Chapter - VI

Health Impact of Arsenic and Mitigation Plan
6.1 Introduction

The contamination of groundwater with arsenic (As) is one of the serious problems in the World mainly in parts of Bangladesh, China, Vietnam, Nepal and the of Ganga Brahmaputra plains of India due to its toxic and carcinogenic nature (Kinniburgh and Smedley, 2001; Tandukar et al., 2001). The people are suffering from this havoc and facing many chronic health effects due to consumption of As contaminated drinking water. Many incidences have reported from throughout the World and large numbers of people are dying due to arsenicosis. Worldwide distribution of As in groundwater, source of As, distribution of As in Ballia district and its relationship with physical features have been discussed in previous chapters. This chapter deals with the health impact of As and its mitigation plan. It is one of the main objectives of present thesis work. Detailed methodology for this study is also discussed in this chapter. This chapter is also a preliminary evaluation of exposure of As in Ballia district which deals with the interaction with As affected people and medical doctors. In literature review chapter, major health effects due to As contaminated water have been discussed in detail. Therefore, brief introductory information about health impact and mitigation are discussed in following paragraphs:

As discussed in previous chapters that As is a major health concern due to its carcinogenic effects and spreading just like an epidemic in many countries of the World specially south Asian countries. About 105 countries are suffering from this havoc. Among them, India is also fighting with As rich contaminated ground water in few provinces. The majority of the As affected people about 75% are from South and South-east Asia i.e. Bangladesh, India, Myanmar, Nepal, Pakistan, Cambodia, China, Laos, Taiwan and Vietnam (Brammer and Ravenscroft, 2009; Chen et al., 2011; Nickson et al., 2000). Past study suggests that it is spreading from Bengal delta to UP, Bihar, north-east states etc. along with Ganga Brahmaputra Rivers (Ahmed et al., 2006). As poisoning in the groundwater of Ganges delta region of Ballia district, eastern Uttar Pradesh is now a well known fact. There may be possibilities of likely to reaching As in Delhi; the capital of India; after few years. If this is the situation, As will spread all over the country making groundwater unfit for drinking.
As is very dangerous at high concentrations for e.g. a person can be killed by ingestion of a teaspoon of As trioxide with wine. So it is very important to observe chronic exposure to As in a long period of time. 10 microgram’s (mg) of arsenite or arsenate in one liter of water is not toxic for human health i.e. 10 ppb which is permissible limit. The permissible limit for maximum contamination level (MCL)) in groundwater varies from 10 ppb to 50 ppb worldwide. Even low concentrations of As, when ingested over a period of years, can lead to a wide range of chronic health problems (arsenicosis). In the ancient times, As has been considered as a poison. The case of Napoleon death is an interesting example of As poisoning (Anonymous, 1961). The extent of the As toxicity in drinking water was high. So keeping in mind this fact, WHO has lowered the permissible limit of As in drinking water from 50 ppb to 10 ppb for considering the negative health effects on human. In September 2003, the Bureau of Indian Standards (BIS) set the desirable limit of As in drinking water as 10 ppb. However, like radiation, the toxicity of inorganic As is linear, so damage to the body is caused at even lower concentrations.

The toxic effects of As ranges from acute lethality to chronic effects. Various studies, described As toxicities depending on its oxidation state. The element As with atomic number 33; exist in ground water naturally into organic form and inorganic form. In natural water, As is mostly found in inorganic form as oxyanions of trivalent [As (III)] and pentavalent [As (V)] (Ali et al, 2011). As attached to inorganic moiety is about 100 times more toxic than the As attached to organic moiety (Ali et al., 2011; Jain and Ali, 2000). Moreover, the trivalent form of As is about 60 times more toxic than the pentavalent form As (Jain and Ali, 2000). Whereas, arsenosugars and arsenobetaines are non-toxic (Craig, 1986). Toxicity of trivalent is due to its soft nature and its capability to interact with –SH groups of enzymes; inhibiting the enzymatic activities (Das, 2008). Arsenate is structurally similar to phosphate and hence, replaces a phosphate group in ATP leading to uncoupling of phosphorylation and breakdown of metabolic processes (Craig, 1986; Manahan, 1997).
6.1.1 Major health effects of groundwater arsenic

As is very toxic elements which can lead to a wide range of health problems. It can also lead to rapid death due to the severe toxicity of As poisoning. As gains entry into the human system through ingestion, inhalation and dermal contact where it binds to skin and hair and get transported by blood in the body (CSE, 2008). The risks associated with As poisoning are varied and differ even among population exposed to the same levels of the contaminant. It has not been possible to define a critical organ for As in the way that the kidney is considered for lead and cadmium intoxication. Urine is the most suitable indicator for assessment of exposure to inorganic As. The first indication of illness caused by long term As exposure or arsenicosis is a black raindrop pattern in the limbs, chest and back, and sometimes on mucus membranes of the tongue and gums which is called hyper pigmentation (RoyÁChowdhury, 1995). White spots on the skin, hypopigmentation, could also occur. Both of these symptoms are known as melanosis (plate 6.1). Typically, after few years of exposure, the skin on the hands and feet hardens and rises into nodules which can reach up to one centimeter across. This stage of As poisoning is called keratosis (plate 6.2). The nodular forms are encountered most frequently on the inner and lateral borders of palms, on roots or lateral surfaces of fingers and soles, heels and toes of feet (Das et al., 1995). The speed at which As related skin diseases arise and progress depends on the intake dose of As which can cause other skin diseases such as ‘black foot’ or peripheral vascular diseases. This ultimately results in gangrene (plate 6.2) in the extremities.

Inorganic As compounds, even in trace amounts, are proven carcinogens and can cause skin, lung and bladder cancer (Ahmad et al., 1997; Hopenhayn-Rich et al., 1998). Inorganic As has also been associated with various respiratory diseases (irritation of the mucous membrane, laryngitis, bronchitis, rhinitis and tracheobronchitis) and gastrointestinal effects (dyspepsia or stomach ache, nausea, diarrhea, anorexia and abdominal pain) (Ahmad et al., 1997; Borgoño et al., 1977; Cebrian et al., 1983; Zaldivar, 1974). Humans exposed to As contaminated water show serious neuropathy and cerebrovascular diseases (Ahmad et al., 1997; Cebrian et al., 1983) occurrences of weakness and fatigue, Conjunctival congestion and nonpitting oedema of the legs and hands people (Ahmad et al., 1997; Mazumder et al., 1992;
The stigma of arsenicosis symptoms has a significant impact on the lives of some of its victims, especially women. In some areas, arsenicosis patients have been shunned by spouses and community members due to a mistaken belief that arsenicosis is a contagious disease and other factors.

Plate 6.1: Melanosis and keratosis skin lesions due to As contaminated water
Source: SOES, Jadavpur University (JU), Kolkata

Plate 6.2: Skin cancer develops on the keratosis and amputated due to gangrene
Source: SOES, Jadavpur University (JU), Kolkata
6.1.2 Arsenic in the food chain

Besides water, the other sources through which one might ingest As are crops and food products. It is evident that As content in food chain i.e. another dietary source of As. Serious health impact can occurs due to continuously intake of relatively low levels of As in the diet. Earlier it was remained a puzzle for a number of years until Professor Andrew Meharg (University of Aberdeen, UK) and his colleagues surveyed paddy soils and rice grain of Bangladesh and revealed that rice grown in certain parts of the world contains relatively high levels of inorganic As (Meharg and Rahman 2003). They found that besides drinking water, tube wells were poisoning food as well. The poison was being liberally poured onto the most precious of all the delta’s natural resources: its soil. It is also informed that rice from India, Bangladesh China, USA etc. contains higher levels of As, and As content in that rice is 10 times more than other crops.

Paddy rice is the staple food of Bangladesh, West Bengal, eastern UP and Bihar. In Bangladesh, around three quarters of the total cropped area is given to rice cultivation and more than four-fifth of the total irrigated area is used for it. Vast quantities of tube well water are pumped up to flood paddy fields during the long, hot dry season. Once As is in the soil, it generally stays there, unless the monsoon floods wash away the contaminated sediment. Rice plants and vegetables can readily accumulate soluble forms of As into their edible parts. Rice grown in Bangladesh has been found with as much as 1,830 ppb As; a normal level would be 200 ppb. Rice, it seems, can contribute almost as much As to the diet as tube well water, especially where it is also cooked in contaminated water (CSE, 2008).

In 2002, a study conducted by researchers from the National Institute of Health Sciences Japan, shows that foodstuff grown in West Bengal too have very high levels of As (CSE, 2008). The study was conducted in the Jalangi and Domkal blocks of Murshidabad district, where the agricultural system is mostly dependent on groundwater. The highest levels of As in the areas of tube well water was found 85 ppb and the level in soil was found 1135 ppb. The results revealed that As levels in various foodstuffs were very high viz 292 ppb in potato skin, 212.34 ppb in vegetable leaves,
341 ppb in arum leaves, 373 ppb in papaya, 245.39 ppb in rice, 362 ppb in wheat, 209.75 ppb in cumin, 280.9 ppb in turmeric powder, 159.37 ppb in cereals and 294.47 ppb in bakery goods. The researchers also found that families in Jalangi block are suffering more than Domkal block. They found that about 63.16 percent of adult females and 100 percent of adult males in Jalangi block are suffering from arsenicosis skin lesions and about 36.4 percent of adult females and 64.3 percent of adult males in Domkal. This is because families studied in Jalangi block are consuming higher amounts of As from foodstuff compared with Domkal block. For instance, adult females are consuming 399 ppb and 300 ppb of As per day from water alone in Jalangi and Domkal respectively. But both from foodstuff and water, the figure was 570.20 ppb and 489.13 ppb respectively.

As per CSE (2008), no country has set any standard of As in foodstuff except Australia. Australia has set 1 particle per million (ppm) As permissible limit in food level because of the high intake or As through seafood, as As is naturally elevated in most seafood. The WHO has set a provisional Maximum Tolerable Daily Intake (MTDI) of 2 µgm/kg body weight per day. Experts have found that rice in Bangladesh and West Bengal often exceeds this MTDI. It is also mentioned that there is no way to eliminate As from the food chain. Even if people stopped drinking tube well water, they would still need it to irrigate paddy fields and other crops. The quantities of water required for cultivation are so vast that it would be uneconomical to rid the water of As. Clean water could be obtained from rainwater harvesting or hydroelectric projects. But even if this happens, the As would still remain in the soil. The cost of removing this, even if it is possible, would be exorbitant.

According to T Roychowdhury, the lead researcher, As is absorbed in the skin of most vegetables and the As concentration in fleshy vegetable material is lower than that in leafy vegetables (CSE, 2008). Furthermore, higher As concentration was found in cooked items than raw foodstuff. A study was carried to examine the extent of As contaminated groundwater and to assess how cooking water source impacts dietary As intake in a rural community in Prey Vêng Province, Cambodia using GIS & statistical analysis techniques (O’Neill, 2013). The author reported several diseases due to consumption of As contaminated water in food stuffs.
6.1.3 Arsenicosis cases in Ballia district

As discussed in previous chapters that Ballia District is severely affected by As pollution and several skin and other effects have been reported in the residents (Ahmed et al., 2006; Chauhan et al., 2009; Mukherjee et al., 2006; Srivastava and Sharma, 2013). Ballia district has the notorious case of As contamination and represents one of the active cases of As poisoning outside West Bengal. The most commonly observed symptoms of chronic arsenicosis are skin lesions (e.g. melanosis, keratosis), black foot disease and in more severe cases, incidents of gangrene, cancer of the skin, lung and bladder, gastro-intestinal, pulmonary, neurological problems and fatal death in the study area. The long-term use of As contaminated drinking water increases the main threat of cancer of skin, liver, kidney, and prostate. Besides, other harmful effects are thickening and discoloration of skin, stomach pain, nausea, vomiting, diarrhea, numbness in hands and feet, partial paralysis and blindness.

In 2003, Dr. Omprakash, of Sonbarsa primary health centre said to Hindustan newspaper that effect of As contaminated water is more toxic than cancer and HIV diseases and groundwater of the area is totally polluted. Hindustan also reported that two brothers Ravindra Choube and Virendra Choube and Bharat Sharma (35 year) from Ramgarh village had lost their lives due to consumption of As contaminated water. Bihari Yadav from Balhar village had also lost his life. The residents of Rajpur Ekwana, Tiwartola, Shahpur, Durjanpur, Chobechapra, Diknichapra and lots of villages of Belhari, Bairia and Murlichapra blocks are dying due to As and rich people are leaving these villages (Dainink Jagran, 2004).

In January 2005 first time a group of researchers from School of Environmental Studies, Jadavpur University Kolkata, and West Bengal reported As contamination in Ballia District and found more than half samples had As above the Indian guideline level of 10 ppb (Mukherjee et al., 2006). In July 2005 Centre for Science and Environment (CSE) also checked the water samples of four hand pumps in Ballia District and reported 73, 47, 15 and 129 ppb As contamination. As in the hairs and nails of the residents were tested in some villages of the district and As content was also found in the hairs and nails (CSE, 2005). Dr Ganesh Kumar Pathak, coordinator
Integrated Development & Research Centre conducted a survey in four villages of Belhari block of Ballia. His study shows that 90 percent people of total population of these villages are suffering from skin lesions, liver, cancer and respiratory diseases and about 30 percent of their income are wasting in medicines (*Hindustan*, 2005). It was also reported that not only mankind but also crops, plants and animals are adversely affected due to As.

As per the study entitled as “Report on Arsenicosis in District Ballia, Uttar Pradesh”, a survey was conducted in As affected areas of Ballia in Feb, 2011 to assess the extent of As problem, its severity and to know the mitigation measures adopted by Jal Nigam, Uttar Pradesh. During this survey, status of pipeline schemes for safe water drinking and community participation in these schemes is also examined. The study revealed that As is found in those sources of groundwater where the withdrawal of groundwater is from 50 to 75 feet below ground level (bgl) and patient of skin diseases such as melanosis, white spot on legs & abdominal area were also found in the residents of these affected villages. In general, the residents of As affected areas are facing arsenicosis skin lesions ranging from melanosis, keratosis to bowens and cancers due to consumption of As contaminated water in long term. Besides, skin lesions and cancers due to As have been linked to a wide range of other health problems in the district i.e. peripheral neuritis, or a tingling sensation in the fingers and toes, Gastro-intestinal disturbances, pulmonary effects etc. The stigma of Arsenicosis symptoms has a significant impact on the lives of some of its victims, especially women. Neha et al., (2013) observed As exposure in water and blood samples of the residents of affected areas of Ballia region. The authors also reported that people are adversely affected due to ingestion of inorganic As and facing health problems such as skin lesions, hyper pigmentation, gastrointestinal effects, liver or kidney, anaemia, etc.

There is no medical cure or treatment for As toxicity (arsenicosis) as well as no cheap and natural techniques to remove As content from groundwater hence the only solution is to stop drinking As-contaminated water. So there must be some essential activities which can help the mitigation and remediation in As affected areas e.g. providing the alternate source of drinking water, developing schemes for providing surface water in affected areas and local people participation in As removal plants etc.
(Ghosh and Singh, 2009). It is very important to generate awareness through local level community participation in schemes to provide the alternate source of drinking water. Along with alternate source of safe water, it is also recommended that the appropriate food habits i.e. nutritious food and vitamins are the only preventive measures to fight the chronic As toxicity. A healthy diet can play an important role to improve immunity which leads in preventing and controlling arsenicosis. To do away with the As menace, it is the primary responsibility of the government, aid-agencies and the researchers to educate and motivate the common masses about this issue of serious concern. Surface water based piped water supply system wherever feasible, is the most appropriate and sustainable solution for As problems in groundwater based drinking water sources.

The above discussion clearly highlights the acute toxicity of As at high concentrations and its chronic health effects in India including Ballia district. Groundwater of Ballia district is getting turned from nectar to poison due to As contamination. Therefore, this chapter is presented to describe the major health effects of As poisoning in the study area. It is very important to come in limelight the current situation in front of the district officials i.e. further mitigation action plans will have to taken by the authorities. For the first time many field surveys have been conducted to interact the affected people to know the adverse effect of As contaminated water. Detailed methodology for this chapter including primary data collection through questionnaires, major health effects, mitigation plans and health facilities in the district are discussed in following paragraphs:
6.2 Data base and methodology

This chapter is based on primary sources of data collected through field survey with the help of questionnaires in March 2015. The highly affected villages of Ballia have been selected based on the results of our As results to collect health data. About 100 questionnaires have been filled by the residents of these most affected areas (plate 6.3).

The secondary data has been collected from National Informatics Centre, Water Board, and district hospital, Ballia etc. which include map of most As contaminated areas, records of wells, tube wells and hand pumps, list of the patients with respect of As contamination etc. During 2012 to 2015, many field visits have been conducted to collect health related data. Medical doctors, media and active people have been interacted to get information about the details of patients, reason of As poisoning and action plan to mitigate the problem by the government (plate 6.4 & 6.5). Some important information has been collected from Dainik Jagran, Ballia and Mr. Bhola Prasad (social activist & reporter Amar Ujala). Most affected villages such as Raipur, Tiwaritola from Belhari block and some villages from Murlichapra, Belhari and Revati blocks have been visited along with Mr. Bhola and Suresh Mishra (Amar Ujala) to fill questionnaires in order to know the impact of As on health. Random sampling
technique has been applied for it. Further statistical analysis was applied to determine the health impact on people of various age groups and other parameters.

Plate 6.4: Visit Jal Nigam & district hospital office, Ballia

Plate 6.5: Interaction with media and social activist Bhola Prasad at Dainink Jagran
6.3 Health effects of arsenic in Ballia district

The district hospital of Ballia was visited and 40 years old Mr. Ashok Singh was interviewed (Plate 6.6). Mr. Singh reported that he is suffering from skin disease because of high concentration of As i.e. 34.40 ppb which was seen in his blood report of Oct. 2009, where as the reference limit of As is mere 1-4 ppb, as per leading Toxicology manuals. He gave much valuable information regarding As problem. He is the son of Late Mr. Dinanath Singh from Ekawana Rajpur village (Belhari block).

Mr. Ashok Singh informed that his father Mr. Dinanath was the first patient found As in his blood and died due to skin cancer. Previous reports and research works also confirmed it. Ashok Singh also informed that his father had cancerous wound on his left foot from which blood and pus continuously oozed. He had black & white spots over all over his body and two fingers of his left hand had developed ulcers which had to be amputated. Dinanath visited AIIMS, New Delhi in June 2004 for medical advice and met with Dr Neena Khanna, a professor of dermatology department. Blood test was observed and the report showed that Dinanath had 34.40 ppb of As, when the reference limit is a mere 1-4 ppb. Further As problem had come on limelight with the efforts of
During the last phase of present research work, a detailed field survey was conducted to observe the health impact of As. Highly affected areas such as Ekwana Rajpur, Tiwaritola, Gangapur, Choubechhapa, Murlichhapra, Tayachhapa, Jaiprakshnagar, Pandetola etc. villages of Belhari, Bairia, Murlichapra blocks (Fig. 6.1) in the eastern part of Ballia district were selected for field survey. Patients of arsenicosis were being interacted in affected villages to determine the impact of As on health.

![Fig. 6.1](image)

Total 100 people were interviewed randomly using the structured questionnaires were filled up by the residents of these affected areas (Annexure-XII). It was observed that many people are suffering from arsenicosis such as skin lesions, respiratory and gastrointestinal effects and table 6.1 shows the summary of health survey. The long
term use of the As contaminated ground water leads some diseases which are discussed in following paragraphs:

Table 6.1: Health effects of As in most affected villages of Ballia district

<table>
<thead>
<tr>
<th>Sign/Symptom/Lesion wise classification</th>
<th>No. of cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skin lesion</td>
<td>32</td>
</tr>
<tr>
<td>Cancer</td>
<td>-</td>
</tr>
<tr>
<td>Respiratory diseases</td>
<td>15</td>
</tr>
<tr>
<td>Gastrointestinal effects</td>
<td>21</td>
</tr>
<tr>
<td>Neurological effects</td>
<td>11</td>
</tr>
<tr>
<td>Skin lesion with respiratory effects</td>
<td>8</td>
</tr>
<tr>
<td>Skin lesion with gastrointestinal effects</td>
<td>6</td>
</tr>
<tr>
<td>Skin lesion with respiratory &amp; gastrointestinal effects</td>
<td>-</td>
</tr>
<tr>
<td>Gastrointestinal effects with respiratory effects</td>
<td>-</td>
</tr>
<tr>
<td>No effects</td>
<td>7</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
</tr>
</tbody>
</table>

(Source: Field survey, 2015)

6.3.1 Skin lesions

The symptoms of the disease known as skin lesions (pigmentation/ melanosis and keratosis) have been found in the bodies of more than 90% of the villagers in most affected blocks such as Murlichapra, Belhari etc. Total 32 persons out of 100 were found with sign/symptoms of skin lesions (table 6.1) during health survey. Change in skin color is called melanosis which is observed in chest, back and abdomen in the arsenicosis patients of Ballia district (plate 6.7 & 6.8). And thickening-hardening of skin into nodules is called keratosis (plate 6.9 & 6.10). The raindrop pattern of pigmentation appearance results due to presence of numerous rounded hyper pigmented macules throughout the body. Moreover, pigmentation is not only restricted to outer body skin but also spreads to mucous membranes like buccal mucosa.
Arseniosis keratosis appears as diffuse thickening involving palms and soles, alone or in combination with nodules usually symmetrically distributed. The nodular forms are encountered most frequently on the inner and lateral borders of palms, on roots or lateral surfaces of fingers and soles, heels and toes of feet. The pigmentation and melanosis can develop after consumption of highly As contaminated water of a period of 10 to 20 years, first melanosis develops and then occurs pigmentation. Mostly cluster of families are using drinking water by sharing of tube wells and hand pumps nearby the area. So this is the main reason for appearing these skin lesions in clusters of people within a community/area.

Plate 6.7: Patients of melanosis skin disease (Source: Field survey, March 2015)
Plate 6.8: Patients of melanosis skin disease (Source: Field survey, March 2015)

Plate 6.9: Patients of keratosis skin disease (Source: Field survey, March 2015)
Office of the Chief Medical Officer (CMO) district Ballia was being visited in order to collect information about the list and number of patients of arsenicosis. But unfortunately they did not give satisfactory information and data regarding it. Dr. B Narayan, skin and sex disease specialist in district hospital, Ballia gave some valuable information regarding skin problems due to As (plate 6.10). He told that many suspected arsenicosis patient (skin lesions) comes from As affected areas but unfortunately we have to refer them IMS, Banaras Hindu University for further treatment due to lack of facility to diagnose and proper treatment. Dr. Narayan also provided a list of suspected As patient of skin lesions which is shown in table 6.2.

Plate 6.10: Discussion with Dr. B. Narayan regarding arsenicosis at district hospital Ballia

Table: 6.2 History sheets of some patients in Ballia district

<table>
<thead>
<tr>
<th>Suspected patient name with age</th>
<th>Date</th>
<th>Village</th>
<th>Symptoms</th>
<th>Necessary action taken by doctor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mr. Dwarika Yadav, 60 year</td>
<td>09-12-2013</td>
<td>Harihar pur</td>
<td>Diffuse melanosis with As poisoning of grade 1</td>
<td>Referred to skin Deptt. IMS, BHU</td>
</tr>
<tr>
<td>Mr. Harishankar Chobe, 55 year</td>
<td>12-12-2013</td>
<td>Rajpur Ekwana</td>
<td>Diffuse spotty huperpigmentation with keratosis over trunk for past 5 years</td>
<td>Referred to skin Deptt. IMS, BHU</td>
</tr>
<tr>
<td>Mr. Dhoomlal, 50 year</td>
<td>16-12-2013</td>
<td>Byasi</td>
<td>Hyper keratosis over sols along with keratosis papules over back for past one year</td>
<td>Referred to skin Deptt. IMS, BHU</td>
</tr>
<tr>
<td>Mr. Rajesh, 70 year</td>
<td>18-12-2013</td>
<td>Rampur</td>
<td>Hyper keratosis papules over both palms and melanosis maculae over trunk for past one year</td>
<td>Referred to skin Deptt. IMS, BHU</td>
</tr>
<tr>
<td>Mrs. Basanti Devi, 60 year</td>
<td>17-02-2014</td>
<td>Rajpur</td>
<td>Diffuse spotty huperpigmentation with chronic As poisoning grade II</td>
<td>Referred to skin Deptt. IMS, BHU</td>
</tr>
</tbody>
</table>

(Source: Dr. B. Narayan, district hospital Ballia, 2015)
Some data was also collected from CMO office which shows the number of suspected cases and sensitization camps. The staffs of CMO have informed that no death is reported till date and they found 49 numbers of suspected cases of skin lesions in the district (table 6.3). It is not acceptable that CMO found only 49 suspected cases and denied for death due to arsenicosis. Death of Mr. Dinanath Singh is an example of arsenicosis. Even though the villagers from Belhari, Murlichapra and Bairia blocks were informed that many people were died due to arsenicosis.

Table 6.3: Data related to chronic As poisoning of district Ballia

<table>
<thead>
<tr>
<th>Total No. of suspected cases</th>
<th>Sign/Symptom/Lesion wise classification</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Skin lesion</td>
</tr>
<tr>
<td></td>
<td>49</td>
</tr>
<tr>
<td>Total no. of sensitization camps</td>
<td></td>
</tr>
<tr>
<td></td>
<td>18-11-2012</td>
</tr>
<tr>
<td></td>
<td>19-11-2013</td>
</tr>
<tr>
<td></td>
<td>15-05-2014</td>
</tr>
<tr>
<td></td>
<td>17-07-2014</td>
</tr>
<tr>
<td></td>
<td>16-09-2014</td>
</tr>
</tbody>
</table>

(Source: CMO Ballia, 2015)

A list of patient along with the letter dated on 07-12-2013 to human rights, New Delhi from Dr. Mansoor Ahmad (CMO, Ballia) was collected. It shows number of suspected arsenicosis patient with name and address. It also shows that arsenicosis patients have been found in Belhari, Murlichapra and Bairia blocks in last few years and many awareness programme, seminar and camps have been organized for its prevention. Dr. Mansoor also informed to human rights that there was no death found as per his knowledge in Ballia district. It is informed that 7 patients from Chenchapra village, 10 from Rajpur Ekwana, 3 from Tiwaritola, 5 from Hariharpur, 6 from Udaychapra and 12 patient from Sugharchapra were found (Annexure-XIII). It’s an irony that CMO reported some arsenicosis patient on above mentioned letter to human rights and on the other hand CMO had also informed zero patients due to As in the district on the letter dated 27-06-2013 regarding As related information year 2012.
6.3.2 Cancer

As is a well-known carcinogenic and drinking As contaminated water leads to various types of cancers (Ali et al., 2012) like skin, lung, liver and bladder cancers etc. Cancer is the greatest health threat in Ballia district. It is found that population of the district consuming drinking water with high levels of As; had high rates of skin cancer. Lots of people are suffering from skin cancer due to consuming the As contaminated water. During health survey, the residents of highly affected villages informed that every year some people are dying due to skin and liver cancer. They also informed that hundreds of people had lost their lives due to cancer in previous 10 years. Mr. Tarkeshwarnath Tiwari, a resident of Rajpur told that he had lost many his family members due to cancer. He also informed that about 90 percent people of his village are affected due to As. No cancer patient was found during health survey in affected areas. Some villagers informed that Kishunram from Tiwaritola is suffering from cancer due to As.

As per Hindustan newspaper in 2004, 16 deaths in Balhar village from liver cancer were reported due As contaminated water in last five year (table 6.4). Skin lesions and respiratory disease patients were also reported in the village.

Table 6.4: List of death in Balihar village due to cancer

<table>
<thead>
<tr>
<th>Name</th>
<th>Age</th>
<th>Village</th>
<th>Cause</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mrs. Madhuri Mishr</td>
<td>62</td>
<td>Balihar</td>
<td>Liver cancer</td>
</tr>
<tr>
<td>Ramvilas Mishr</td>
<td>65</td>
<td>Balihar</td>
<td>Liver cancer</td>
</tr>
<tr>
<td>Fulhari</td>
<td>60</td>
<td>Balihar</td>
<td>Liver cancer</td>
</tr>
<tr>
<td>Varmeshwar Mishr</td>
<td>58</td>
<td>Balihar</td>
<td>Liver cancer</td>
</tr>
<tr>
<td>Jakhdi Devi</td>
<td>63</td>
<td>Balihar</td>
<td>Liver cancer</td>
</tr>
<tr>
<td>Shivji Mishr</td>
<td>70</td>
<td>Balihar</td>
<td>Liver cancer</td>
</tr>
<tr>
<td>Shriram Mishr</td>
<td>50</td>
<td>Balihar</td>
<td>Liver cancer</td>
</tr>
<tr>
<td>Shelesh Mishr</td>
<td>38</td>
<td>Balihar</td>
<td>Liver cancer</td>
</tr>
<tr>
<td>Dhanji Mishr</td>
<td>40</td>
<td>Balihar</td>
<td>Liver cancer</td>
</tr>
<tr>
<td>Fantu Mishr</td>
<td>25</td>
<td>Balihar</td>
<td>Liver cancer</td>
</tr>
<tr>
<td>Tengar Gour</td>
<td>50</td>
<td>Balihar</td>
<td>Liver cancer</td>
</tr>
<tr>
<td>Janki Devi</td>
<td>65</td>
<td>Balihar</td>
<td>Liver cancer</td>
</tr>
<tr>
<td>Govardhan Gour</td>
<td>51</td>
<td>Balihar</td>
<td>Liver cancer</td>
</tr>
<tr>
<td>Awadh Bihari Mishr</td>
<td>70</td>
<td>Balihar</td>
<td>Liver cancer</td>
</tr>
<tr>
<td>Lakshmi Devi</td>
<td>71</td>
<td>Balihar</td>
<td>Liver cancer</td>
</tr>
</tbody>
</table>

(Source: *Hindustan Newspaper*, 2004 Ballia)
Internal cancers can occur without any development of skin lesions, so simply relying on early onset symptoms to estimate the likely disease burden is not reliable. Cancers have a long latency period, and can occur even several decades after exposure has ceased. This high level of risk is unique among environmental carcinogens. The lung cancer risk of drinking water having 500 ppb As is comparable to that of smoking cigarettes regularly, while the risk of consuming As at 50 ppb is roughly equivalent to that posed by second-hand smoke.

6.3.3 Other related effects of arsenic

Besides, skin lesions and cancers due to As have been linked to a wide range of other health problems in the district. Some other effects were also reported i.e. gastrointestinal effects, neurological effects, respiratory system effects etc. which are discussed following paragraphs:

The effects of As on the human respiratory system have been reported from drinking of As contaminated water during health survey in affected areas. The residents are exposed to As contaminated water, show various respiratory diseases like irritation of the mucous membrane, laryngitis, bronchitis, rhinitis and tracheobronchitis; causing stuffy nose, sore throat, hoarseness, chronic cough etc. Total 15 patients of respiratory diseases were found during health survey (table 6.1). Gastrointestinal effects were also noticed in the residents. The symptoms of dyspepsia or stomach ache were reported in 21 cases out of 100 of chronic As toxicity in affected villages. It is also reported symptoms like nausea, diarrhea, anorexia and abdominal pain. People were informing that the groundwater is so heavy to digest and they feel heaviness and gas in their stomach after consuming it. Some neurological effects such as peripheral neuritis, sleep disturbances, weakness and cognitive and memory impairment were also observed due to chronic exposure of As through drinking water in the residents. The peripheral neuritis characterized by tingling, numbness, limb weakness, etc. was found in 11 people out of 100 due to drinking of As contaminated water in the villages (table 6.1). The residents are also suffering from headache, irritability, lack of concentration, depression and sleep disorders.
It was also observed that 7 people out of 100 were found with no effects of arsenicosis due to As. Total 8 and 6 people were found suffering from skin lesion with respiratory effects and skin lesion with gastrointestinal effects respectively (table 6.1). Moreover, various other diseases like hypertension, anemia and enlargement of the liver, spleen and fluid in abdomen had also been reported by the people and media.

### 6.4 Medical treatment for arsenicosis

During health survey, arsenicosis patients were being interacted to know the symptoms of chronic As disease and its treatment. The residents were telling that they had asked many times to medical doctors and researchers such as Dr. Dipankar about the treatment of arsenicosis but there is no available medicine for chronic As toxicity as well as no cheap and natural techniques to remove As content from groundwater. Mr. Tarkeshwar Tiwari, an arsenicosis patient from Rajpur village informed that he had interacted many times with Dr. Dipankar regarding arsenicosis treatment but Dr. Dipankar replied him that there is no cheap treatment is available for it. Dr. Dipankar also informed him that injection of rupees 4500 is used for three times a day for treatment of arsenicosis. As per reporters from Amar Ujala newspaper, Ballia, Dr. Dipankar had a detailed conversation with district magistrate regarding treatment of arsenicosis and he wrote many times to govt officials about the independent report from the dermatologist of UP which shows arsenicosis patients in some villages of Ballia district. It was noted by Dr. Dipankar that UP doctors have also prescribed “Dimercapral” (a very costly medicine) for the treatment of an arsenic patient but this is not any more recommended for people suffering from chronic As toxicity.

After conducting health survey in the district, CMO and district hospital were being visited to collect the arsenicosis patients list and its treatment. Additional CMO Dr. Lallan Prasad informed that we don’t have proper As testing lab and dermatologist in the district hospital. Government didn’t provide sufficient funds to diagnose and treat the arsenicosis patient. He also told that whenever a suspected arsenicosis patient comes for treatment, only symptomatic treatment is given and further the patient is being referred to IMS, Banaras Hindu University Varanasi. Dr. B. Narayan, told the same information which was given by Dr. Lallan.
In the Indian subcontinent, it is commonly believed that Homeopathic medicines are harmless with zero side effects, and easily available with low cost. Some people are taking these homeopathic medicines for the treatment of arsenicosis. As per SOES, JU, it is a contrary belief that homeopathic treatment is harmless, but actually it may be quite unsafe. They investigated three patients and found significantly elevated in integument tissue samples As concentrations in all 3 cases due to the As content in the homeopathic preparations (Chakraborti, et. al 2003). They found that a patient had arsenosis melanosis after consuming Arsenicum Sulfuratum Flavum- 1-X (Arsenic S.F. 1-X) as treatment of his skin patches for one year. Similarly it was also found in two patients whose were taking Arsenic Bromide 1-X for a period of time for treatment of diabetes but they developed arsenicosis melanosis, keratosis and gastrointestinal illness.

6.5 Socio economic impact of arsenic contamination

The study area is not rich, and the residents are drinking As polluted groundwater due to poverty and ignorance for a long period i.e. it leads the arsenicosis. The people have poor economic and social conditions. It was also found that the residents are also living with illiteracy, bad food habits and malnutrition. It is evident that the people with lack of nutrition are more prevalent to develop arsenicosis (CSE, 2008). Many socio economic problems have been arised due to skin lesions and other effects of arsenicosis in most of the villages of Ballia. It was found that mostly As affected people are those who belongs to poor background with poor nutrition. Generally an arsenosis patient does not have strength and stamina to work, so his family members have to bear more expenses due to his illness and medicines.

The As affected villages are calm and quite full of their own traditions. During the health survey, the innocent affected people were telling that nobody wants to marry our girls or boys because we belong to As affected areas and suffering from skin lesions after consuming As contaminated water. Everybody has to parade half-naked in front of the groom’s family to prove themselves free from these skin lesions. Society too, turns an As patient into an outcast. Because people relate the skin lesions to other contagious skin diseases. Marriage and other social interactions are becoming painful for the
arsenicosis patient due to mistaken belief of society. The condition of arsenicosis patient has become like the victim.

6.6 Arsenic mitigation plan for Ballia

After conducting health survey in the district, it is realized that chronic health effects of As was more prevalent in the above mentioned villages. It is recommended that suitable approach to mitigate the As problem in Ballia district and mitigation strategy should not be generalized for all areas. Because a specific area has different topography, sub-surface lithology conditions as well as different socio-economic and literacy conditions. So that mitigation method/strategy must be location oriented which depends on the basis of above mentioned aspects.

6.6.1 Provisions of arsenic free drinking water

As we know that there is no available medicine for chronic As toxicity as well as no cheap and natural techniques to remove As content from groundwater. Therefore, only solution is to stop As contaminated water and provide As free drinking water to protect people from harmful effect. There must be some essential activities which can help the mitigation and remediation in As affected areas e.g. providing the alternate source of drinking water, developing schemes for providing surface water in affected areas by the Municipal Corporation and local people participation in As removal plants. It is very important to generate awareness through local level community participation in schemes to provide the alternate source of drinking water. UNICEF, 2008 has provided blanket testing programme regarding decision tree for provision of safe water in As affected areas for mitigation arsenicosis (fig. 6.2).
Here are some alternative sources of drinking water which may be the most likely to be viable options in As-affected areas are as follows:

I. Surface water based piped water supply system wherever feasible, is the most appropriate and sustainable solution for As problems in groundwater based drinking water sources.

II. Groundwater is easily available and cheap source of water. And some As-free sources are present even in high As contamination zones. Therefore, these sources of groundwater can be used for drinking. Generally most deep aquifers and dug wells are As-free or less contaminated so these source could be a viable source of drinking water. In view of these facts the study dictates that people in the Ballia district should drink deep aquifer water. Besides, Govt. should restrict the excessive withdrawal of groundwater from this district. There is a danger
that As may contaminate medium and deeper aquifers in near future. Therefore, there is urgent requirement to save medium and deeper aquifers. The future scientific danger may be the spreading of As contamination in adjoining districts. This needs urgent and advance attention to control the As spreading.

III. Rainwater is considered as the safest among all sources of water. Therefore, storage of rainwater and rainwater harvesting schemes can be best option for safe drinking water in Ballia district and other area too. Rainwater can be utilized during rainy season and dug well and deep bore wells in dry season.

6.6.2 Good nutrition

Along with alternate source of safe water, it is also recommended that the appropriate food habits i.e. nutritious food and vitamins are the only preventive measures to fight the chronic As toxicity. Many studies suggest a strong association between nutritional status, dietary intake and clinical manifestations of chronic arsenicosis i.e. good nutrition is remedy for As poisoning. A healthy diet can play an important role to improve immunity which leads in preventing and controlling arsenicosis. People with low dietary intake of protein and micronutrients (calcium, selenium or vitamins) are more prone to arsenicosis. It is fact that once arsenicosis patient stop drinking As contaminated water, his skin diseases improve, and it may be accelerated through selenium, Vitamins A, C and E which are anti-oxidant (UNICEF, 2008).

As per CSE (2008) continuous exposure to As concentrations lower than the threshold does not reduce or negate the possibility of cancer (or other manifestation), simply because nutrition also plays a vital role in preventing the onset of symptoms. Researchers from Japan based National Institute of Health Services and UK ’s University of Aberdeen explain that nutrition deficiency might result in slow elimination of As from the body i.e. people with poor nutrition develop skin manifestations after consuming water containing As at a concentration of 0.3 ppb per liter. On the other hand, people with good nutritional status did not manifest any such symptom even after drinking water containing As at a concentration of 0.4 ppb.
Therefore, a high protein diet can help reduce the adverse affects of As poisoning. Thus, people should be urged to take food containing proteins in good quantities, either from animal sources or from vegetable sources like pulses, soybeans and wheat, among other things. Intake of plenty of vegetables and fruits can ensure ingestion of vitamins and anti-oxidants, which also help in reducing As toxicity.

6.6.3 Elimination of arsenic from the food chain

In fact, there is no way to eliminate As from the food chain. Even if the residents of Ballia district stopped drinking contaminated water, they would still need it to irrigate paddy fields and other crops because of need of large amount of water for cultivation. The agricultural system of the district is mostly dependent on groundwater. Paddy rice is the staple food of Ballia and a lot of cropped area is given to rice cultivation through irrigation. Rice plants and vegetables can readily accumulate soluble forms of As into their edible parts. Vast quantities of tube well water are pumped up to flood paddy fields during the long, hot dry season in the district. Therefore, it would be uneconomical to rid the water of As for the residents. However, even if clean water could be obtained through rainwater harvesting or hydroelectric projects, As in the soil would remain. Once As is in the soil, it generally stays there, unless the monsoon floods wash away the contaminated sediment. Ballia district has poor economic condition therefore; the residents can not afford high cost for removing As from soil.

Rice and other crops along with vegetables can contribute almost as much As to the diet as groundwater, especially where it is also cooked in contaminated water in the district. Therefore, it is recommended in the district to examine As in various foodstuffs viz vegetable leaves, potato skin, arum leaves, papaya etc. Government must install deep bore wells and extend canal network towards highly As affected areas for irrigation as well as drinking water. The district comes in the Doab area of Ghaghra and Ganaga River so there must be more surface water based pipeline schemes. A lot of funds have been sanctioned to Uttar Pradesh Jal Nigam by the government and UNICEF for constructing surface water based pipeline schemes at highly As affected areas viz Murlichapra, Belhari, Bairiya block etc. So local public representatives,
politicians and active people of the district must take initiatives for starting these schemes.

6.6.4 Provision of awareness programme and specialized health facility

To do away with the As menace, it is the primary responsibility of the government agencies, NGOs and researchers to educate and motivate the common masses about this issue of serious concern. There must be separate specialized medical department and call center constituted for diagnosis and treatment of arsenicosis and to register affected location. A specialized medical person with As mobile team must be appoint for each highly affected block by government i.e. the team can easily find out the patients in villages of those blocks. Mass awareness programme on the theme "As problem in groundwater in Ballia district” must be organized to create awareness about health hazards due to intake of As contaminated water, role of better nutrition and use of safe water, groundwater quality and impact of As on human health and probable mitigation measures.

6.6.5 Development of effective and eco-friendly arsenic removal methods

Arsenic removal methods are considered the last option for mitigation of As. Existing As removal technologies are areoxidation, precipitation, coagulation, membrane separation, ion exchange, biological treatment, chemisorption, filtration and adsorption. These main arsenic removal technologies are presented in Annexure-XIV along with advantages and disadvantages of the processes (Ahmed, 2001; Feenstra et al., 2007; Johnston and Heijnen, 2001). Historically, the most common technologies for arsenic removal have been coagulation and adsorption but sometimes coagulation method is unable to efficiently remove As to these low levels. As a result, various alternate technologies have been developed or adapted that are capable of removing arsenic to trace levels. These technologies have been shown to be effective in laboratory or pilot scales but rarely used for real world problems.

There is no method available, which can remove As at economic and eco-friendly levels. Of course, removal of arsenic has been successfully carried out by
physical, chemical and biological methods at laboratory scale. Some attempts have also been made to develop arsenic removal technologies at pilot and commercial scales. But still no technology is available, which can be used at household level economically, especially in the developing and under developed countries. The use of chemicals, waste disposal problem and low efficiency are some of the drawbacks of these methods. Besides, these methods are expensive and not easy to handle at household level. The oxidizing chemical agents used to convert arsenite into arsenate induced production of certain other byproducts. At present, Reverse Osmosis (RO) is supposed as the best method for arsenic removal but it is expensive and cannot be afforded in the rural and backward areas of developing countries like India.
Conclusion and Suggestions
Ballia, the eastern most district of Uttar Pradesh has high As contamination which represents one of the active cases of arsenic (As) poisoning outside West Bengal. The district is severely affected by As pollution and the residents are suffering from chronic As diseases (arsenicosis). Every year many people are dying due to consumption of As contaminated water in highly affected areas of the district. However, some studies have been carried out on groundwater As contamination in the study area by the CGWB and SOES, partly in collaboration with UNICEF but detailed finding was yet to be found. Therefore, a systematic study was conducted to monitor the concentration of As in ground water with a view to obtaining a better understanding regarding As distribution trend, source and the mechanisms governing the mobilization of As into the groundwater of this district. The attempt has been made to study the behavior of arsenic movement in the groundwater of the district by using chemical and geo-spatial analysis of As distribution in pre and post monsoon seasons of 2010 to 2012 to understand the As distribution pattern in groundwater of the district. Besides, GIS and statistical techniques were also used to show the As distribution pattern in the groundwater of Ballia District. Depth wise sediments were also collected using hand operated bore hole in 2014 in order to prepare litho-chemical columns for understanding the root cause and mechanism of mobilization of As in groundwater of the district. The analyses of water samples containing As were analyzed AAS. IDW interpolation model was used of prepare As concentrations maps and water table maps. Detailed health survey was conducted in 2015 to know the impact of As on health of the residents of highly affected areas.

The study involved the collection of groundwater samples in Ballia district for 3 years during pre and post-monsoon in 2010, 2011 and 2012. Total 100 groundwater samples (34 shallow, 33 medium and 33 deep aquifer) were collected from 34 sampling sites covering all 17 blocks of the district. From each block, two sites were selected and for each site, three water samples were collected from shallow, medium and deep aquifers. The study shows that the concentration of arsenic is found in all blocks of the study area. The chemical analyses indicated min-max As concentrations in shallow, medium and deep aquifers as 6.02-69.62 ppb, 3.98-36.91 ppb and 2.89-18.54 ppb in pre-monsoon 2010 respectively. In post-monsoon these values were 6.83-59.03 ppb, 4.23-26.46 ppb and 2.33-13.45 ppb respectively. In the year 2011 results shows min-
max As concentrations in shallow, medium and deep aquifers as 6.04-72.42 ppb, 4.78-38.56 ppb and 2.45-20.78 ppb in pre-monsoon. In post-monsoon these values were found as 5.99-62.85 ppb, 4.90-28.50 ppb and 2.01-14.56 ppb respectively. As concentrations have varied from 6.33-74.98 ppb, 4.44-39.21 ppb and 1.24-22.93 ppb in pre-monsoon 2012 respectively. In post-monsoon these values were found as 5.99-66.20 ppb, 5.23-23.61 ppb and 2.34-17.19 ppb respectively.

It can be clearly seen that highest As concentration was found in shallow aquifer and lowest in deep aquifer. The distribution pattern of As in groundwater shows that all shallow aquifer exceeds 10 ppb in all parts of Ballia district except Rasra block. The results indicated that the order of As concentration was in the order of shallow > medium > deep aquifers during 2010 to 2012 both in pre and post-monsoon season. Highest concentrations were reported in shallow aquifer due to the leaching of As from sediments due to the interaction with oxygen. The oxygen in shallow aquifer is present because of excessive withdrawal of water. Most people of the district are using groundwater from shallow aquifer in the district due to cheap and easily available source of water. As bearing minerals are depositing through fluvial erosion and chemical processes in groundwater and in the particular depth of shallow aquifers, iron is exposed to oxygen and its capacity to absorb As reduces therefore As starts leaching into these aquifers. Briefly, there are chances that water-table may go down and oxygen reach to medium and deep aquifers leading to dissolution of As from sediments into these aquifers. Decrease in As concentration was found in medium aquifer as compare to shallow from 2010 to 2012 but still these aquifer was under threat. The results also suggest that most of the deep aquifers were found free from As during pre and post-monsoon season. Because deeper aquifers are located much lower than nearby shallow aquifers and considered as As free source of water. Therefore, deeper aquifers could be a viable and cost-effective source of drinking water in the short to medium term. However there is a risk that excessive ground water withdrawal could induce infiltration of high As ground water and contaminate the deeper aquifers.

During pre and post-monsoon season from 2010 to 2012, about more than 90% samples exceeded WHO and BIS standard of 10 ppb and about 75% of the samples have As more than 15 ppb in shallow aquifer. The least affected was Rasra block where
As concentration was under the permissible limit from 2010 to 2012. Belhari, Bairiya and Murlichapra blocks were the most severely As-affected areas, where samples contained 50 to 70 ppb As concentration in shallow aquifer during pre and post-monsoon 2010 to 2012. Rajpur village from Belhari and Majhwa village from Murlichapra block were the most severely As-affected areas, where sample contained more than 65 ppb As concentration. In medium aquifer, Belhari, Bairiya and Murlichapra blocks were also found as highly affected areas with more than 30 ppb As concentration. Rajhwa from Belhari block and Murlichapra town were found highest concentration in deep aquifer samples with more than 15 ppb. These areas are situated near by Ghaghra and Ganga rivers and comes in younger alluvium plain which is being deposited alluvium containing As every year by these great rivers. These pains are not oxidized in nature and have low topography and groundwater elevation, which favours the accumulation of As content in groundwater.

A small seasonal variation was found in As concentration during pre and post-monsoon seasons i.e. the concentration is found more in pre monsoon than post-monsoon from 2010 to 2012. This decline may be due to dilution of groundwater after rainfall due to increasing of water table. It is also reported that the order of As concentration was in the order of 2010 > 2011 > 2012 in shallow, medium and deep aquifers. It means that As is slightly spreading in the district because of excessive ground water withdrawal from aquifer for fulfillment of the need of large population. It is also found that the order of As concentration in shallow aquifer was in the order of pre-monsoon 2012 > pre-monsoon 2011 > pre-monsoon 2010 > post-monsoon 2012 > post-monsoon 2011 > post-monsoon 2010. Same trends have been reported in medium and deep aquifer group.

It is evident that there is a possible link between groundwater As and land use pattern. Most area is covered by agricultural land therefore; it may be some chance for some possible relationship of As with land use features (agricultural land, water bodies etc.). It has been assumed that high As contaminated area are excessively withdrawing groundwater for agricultural activities due lack of canals and surface water pipe lines. Therefore, present thesis work carried out the LU/LC of 2012 of Ballia district and the relationship between land use/land cover with As concentration was carried out in the
district. The relationship of As with LULC was also examined by overlaying As distribution layers of pre- and post-monsoon season 2012 in shallow, medium and deep aquifers with land use of 2012. But on the basis of overlay analysis in GIS, no spatial relationship among groundwater As and land use pattern found in the study.

It was found that district Ballia is very rich in agriculture, which constitutes about 85% of the total area of the district. This shows that the main occupation of the people here is agriculture. Built-up area is unevenly distributed and comprises small towns and villages. High-dense built-up can be seen in the central and western parts because of urban development. River Ganga flows in the eastern part and forms the eastern boundary of the district. Some small rivers and thin canals can also be seen flowing from north to south.

Results suggest that As concentration is controlled by the regional topography rainfall, withdrawal of water and the local-scale groundwater level and these components are inter related. The study area comes under the central Ganga plain where topography is flat to gentle undulation with seasonal water-table fluctuations due to paleo-channels and the major landforms in the district are flood plain, younger and older alluvial plain. The stratigraphy of Ballia district is similar to the stratigraphy of the Ganga alluvial plains as it comprises older, younger alluvium and active flood plain (deposits of recent age). Therefore, keeping in mind the physiographic conditions of the study area, present work also assessed geo-chemical analysis of As and its relationship with topography (elevation and slope), geology and sub-surface geology in shallow, medium and deep aquifers in GIS environment. An attempt has also been made to study the relationship between near-surface lithology and the spatial variability of As concentrations using sediments samples from groundwater in different depth with a view to obtaining a better understanding regarding the mechanisms governing the mobilization of As into the groundwater of the district. It is very important to study the near surface lithology to find out the chemistry involved in leaching out of arsenic and the mode of occurrence and origin. So, it will be better to throw some light on the very fundamental aspects of root cause of As problem which involve the understanding of controlling of groundwater As by the regional topography, rainfall etc. Descriptive
statistical analysis was applied to examine the nature of relationships and statistical association amongst the variables.

The spatial relationship between surface elevation and groundwater As shows that the association of high As with low surface elevation and low As in high surface elevation in the district. Correlation of coefficient ($r^2$) between As and elevation was found 0.85, 0.83 and 0.75 in shallow, medium and deep aquifer respectively in pre-monsoon and 0.84, 0.81 and 0.75 in shallow, medium and deep respectively in post-monsoon 2011. Similarly Correlation of coefficients between As and slope were found 0.75, 0.72 and 0.70 in shallow, medium and deep aquifer respectively in pre-monsoon and in post-monsoon, the coefficients ($r^2$) were found 0.73, 0.70 and 0.69 in shallow, medium and deep aquifer respectively. This suggests that the relationship is non-linear and groundwater As is negatively correlated with surface elevation and topographic slope. This means that the topography is inversely related with As concentration in the study area, therefore, high As values are found in areas which are relatively flat. In other words, low lying areas have high As values in the district because low surface elevation with gentle slope favors accumulation of finer sediments of As iron-oxyhydroxide.

It is also found that As and groundwater elevation values are negatively correlated and have non-linear relationship. Correlation of coefficients between As and water table were found 0.89, 0.86 and 0.79 in shallow, medium and deep aquifer respectively in pre-monsoon and in post-monsoon and 0.84,0.83 and 0.76 in shallow, medium and deep aquifer respectively in post-monsoon. Groundwater elevation shows that the water levels are higher in the north-western part of Ballia district, where surface elevations are also high. This means that the groundwater elevation is inversely related to As distribution therefore, aquifers with low concentrations of As are also found within high groundwater elevation areas whereas high As wells are found in the areas of low groundwater elevation. Briefly, present study shows that high As are generally found in areas of low surface elevation, low slopes, and low groundwater levels on a regional-scale in the district.
This study also investigated the spatial variability of As concentrations with geology and near-surface lithology to understand the source and mechanism of mobilization of As in the groundwater of Ballia district. The district falling in Doab region of the rivers Ganga and Ghaghara underlain by newer and older alluvium. As was reported in both older and younger alluvium plains yet the high concentrations were reported in younger alluvium plain. Because the younger alluvium is not oxidized in nature and has organic-rich sand silt and clay, which favors the accumulation of As rich minerals. The spatial variability of As concentrations with sub surface geology/near surface lithology were assessed using sediment grain-size analysis and digestion process. It has been observed that the distribution of As in different strata at all the 3 places is random. This is due to fact that the strata may be by the formation of sedimentation from Himalaya’s rocks. The different concentration of As in these strata is because of the different type of sediment setting during rainy season within millions of years. The different concentration of As in these sediments is attributed due to different metrological condition during their sedimentation.

It may be concluded that As contamination in groundwater of the study area is a geogenic problem. As bearing pyrite minerals are transported with the fluvial erosion from the Himalayas along with the Ganga River in the district. During the course of time these minerals get deposited into and younger alluvium plains. This may be the basic source of As contamination into the groundwater of Ballia district. Hence, Himalaya may be the main source of As. It may also be concluded that As contents are present at each depth of the soil and the concentration is relatively found high in clays. But high concentration of As found in shallow aquifer is due to the leaching of As from sediments due to the interaction with oxygen. The oxygen in shallow aquifer is present because of excessive withdrawal of water. Briefly, there are chances that water table may go down and oxygen reach to medium and deep aquifers leading to dissolution of As from sediments into these aquifers.

A detailed health survey was conducted during February 2015 in most affected villages of different block viz Belhari, Bairia, Murlichapra in the eastern part of Ballia district to investigate the health impact of As. It is found that hundreds of people had lost their lives due to skin and liver cancer in previous 10 years as per the local people
and media. Although, No cancer patient was found during health survey in affected areas. It was observed that the symptoms of the disease known as skin lesions (pigmentation/ melanosis and keratosis) have been found in the bodies of more than 90% of the villagers in most affected blocks. Besides, skin lesions and cancers due to As have been linked to a wide range of other health problems in the district such as respiratory effects, gastrointestinal effects like the symptoms of dyspepsia or stomach ache, the peripheral neuritis characterized by tingling, numbness, limb weakness, etc. Beside health impact, many social problems have been aroused due to arsenicosis in Ballia district. The condition of arsenicosis patient has become like the victim due to mistaken belief of society.

It was observed that there is no available medicine for chronic As toxicity as well as no cheap and natural techniques to remove As content from groundwater. The doctors have also prescribed “Dimercapral” (a very costly medicine) for the treatment of an arsenic patient but this is not any more recommended for people suffering from chronic As toxicity. Moreover, the district doesn’t have proper As testing lab, dermatologist and sufficient funds to diagnose and treat the arsenicosis patient in the district hospital.
Suggestions

After conducting this work in the district, it is realized that there must be suitable approach to mitigate the As problem in Ballia district. It is suggested that As mitigation strategy should not be generalized for all areas. Because a specific area has different topography, sub-surface lithology conditions as well as different socio-economic and literacy conditions. So that mitigation method/strategy must be location oriented which depends on the basis of above mentioned aspects. Based on the present research work some suggestions including remedial measures are suggested for awareness about As poisoning, As mitigation approaches and alternative arrangements for drinking water, which are as follows:

i. Deep aquifers (above 120 feet) do not have high As concentration so it’s safe water therefore, deeper aquifers should be explored. The study suggests that people in the Ballia district should drink deep aquifer water. Besides, Govt. should restrict the excessive withdrawal of groundwater from this district.

ii. As we know that there is no available medicine for chronic As toxicity as well as no cheap and natural techniques to remove As content from groundwater. Therefore, the alternate source of drinking water such as dug well; rainwater harvesting, surface water with proper watershed management should be studied and prioritised.

iii. Surface water based piped water supply system wherever feasible, is the most appropriate and sustainable solution to overcome As problems in groundwater based drinking water sources.

iv. As per report of Central Groundwater Board (CGWB), the ground water in the area occurs under unconfined to semi-confined to confined conditions thus there is good scope of ground water development through hand pumps, bore wells and tube wells constructed at favourable sites and particularly for drinking purpose in view of occurrence of As in ground water.

v. Temporal study of ground water quality should be undertaken periodically, because a recently installed deep tube-well may not show As contamination but in the long run it may get contaminated.
vi. The groundwater movements should be studied by in-depth for the characterization and routine verification of physical hydrogeology.

vii. Wide coverage sampling of lithology (through manual boring) should be done to study the correlation and depositional trend of sediments.

viii. As in food chain may be assessed and roles of pesticides used for agricultural activities may be carefully observed. Detail survey of food habits may be done to find out the vulnerable sections of the population in terms of As accumulation in their bodies.

ix. Along with alternate source of safe water, it is also recommended that the appropriate food habits i.e. nutritious food and vitamins are the only preventive measures to fight the chronic As toxicity. A healthy diet can play an important role to improve immunity which leads in preventing and controlling arsenicosis.

x. To do away with the As menace, it is the primary responsibility of the government agencies, NGOs and researchers to educate and motivate the common masses about this issue of serious concern.

xi. There must be separate specialized medical department and call center constituted for diagnosis and treatment of arsenicosis and to register affected location.

xii. It is also suggested that a specialized medical person with As mobile team must be appoint for each highly affected block by Govt. i.e. the team can easily find out the patients in villages of those blocks.

xiii. Lastly Mass Awareness Programme on the theme “As Problem in Ground water in Ballia district” may be organized to create awareness about health hazards due to intake of As contaminated water, role of better nutrition and use of safe water, groundwater quality and impact of As on human health and probable mitigation measures.