at Site- II. Of the total 83 dug well water samples, 92.77% samples had arsenic less than 10 µgL$^{-1}$ and safe for drinking and domestic purposes. 6.02% water samples had arsenic between 10 to 50µgL$^{-1}$ and 1.20% water samples had arsenic between51to 100 µgL$^{-1}$ only. Seasonally it was observed that the percentage of arsenic contaminated dug well water was minimum (6.25%) during rainy season and maximum (9.09%) during winter season.

**Table - 11: Monthly and Seasonal Fluctuations in Arsenic Contamination of Dug Well Water of Katihar Dist. at Site-III**

| Seasons | Months | Number of water samples analyzed | Arsenic contaminated water samples( $\mu gl^{-1}$) | | | | Percentage of arsenic contaminated water samples ( >10 $\mu gl^{-1}$) |
|---|---|---|---|---|---|---|---|
| | | | <10 | 10-50 | 51-100 | 101-500 | |
| **Summer** | Mar | 8 | 8 | 0 | 0 | 0 | 0.00 |
| | Apr | 8 | 8 | 0 | 0 | 0 | 0.00 |
| | May | 7 | 6 | 1 | 0 | 0 | 14.29 |
| | Jun | 8 | 7 | 1 | 0 | 0 | 12.50 |
| | Total | 31 | 29 | 2 | 0 | 0 | 6.45 |
| **Rainy** | Jul | 9 | 7 | 1 | 1 | 0 | 22.22 |
| | Aug | 7 | 6 | 1 | 0 | 0 | 14.29 |
| | Sep | 9 | 8 | 1 | 0 | 0 | 11.11 |
| | Oct | 8 | 7 | 1 | 0 | 0 | 12.50 |
| | Total | 33 | 28 | 4 | 1 | 0 | 15.15 |
| **Winter** | Nov | 8 | 7 | 1 | 0 | 0 | 12.50 |
| | Dec | 7 | 7 | 0 | 0 | 0 | 0.00 |
| | Jan | 7 | 7 | 0 | 0 | 0 | 0.00 |
| | Feb | 6 | 6 | 0 | 0 | 0 | 0.00 |
| | Total | 28 | 27 | 1 | 0 | 0 | 3.57 |
| | **SumTotal** | **92** | **84**<br>**91.30%** | **07**<br>**7.61%** | **01**<br>**1.09%** | **0** | **8.69** |

Table-11 shows that out of 92 dug well water samples at Site- III, 91.30% samples were containing arsenic less than 10 $\mu gL^{-1}$ and safe for drinking. 7.61% water samples had arsenic between 10to 50 $\mu gL^{-1}$ and 1.09% samples had arsenic between 51to100 $\mu gL^{-1}$. The percentage of arsenic contaminated dug well water samples was maximum during rainy season (15.15%) and minimum during winter season (3.57%).

**Table -12: Monthly and Seasonal Fluctuations in Arsenic Contamination of River Ganga Water of Katihar Dist. at Site-II**

| Seasons | Months | Number of water samples analyzed | Arsenic contaminated water samples( $\mu gl^{-1}$) | | | | Percentage of arsenic contaminated water samples ( >10 $\mu gl^{-1}$) |
|---|---|---|---|---|---|---|---|
| | | | <10 | 10-50 | 51-100 | 101-500 | |
| **Summer** | Mar | 3 | 3 | 0 | 0 | 0 | 0.00 |
| | Apr | 4 | 3 | 1 | 0 | 0 | 25.00 |
| | May | 1 | 1 | 0 | 0 | 0 | 0.00 |
| | Jun | 4 | 4 | 0 | 0 | 0 | 0.00 |
| | Total | 12 | 11 | 1 | 0 | 0 | 8.33 |
| **Rainy** | Jul | 4 | 3 | 1 | 0 | 0 | 25.00 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Aug | 3 | 2 | 1 | 0 | 0 | 33.33 |
| | Sep | 4 | 2 | 0 | 1 | 1 | 50.00 |
| | Oct | 4 | 4 | 0 | 0 | 0 | 0.00 |
| | Total | 15 | 11 | 2 | 1 | 1 | 26.67 |
| **Winter** | Nov | 3 | 2 | 1 | 0 | 0 | 33.33 |
| | Dec | ND | ND | ND | ND | ND | ND |
| | Jan | 3 | 3 | 0 | 0 | 0 | 0.00 |
| | Feb | 2 | 2 | 0 | 0 | 0 | 0.00 |
| | Total | 8 | 7 | 1 | 0 | 0 | 12.5 |
| | **SumTotal** | **35** | **29 82.86%** | **04 11.43%** | **01 2.86%** | **01 2.86%** | **17.14** |

ND =Not Done

Monthly and seasonal variations in arsenic contamination in river Ganga water at Site - II was depicted in Table-12. Out of the total 35 water samples, 82.86% samples had arsenic below 10 µgL$^{-1}$ (WHO guideline value), 11.43% between 10to 50 µgL$^{-1}$, 2.86% in each between 51 to 100 µgL$^{-1}$ and 101 to 500 µgL$^{-1}$ of arsenic. There was evidence of seasonal variations in concentration of arsenic in water with minimum percentage of contaminated Ganga water (8.33%) occurring in the summer and maximum (26.67%) in the rainy season.

**Table -13:Monthly and seasonal fluctuations in arsenic contamination of River Ganga water of Katihar dist. at Site-IV**

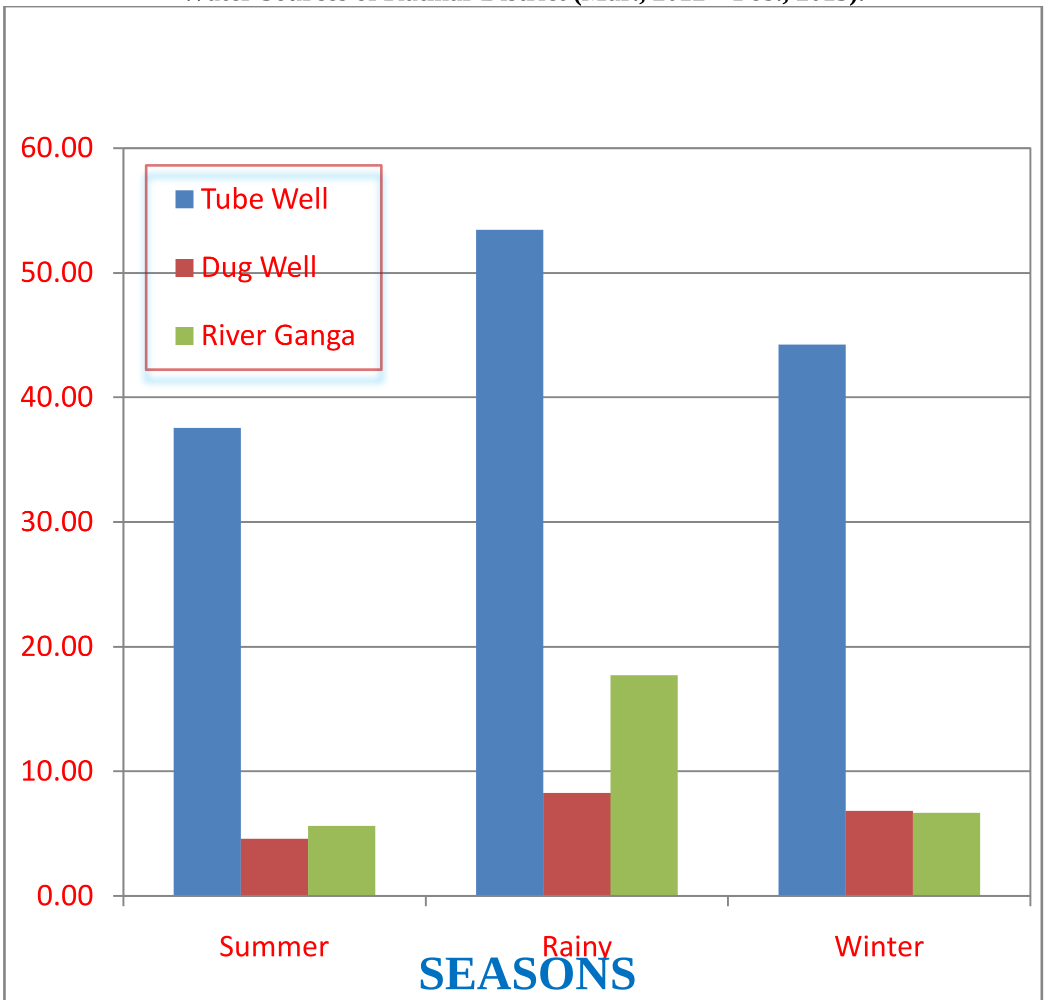
| Seasons | Months | Number of water samples analyzed | Arsenic contaminated water samples( µgl$^{-1}$) | | | | Percentage of arsenic contaminated water samples ( >10 µgl$^{-1}$) |
|---|---|---|---|---|---|---|---|
| | | | <10 | 10-50 | 51-100 | 101-500 | |
| **Summer** | Mar | 3 | 3 | 0 | 0 | 0 | 0.00 |
| | Apr | 2 | 2 | 0 | 0 | 0 | 0.00 |
| | May | 2 | 2 | 0 | 0 | 0 | 0.00 |
| | Jun | 3 | 2 | 1 | 0 | 0 | 33.33 |
| | Total | 10 | 9 | 1 | 0 | 0 | 10.00 |
| **Rainy** | Jul | 4 | 2 | 1 | 0 | 1 | 50.00 |
| | Aug | 3 | 3 | 0 | 0 | 0 | 0.00 |
| | Sep | 3 | 3 | 0 | 0 | 0 | 0.00 |
| | Oct | 2 | 2 | 0 | 0 | 0 | 0.00 |
| | Total | 12 | 10 | 1 | 0 | 1 | 16.67 |
| **Winter** | Nov | 3 | 3 | 0 | 0 | 0 | 0.00 |
| | Dec | ND | ND | ND | ND | ND | ND |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Jan | 2 | 2 | 0 | 0 | 0 | 0.00 |
| | Feb | 2 | 2 | 0 | 0 | 0 | 0.00 |
| | Total | 7 | 7 | 0 | 0 | 0 | 0.00 |
| | **SumTotal** | **29** | **26 89.66%** | **02 6.89%** | **0** | **01 3.45%** | **10.34** |

ND =Not Done

Monthly and seasonal variations in arsenic contamination in river Ganga water at Site- IV is depicted in Table -13. Of the total 29 water samples, 89.66% had arsenic below 10 µgL$^{-1}$(WHO guideline value), 6.89% and 3.45% sample were in range of 10to 50µgL$^{-1}$ and 101 to 500 µgL$^{-1}$ of arsenic respectively. Not a single water sample was detected with arsenic in the range of 51 - 100 µgL$^{-1}$. A seasonal variation was profoundly observed. The percentage of arsenic contaminated Ganga water samples was recorded maximum (16.67%) during rainy season. However, during winter season arsenic was not detected in Ganga water samples.

**Fig -1: Average Seasonal Variations (%) of Arsenic Contaminated water Samples at Different Drinking Water Sources of Katihar District (Mar., 2012 – Feb., 2015).**




| Seasons | Tube Well | Dug Well | River Ganga |
|---|---|---|---|
| Summer | 37.57 | 4.60 | 5.63 |
| Rainy | 53.54 | 8.26 | 17.71 |
| Winter | 44.23 | 6.82 | 6.67 |

Fig-1: shows that among different drinking water sources average maximum value of arsenic contamination was recorded in tube well water during rainy season and minimum value in dug well water during summer season.

**Table - 14: Correlation Coefficient between Physico-chemical and Arsenic Parameter of Different Drinking Water Sources of Katihar Dist.**

| Parameter | Tube well | | | Dug well | | River Ganga | |
|---|---|---|---|---|---|---|---|
| | Site - II | Site - III | Site- IV | Site - II | Site - III | Site- II | Site- IV |
| **Atm.Temp.** | 0.21105 | 0.01965 | -0.286 | 0.10742 | -0.01756 | -0.04326 | 0.09604 |
| **Water. Temp.** | 0.18795 | -0.05008 | -0.1834 | 0.08286 | -0.10544 | -0.05358 | 0.09759 |
| **Turbidity** | 0.50218 | 0.45788 | 0.20884 | 0.12778 | 0.39636 | 0.4445 | 0.38518 |
| **PH** | -0.12818 | -0.15217 | 0.24198 | 0.08308 | -0.17494 | 0.16041 | -0.22981 |
| **T. Conductivity** | 0.26097 | -0.63246* | -0.0029 | 0.38483 | -0.16305 | -0.19298 | -0.21281 |
| **Total Hardness** | -0.04593 | 0.13633 | -0.3218 | -0.03666 | -0.33696 | -0.20271 | -0.18818 |
| **Dissolved Oxygen** | 0.12235 | -0.43638 | -0.1938 | 0.52092 | -0.13549 | -0.32356 | -0.04841 |
| **F. $CO_2$** | -0.12433 | -0.12316 | -0.2299 | 0.21662 | -0.55274 | 0.16123 | 0.63154* |
| **TDS** | 0.07613 | -0.22048 | -0.1446 | 0.11514 | -0.19027 | 0.48896 | 0.6034* |
| **Calcium Hardness** | 0.11989 | 0.45121 | 0.4108 | -0.17001 | -0.32611 | -0.16522 | -0.01149 |
| **Nitrate** | 0.32823 | -0.17488 | 0.16309 | -0.13165 | 0.09775 | 0.05755 | 0.2676 |
| **Total Alkalinity** | 0.18636 | 0.47391 | -0.0886 | -0.32875 | -0.17549 | -0.4304 | -0.15627 |
| **Chloride** | 0.62534* | -0.04591 | 0.55255 | -0.14714 | 0.24141 | -0.33851 | 0.2259 |
| **Fluoride** | 0.20431 | 0.25847 | 0.40914 | 0.13113 | 0.27015 | 0.40446 | 0.56309 |
| **Calcium** | 0.02688 | 0.20098 | 0.38677 | 0.35004 | -0.26041 | -0.2328 | 0.05939 |
| **Magnesium** | 0.02137 | -0.235 | -0.0482 | 0.13484 | -0.1454 | -0.3932 | 0.02116 |
| **Iron** | -0.42191 | -0.12855 | -0.4345 | -0.07094 | -0.319 | -0.19997 | -0.21181 |
| **Arsenic** | 1** | 1** | 1** | 1** | 1** | 1** | 1** |
| | *** = Significant at 5% ;** | | | **** = Significant at 1%** | | | |

Table-14 indicates that arsenic shows positive significant correlation with F. $CO_2$, TDS and chloride and negative significant correlation with electrical conductivity at 5% level.

**Fig-2:Arsenicosis inKatihar Dist. Fig-3:Arsenic Analyses and Filtration Process**

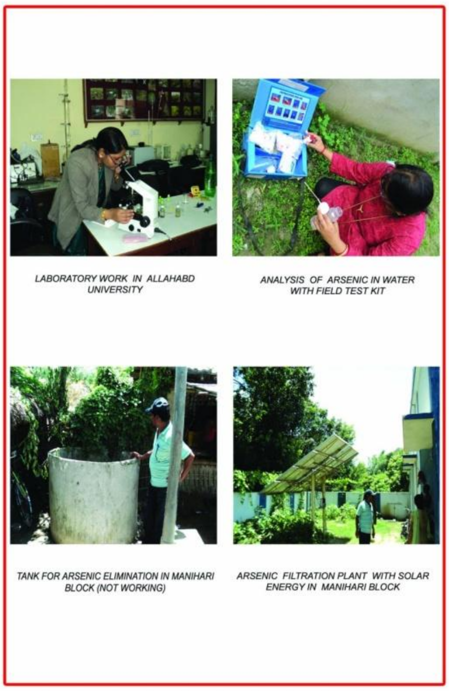




Fig-2 represents the people showing arsenical skin lesion. They are affected by chronic arsenic poisoning showing pigmentation and thickening in skin of palms and legs and in nails. Several people reported they have some problems of gastrointestinal, lever, lungs, diabetes, neurological abnormalities, digestive and endocrine systems. An apparent increase in fetal loss and premature delivery in women was also observed in the present study. Children were more affected with toxic substances than adults and show diarrhoea. It appears from the analyses that many villagers may be sub-clinically affected and they are continuously drinking the contaminated water since they were mostly unaware of the problem before we surveyed them.

## IV. Discussion

Out of 16 blocks of Katihar district, 4 blocks namely Katihar, Manihari, Amdabad and Barariwere selected for arsenic contamination in drinking water. The manifestations of arsenicosis after exposure to contaminated groundwater in the villages of these blocks were remarkably similar to the previous studies of arsenic affected areas of Bihar[21]. In the present investigation, out of four blocks (sites), groundwater of three blocks, Manihari, Amdabad and Barari (Site-II, III and IV) was found intoxicated with arsenic. However, drinking water of Katihar block (Site-I) was found free from arsenic contamination. Out of 1596 water samples of tube wells collected from four selected sites, 56.27% tube well water samples were safe to drink considering WHO (2004) guidelines and 86.41 tube well water samples were safe to drink considering BIS (1998) guidelines of drinking water. These observations corroborate with the report of SOES[21] in Katihar district which recorded the 61.06% and 82.26% of tube well water were safe to drink considering WHO and BIS guidelines values respectively. Mukherjee *et al*. (2006)have analyzed 9597 water samples of hand tube well and found 39.02% samples contained $>10\mu gl^{-1}$ and 23% contained $>50\mu gl^{-1}$ arsenic in Bihar[22].Dug well and river Ganga water were likely to contain very less amount of arsenic. Only 6.48% dug well water had arsenic above $10\mu gl^{-1}$ and 0.93% above $50\mu gl^{-1}$. Thus 93.52% and 99.07% dug well water were safe for drinking and domestic purposes considering WHO and BIS guidelines of arsenic respectively. This finding is also supported by the studies of CGWB and PHED, Govt. of Bihar, which indicated the contamination as high as 0.178 $mgl^{-1}$ in villages of Bhojpur district in Bihar, affecting the hand pumps which are generally of 20-40 m depth[35]. However, dug wells (depth 8-12 m) have been marked with low arsenic (max. 008$mgl^{-1}$) in those villages[36]. In well oxygenated surface water, arsenic ($As^{5+}$) is generally the most common arsenic species present[37], under reducing conditions such as those often found in deep groundwater, the predominant form is arsenic ($As^{3+}$)[38]. Considering WHO and BIS guidelines for arsenic, 85.94% and 95.32% of river Ganga water may be considered for drinking and domestic purposes. It may be attributed to low iron concentration, sufficient amount of oxygen and water depth of river Ganga.

Season wise, the higher percentage of arsenic contaminated tube well water was recorded during rainy season and lower percentage during summer season. The rise in arsenic concentration during the rainy season can be attributed to the local dissolution of iron oxyhydroxides as conditions became more reducing while during summer season arsenic is scavenged onto fresh iron oxyhydroxides. Savarinmuthu*et al.* (2006) have recorded similar findings during their study[39]. Higher percentage of arsenic contaminated dug well water was found during winter at Site-II and during rainy at Site-III. Previous investigations in Nevada have demonstrated that arsenic concentrations remain stable over years[40]. The reason why these large seasonal changes have been seen in some wells is not completely clear, although mechanisms such as dilution by recharge of water with low arsenic concentration or change in redox conditions due to seasonal changes in pumping rates, water movement or water table depth have been proposed[41].Thundiyil*et al*. (2007) also recorded small seasonal variability in arsenic concentration in wells in Nevada[42].

In river Ganga, arsenic contamination in water was recorded with higher percentage during rainy season and lower percentage during summer season at Site-II. However Site-III showed lower percentage of arsenic contaminated water samples during winter season and higher percentage during rainy season. It may be related to pollution, water pH and release of other metals which can absorb arsenic. Previous studies have also demonstrated seasonal variability of arsenic level in surface stream[41,43].

Arsenic shows positive correlation with turbidity, nitrate, fluoride and iron. At 5% significant level it showed positive correlation with $CO_2$, TDS and chloride and negative correlation with electrical conductivity in tube well water. According to Saha*et al*.(2009) a positive significant correlation was observed between arsenic and iron in groundwater of affected area of Sone-Ganga Interfluve[36].

Based on the findings of the present study, dug well water may be considered as the best option for drinking as far as arsenic contamination in concerned. Although dug wells were found more likely to contain pathogens, they can be killed by using a variety of methods including filtration, chlorination and boiling. As a general rule, open wells also contain significantly lower level of iron hence making the water more potable. Ganga water is also found less likely to contain unsafe arsenic level but this water is neither available to most villagers nor it is easy to transport. Besides, Ganga water contains a large number of bacterial pathogens. Therefore, dug well establishment should be expended throughout the district of Katihar coupled with proper education on how to treat the water against pathogen contamination which can be controlled through medicine. There is no medication for arsenic poisoning. The above conclusion gets support from Ahamed*et al.*[18],Alam and Rahman[44], Williumand Andrew[45] who emphasized the safe water option from surface and sub-surface water. Therefore, dug wells provide a sustainable solution to water with less arsenic content. They can be easily installed and at low cost.

## V. Conclusion

Arsenic concentration in different drinking water varied from negligible to 300 $\mu gl^{-1}$ in the present investigation.Out of the four blocks of the study area, the drinking water of three blocks Manihari, Amdabad and Barari were found contaminated with arsenic. The drinking water of Katihar block was found totally free from arsenic contamination. Present observation revealed that samples of 43.73 % tube wells, 6.48 % dug wells and 14.06 % river Ganga water were containing arsenic above 10 $\mu gl^{-1}$. However railway supply and municipal supply water were totally free from arsenic. The study also showed that sub surface and surface water contained arsenic in very low concentration whereas neighboring underground water contained high amount of arsenic. Arsenic contamination in drinking water may create problem of *arsenicosis*. Many arsenical problems were observed amongst the people ofKatihar dist. And there is no medication of *arsenicosis*. To avert these problems periodicawareness programs should be organized in arsenic contaminated drinking water areas. Consumption of arsenic free drinking water is the only solution of the problem. The use of surface water (river Ganga), dug well water and rain water may provide a permanent solution for arsenic free drinking water. However, these sources still need to be properly treated against bacterial and other chemical contamination before use. Additionally, generating awareness regarding the arsenic related health problems and adequate supply of arsenic safe water to the affected population are required.

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