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SITUATION PAPER ON ARSENIC CONTAMINATION IN WATER IN BIHAR

Sreenita Mondal, Manoj Kumar, Suchita Jain

SaciWATERs

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Cover photo: https://ilookilisten.files.wordpress.com/2011/04/water_pot.jpg

Maps: SaciWATERs.

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Further information about this report –
Website: www.saciwaters.org
Email: info@saciwaters.org
Contact: +91 4027116721

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Content

Summary and Acknowledgement

The Situation Paper on Arsenic Contamination in Water in Bihar provides the detailed information on arsenic occurrences in the ground water of Bihar as they affect public health. Groundwater arsenic contamination has affected millions of people in the Middle-Gangetic Plain in India. In Bihar, 18 districts have been reported to be affected with groundwater arsenic contamination in which majority of the affected population belongs to rural areas. This paper has provided the details of spatial distribution of arsenic contamination in Bihar and how the geological formation of the region has affected the quality of groundwater in this region. Sources of arsenic contamination in this region were identified as of geogenic origin. The arsenic hotspots are essentially confined to the younger alluvial deposit (Holocene) aquifers within a depth of 50-60 meter beneath the surface. A synthesis of information includes an estimate of the exposed population of more than 10 million people across the state. Despite having the potential fatal toxicity, there is no effective treatment for Arsenicosis, a chronic illness resulting from uptake of soluble inorganic arsenic. In order to detect the trace of As in water, water quality laboratories are working under PHED, however, instances of not functioning properly due to ill maintenance and lack of trained staff has also been reported. This paper also includes the information technological intervention of the state in mitigating arsenic. It also provides information on existing policies, acts, guidelines both at state and national level, initiative taken to tackle the water quality issues in general and arsenic issues in particular. Finally it focuses on the details of various institutions (government and non-government) working on water quality issues and also tries identifying the utmost power held by that stakeholder who can change the rules of the game. This review work could be a crucial tool for governments, industries, non-profit organizations, medical professional, public health workers, scientists, water experts, and communities in tackling the issues of arsenic contamination and better management of groundwater.

This report is an outcome of action research projects - 'Technical Assistance to Buxar and Bhagalpur district administration to work on Arsenic Mitigation in Selected 50 habitations' supported by UNICEF and 'Civil Society voices, vulnerable communities and Localised platforms for addressing water quality' funded by European Union (EU). We thank UNICEF and EU for the financial support, and specially acknowledge the encouragement by Mr. Rajeev Kumar, Water Sanitation and Hygiene (WASH) Officer at UNICEF and Dr Prabhakar, WASH Specialist at UNICEF in this study. We also gratefully acknowledge the cooperation and support extended by the project team members. We thank Dr Gautam Kumar Basu, School of Environmental Studies, Jadavpur University, Kolkata, India for providing valuable comments on this report.

Dr. Sreenita Mondal
Ms. Suchita Jain
Dr. Manoj Kumar
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Section 1: Introduction

This section of the paper consists of the following components: elemental information of Arsenic; a brief background of the arsenic contamination situation in the groundwater; the purpose and scope of developing the situation paper; and a user guide for the overall situation paper.

1.1 What is Arsenic?

Arsenic (As) is a metalloid element found in rocks, soil, water, air, plants and animals. Arsenic combined with inorganic substance is very toxic, but when combined with organic substance becomes less toxic. The toxicity of arsenic is determined by its form. Scientific studies (Charlet et al. 2007; Van Herreweghe et al. 2003; Mandal and Suzuki, 2002) show that arsenite (trivalent arsenic), is ten times more soluble, mobile (weakly adsorbed) as well as toxic than arsenate (pentavalent arsenic).

Most Arsenic compounds have no smell or taste, so usually we take small amounts in the air we breathe, the water we drink and the food we eat. The arsenic level is generally found to be higher in drinking water that comes from ground sources such as deep tubewells as opposed to water from surface sources such as lakes or reservoirs, springs etc. Researchers have mentioned that the high levels of Arsenic (in all forms) can be found in the seafood, rice, cereals, mushrooms, poultry etc. Although the levels vary, rice and rice products in India have been found to contain high levels of Arsenic. Presence of As is dangerous even in minute quantities (>10 µgl1) although the World Health Organization (WHO) recommends 10 µgl1 as a standard limit, while India and Bangladesh allow up to 50 µgl1.Excessive ingestion, absorption or inhalation of dangerous levels of arsenic is known to cause cancer in the long run.

The primary natural source of arsenic (As) entering the soil is weathering of rocks containing Arsenic compounds. It may also get released into the environment from some agricultural and industrial sources.The anthropogenic sources include combustion of coal, activities like- smelting of base metal ores, application of As-based pesticides, Chromate Copper Arsenate (CCA) for wood preservation, and mining activities (Smedley and Kinniburgh,2002).

1.2 Background

Arsenic contamination in groundwater has been reported in many countries around the world.Except for Greenland and Antarctica,the occurrence of Arsenic in groundwater has been reported in more than 105 countries across all the continents (Chakraborti et al., 2018; Barringer and Reilly, 2013; Naujokas et al., 2013; Chakraborti, 2011). Countries reporting widespread problem include India, Bangladesh, Pakistan, Nepal, Cambodia, Myanmar,Vietnam, China, Mongolia, Chile, Argentina, Mexico, and the United States. It has been observed that the problem is most acutelyassociated with the fluvial and fluvio-deltaic regions viz. Ganga-Brahmaputra-Meghna river system in some parts of

West Bengal, India and Bangladesh, the Indus River in Pakistan, the Red River in Vietnam, the Irrawaddy River in Myanmar, the Mekong River in Laos and Cambodia and finally, the Yellow River in China (Murcott, 2012).The higher As concentration is also associated with the shallow depth (Saha et al., 2018;Jangle et al., 2016; Kumar et al., 2016; Singh et al., 2016) and proximity to the river channels.

Ganga-Brahmaputra-Meghna (GBM) basin which covers a large area of South Asia, has been recognized as the world's most severely As affected region over the past three decades (Brammer and Ravenscroft, 2009; Burgess et al., 2010; Chakrabarti et al., 2018; Chakraborti et al., 2018; Nickson et al., 1998; Saha et al., 2018). In India, Groundwater arsenic contamination was first reported in 1976 in Chandigarh. Later, in 1983, instances of arsenic poisoning were reported in the state of West Bengal. Much later, in the year 2002, elevated levels of arsenic in groundwater was discovered in Bhojpur district of Bihar by The School of Environmental Sciences (SOES) of Jadavpur University, West Bengal.

Box 0.1: Standards for Arsenic in water and food

Agency	Focus	Level
World Health Organization	Drinking water	0.1 mg/L
UN Food and Agricultural Organization	Irrigation water	0.1 mg/L
Chinese Ministry of Health's standard	Food in South Asia	0.15 mg/kg

The Gangetic basin occupying approximately 0.25 million sq. km is the primary repository of groundwater in India. It is source to nearly one-third of the (approximately 27 million) wells in the country, meeting the needs of the irrigation sector (Saha and Dwivedi, 2018). A recent study reported that the entire Ganges River basin has high concentration of As in the groundwater (up to 4.73 mg/L), irrigation water (around 1 mg/L), and in food components (up to 3.947 mg/kg). All the values exceed the International Standards provided by various organizations (Box 1.1).

The issue of arsenic poisoning in the groundwater has received significant attention in the last few decades due to its serious health effects (like dermal, neurological, reproductive, cognitive, and cancerous effects) on millions of people. According to a recent study, worldwide over 296 million individuals are potentially at risk due to Arsenic contamination in the groundwater (Chakraborti et al., 2018). It is also posing a massive challenge to clean water supplies in the affected areas. The emergence of Arsenic into the food chain and human placenta and adverse impacts on the genes are growing concerns among the global communities Chakrabarti et al., 2018).

Groundwater Arsenic contamination is most appropriately considered a chronic environmental hazard owing to its long-term, cumulative harmful effects. It not only brings unique challenges in terms of public health but also influences the perception of people and subsequent policy responses.

Countries like- Bangladesh, China and some South-East Asian countries have already advanced with various arsenic mitigation technologies. India is also trying to tackle the issues related to water quality, however, still at a very nascent stage. This situation paper provides a detailed understanding of the spatial distribution of Arsenic contamination in groundwater, possible sources of Arsenic contamination of groundwater, associated health risks, the best available strategies for mitigation of Arsenic pollution in groundwater and also institutional roles and policy responses considered so far in the context of Bihar.

1.3 Purpose of the situation paper

The situation paper is meant to present state of the art knowledge for guiding research and policy on all aspects of arsenic especially in the context of Bihar, from spatial distribution to vulnerability assessment, testing methods, mitigation technologies, and policies addressing arsenic issues in drinking water androle of different institutions mitigating arsenic issues. Therefore, it can be used by various the public officials and policy makers tackling the issues of arsenic contamination and better management of groundwater.

The situation paper can also be used by the water quality experts, practitioners, implementers, NGOs, academia and the general public, with the purpose of effective management of water quality issues and reducing negative impact on health.

1.4 About the situation paper

This report is divided into nine sections. The *introductory chapter* is followed by eight chapters outlining the various aspects related to arsenic contamination in drinking water in Bihar. *Chapter 2* discusses the history of Arsenic in drinking water and its impact on public health and society in Bihar. *Chapter 3* focuses on the epidemiology and prevention of chronic arsenicosis, a chronic illness resulting from drinking water with high levels of arsenic over a long period of time in the context of Bihar. *Chapter 4* presents the water testing and health assessment procedures available to test the levels of arsenic contamination. *Chapters 5 and 6* focus on the available options for arsenic mitigation (institutional and technological), as well as the challenges faced in adoptingthese solutions. *Chapter 7* focuses on the policies of both the central government and state government of Bihar in addressing the issues of arsenic in drinking water. *Chapter 8* provides the details of various institutions (government and non-government) working on water quality issues and also tries identifying the utmost power held by that stakeholder who can change the rules of the game. Chapter 9 concludes this situation paper summarizing the key findings and way forward.

Section 2: History of Arsenic in drinking water and impact

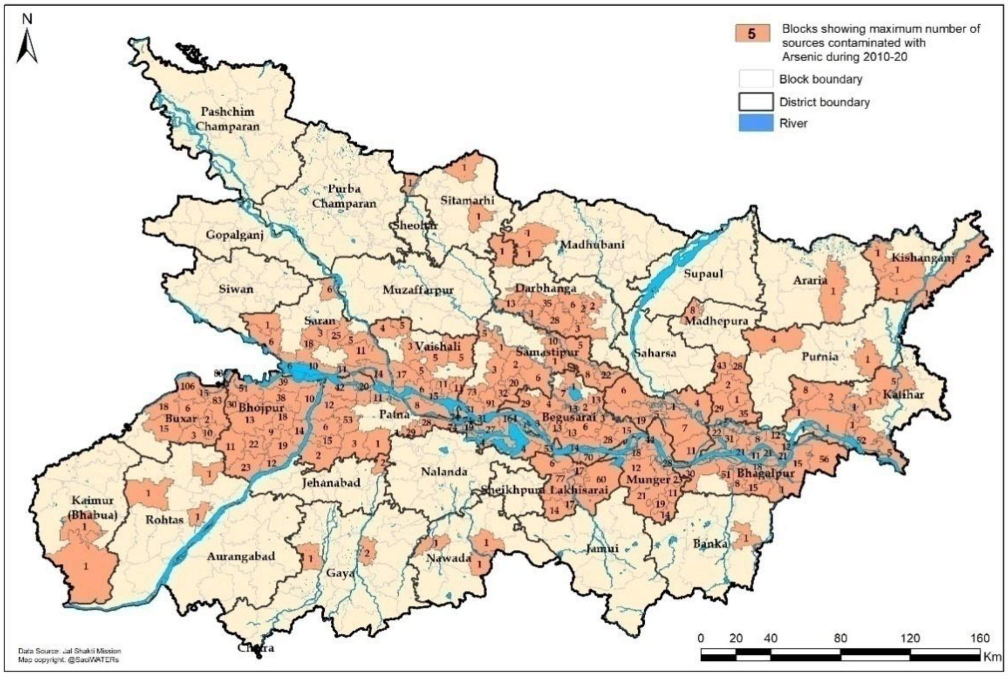
The groundwater of entire Ganga-Brahmaputra-Meghna (GBM)Basin that covers the states of Uttar Pradesh, Bihar, West Bengal and Assam in India, Western part of Bangladesh and the Terai region of Nepal is critically affected by Arsenic contamination. In India 86 districts located in Bihar, West Bengal, Assam, Punjab, Karnataka, Haryana, Jharkhand, Uttar Pradesh and parts of Manipur and Chhattisgarh are affected (Central Ground Water Board, 2014). Using existing literature and secondary data, the second section intends to show the regional variation of As-contaminated in the groundwater of Bihar and also to document the As impacts on the food chain, human health, society and economy.

2.1 Occurrence of Arsenic in drinking water in Bihar: A spatio-temporal picture

Arsenic contamination of groundwater in Bihar is known for around two decades. The problem of arsenic contamination of tube wells in Bihar was first reported in 2002 in Semria Ojha Patti village of Sahapur block in the Bhojpur district of Bihar (Chakraborti et al., 2003). Geographically, this region is located in the flood-prone belt of the Sone-Ganga interfluves region. Investigations in 2005 by Central Ground Water Board (CGWB) and Public Health Engineering Department (PHED), Bihar reported that 13 districts were affected by elevated concentrations of arsenic of more than 50 ppb in drinking water. It also highlighted that sometimes the level of arsenic contamination as high as .178 μg/L in the surrounding villages, affecting around 59% of hand pumps, which are generally at 20-40 m below ground surface (Chakraborti et al., 2003). With ongoing studies, more and more arsenic contaminated districts have been identified. A recent study by Rahman et al. (2019) revealed that 18 (61 Blocks) of the 38 districts of Bihar are affected by groundwater arsenic.

There is a marked geographic variation in terms of Arsenic contamination in the groundwater as well as its impact on the communities. Fig 2.1 depicts the spatial pattern of Arsenic contamination in the groundwater in Bihar. While some districts within Bihar have recorded higher levels of Arsenic in the groundwater, few districts within Bihar are free of Arsenic contamination. Patna, Bhojpur, Buxar, Vaishali, Bhagalpur and Samastipur are some of the worst affected districts by Arsenic contamination. On the other hand, districts like- East and Champaran, Saharsha, Muzaffarpur, Gopalganj, Aurangabad, Jamui and Sheikhpura are free of Arsenic contamination.

Fig 0.1: Spatial (Block wise) distribution of Arsenic in groundwater



Source: Map prepared by SaciWATERs

Note: Blocks were marked based on the water quality testing data from 2010-2020 under Jal Jeevan Mission. If any of the water sources have Arsenic levels beyond the permissible limit of 0.05 mg/l, the entire block is marked as arsenic affected district.

The spatial distribution of Arsenic in the groundwater in Bihar has a distinctive regional pattern. Scientists have proved that the geo-hydrological structure of the region has a direct relation with the elevated arsenic level in the groundwater. The Arsenic affected districts are mostly distributed along the course of the river Ganga in Bihar, more specifically to say Arsenic affected regions are located close to abandoned or present meander channels (Shah, 2008). Hand pumps located on newer alluvium and extracted water from a depth between 15-35 m, show high Arsenic content.In contrast, irregularity in spatial distribution was also found in Darbhanga, Purnea, and Kishanganj. In these districts, the contamination occurs in patches (Singh and Vedwan, 2014).

2.2 Impact of geological formation on groundwater

In Bihar, the arsenic content in groundwater is largely determined by the geological formations.About 89% geographical area of Bihar (approximately 94,000 sq km) is located in the Gangetic plain and covered by Quaternary sediments of Recent to Sub-Recent age (CGWB, 2016). It also holds a multi-tire aquifer system. The shallow aquifer system is consist of medium to fine sands having occasional coarse-grained sand layers alternating with clay, sandy clay and confined within 120-130 m depth, followed by a laterally continuous 20-30 m thick clay/sandy-clay zone forming the aquitard. The deeper aquifer system exists below the aquitard, which continues down to 240-260 m below ground. The sediment in the central Gangetic Basin differentiates into Holocene and Pleistocene depositions and appears to have a grey and brown colour, respectively. The arsenic hotspots are essentially confined to the younger alluvial deposit (Holocene) aquifers within a depth of 50-60 meter beneath the surface.

The arsenic contamination in the aquifers of Bihar has a geogenic origin. It probably originates from ore zones of the Himalayas and thereafter eroded by the Ganges River and its tributaries those originate from the Himalayan region. The eroded materials are then transported and deposited along its course. Mukherjee et al. (2012) described that rainfall received on the flood plains of Bihar facilitates percolation of organic carbon to the groundwater, which stimulates microbial respiration, triggering a reductive dissolution of Arsenic and iron in the solid phase (Mukherjee et al., 2012). These hydro-geochemical phenomena produce bicarbonate (HCO^3) in shallow groundwater that helps further mobilization of Arsenic in the groundwater (Saha et al., 2010). It is worth mentioning that at present the affected aquifer is the main supplier of drinking water in most parts of rural Bihar through shallow hand pumps (Srikanth, 2013).

The aquifers of older deposition (Pliocene-Pleistocene) are to a large extent free of Arsenic contamination (Winkel et al.,2008; Shah, 2008;Smedley and Kinniburgh,2002).The deeper aquifer is protected by a layer of clay can be used for community drinking water supply by deep tube wells having a yield capacity of 150 m^3 /h (Saha et al., 2011).

2.3 Impact of Arsenic

Groundwater is a major source of water for drinking, domestic and agriculture usage in Bihar. However, in the last two decades, the trace of elevated levels of arsenic has been found in drinking, irrigated water and also in food products in various places of Bihar plain. According to the scientists (Srikanth, 2013) increased access to shallow water sources has a direct impact on arsenic exposure among the community.

Various government and non-government organizations have tried to estimate the total population potentially exposed to arsenic contamination, however, it is a difficult task as there is a possibility of arsenic exposure through the food chain. Therefore the exposure may not be restricted to contaminated areas but may also affect areas with no groundwater contamination due to open market sale of food products (Kumar et al., 2016; Mandal et al., 2012). A recent study has revealed that the total population residing in the risk zones of Bihar is around 9 million (Bhattacharya, 2019). Arsenic contamination has acute negative impact on human health and far-reaching consequences on other socio-economic aspects (Thakur and Gupta, 2016; Kumar et al., 2016). Not only human beings but also livestock in large numbers have been exposed to arsenic-contaminated groundwater.

Impacts of arsenic on human health in chronically exposed population

Drinking water rich in Arsenic over a long period leads to arsenic poisoning also known as arsenicosis (WHO, 2010). It includes skin problems such as changes of skin colour and hard patches on the palms and soles of the feet, skin cancer, cancer of the bladders, kidney and lung, and diseases of the blood vessels of the legs and feet, and possibly also diabetes, high blood pressure and reproductive disorders (WHO, 2010). A four-stage arsenic-induced health effects have been identified:

- **ThePreclinical Stage** **-**the body tissues (hair, nail) and urine shows high arsenic metabolite levels without any clinical symptoms.

- **Primary stage/ Clinical stage** - symptoms of arsenicosis are primarily manifested in the form of dermatological detections (major and minor) such as skin lesions, Keratosis and Melanosis, redness of the conjunctiva, conjunctivitis, inflammation of the respiratory tract and gastroenteritis.

- **Secondary / Internal complications stage** **-** health effects include white and black spots on the body, hyperkeratosis, non-pitting oedema, peripheral neuropathy, and liver and kidney disorders.

- **Tertiary/ Malignancy stage** **-** include Gangrene of the distal organs and cancer due to excessive consumption of Arsenic.

Fig0.2:Physical manifestation of Arsenicosis

Source: SaciWATERs

Arsenic contamination does not only have an impact on physical health but also the psychological health of the communities. Very few studies so far have focused on the issues of the impact of Arsenic contamination on mental health. It was reported by Thakur and Gupta (2016) that more often, a patient afflicted with arsenic poisoning repeatedly becomes depressed and sometimes even tries to commit suicide.

Social Problems associated with Arsenic contamination

Arsenic contamination has widespread social problems among the affected households. It is found that social problems are linked to health and economic problems.

- The social problems start with the lack of adequate information among the communities, especially in the rural areas about Arsenic toxicity and the ill effects of using Arsenic-contaminated water (Bhattacharya, 2019; Singh and Vedwan, 2014).
- Due to lack of knowledge, people often mistake symptoms of arsenic poisoning as leprosy or other contagious skin diseases and start practising malpractices, like- untouchability and discrimination.
- Studies have also reported social stigmatization. Skin diseases due to arsenic contamination restrict people with symptoms to appear in public and social interaction with others.
- Sometimes, jobs or services are also denied to the arsenic affected persons especially in the rural areas.
- The young people irrespective of their sex face problem in their marriage due to skin diseases.
- Similarly, affected school-going children are prevented from attending schools.

More specifically, the arsenic-related health problem aggravates the issue of social exclusion.

Impact on economy

Arsenic contamination ingroundwater has a severe economic effect on the people residing in the Arsenic affected areas. Studies(Bhattacharya et al., 2019; Singh and Bedwan, 2014) have found that the poor population is more exposed to such problems as on the one hand they are unable to adopt mitigation measures to reduce the risk of health threat and on the other hand they do not have access to adequate nutritional intake. All these factors ultimately increase the economic burden of the poor householdsin the form of medical expenditure. Additionally, the cost of obtaining arsenic free water further increases the economic burden.

Impact on agriculture and food

In Bihar, there are very few studies highlighting the degree of Arsenic contamination in food components and the associated health risks through the consumption of food. Based on a health risk assessment study due to presence of arsenic and other elements in drinking water and dietary components in two blocks of Samastipur district of Bihar, Kumar et al (2016) reported that along with direct consumption of the arsenic-contaminated drinking water, vegetables and other food grain consumption contributes to major daily dietary Arsenic intake. Bihar, which is part of the middle Gangetic plains, is a very fertile belt and rice and vegetables are the regular staple food for a large population in this region. Existing literature shows that the irrigation of this region mostly is dependent on the shallow aquifers. As a result of that, rice and vegetables get affected by Arsenic contaminated irrigated water. Studies (Bhattacharya 2019) have reported higher Arsenic accumulation in potato, brinjal, arum, amaranth, radish, lady's finger and cauliflower and relatively low level of Arsenic accumulation in beans, green chilli, tomato, bitter gourd, lemon and turmeric.

Arsenic contaminated groundwater which is used for irrigation not only impacts the quality of food grains and vegetable but also adversely affects the soil quality and reduces the quantity of food production. In sum, arsenic contamination in groundwater puts a question mark on the sustainability of agricultural production and also on the associated livelihoods and health of the affected population.

2.4 Key findings and recommendations

1. Though numerous studies were carried out to understand the situation of Arsenic contamination in the Bihar plains, however, longitudinal studies in the affected areas are missing.
2. There found a lack of comprehensive study on geochemical analysis of Arsenic contamination in the soil, water, foods (grains, vegetables, fruits, etc.), and its impact on human health in the context of Bihar.
3. The understanding of the hydro-stratigraphic environment and the processes are extremely important not only for addressing the elevated arsenic level in groundwater in Bihar but also it provides the scope of further investigation and mitigation planning.
4. Studies conducted so far were mostly confined to certain geographical locations, like- Patna, Bhojpur, Bhagalpur, Buxar, Darbhanga, etc., while the traces of elevated level of As contamination have been found in almost 18 districts of Bihar.
5. It can be suggested that systematic monitoring and analysis of Arsenic contamination in groundwater, soil and food chain in all the affected districts of Bihar will help in mitigation planning and action.
6. Itwas recorded that the number of incidents and studies related to acute arsenic toxicity is meagre compared to chronic arsenic exposure. Therefore, a regular health assessment through proper hair, nail, urine and blood samples testing in all the affected districts is highly required. Along with regular health check-ups, awareness generation among people is equally important as most communities in affected habitation are not even aware of the problem and continue to expose to the health risk of arsenic contamination and related diseases (arsenicosis).

Section 3: Epidemiology of Arsenicosis

This section on the epidemiology of Arsenicosis presents the risk factors associated with arsenicosis as a public health problem and how it can be controlled and prevented across communities using knowledge from multiple disciplines like- public health, clinical medicine, pathophysiology, bio-statistics, social-science and other fields in the context of Bihar.

3.1 About Arsenicosis

What is Arsenicosis?

Arsenicosis is a chronic illness resulting from uptake of soluble inorganic arsenic.

Who gets Arsenicosis and how soon after exposure does symptoms appear?

Drinking water and eating food rich in soluble inorganic arsenic (>10 ppb) over a long period (such as 5-20 years) leads to arsenic poisoning or arsenicosis[1]. In Bihar, arsenicosis occurs in persons who live in the region where water sources are contaminated with Arsenic and drink contaminated water and food cooked with that water.

What are the symptoms of Arsenicosis?

Arsenic poisoning results in various health outcomes including skin problems, skin cancer, cancers of the bladder, kidney and lung, and diseases of the blood vessels of the legs and feet, and possibly also diabetes, high blood pressure and reproductive disorders. The symptoms are often insidious in onset and varied in nature.

How is Arsenicosis diagnosed?

Diagnosis of arsenicosis depends on both clinical and laboratory criteria, but initially it can be diagnosed on the basis of its physical manifestations. Physical manifestations (melanosis, keratosis, and cutaneous cancers) are essential signs in the diagnosis, and trained dermatologists or arsenic experts are able to clinically confirm a case even without laboratory backup. However, special laboratory testing of biological samples like- blood, urine, nail and hair sample is practiced to confirm that a person has arsenicosis.

What is the treatment for Arsenicosis?

Despite having the potential fatal toxicity, there is no effective treatment for this disease. People once affected may not recover even after remediation of the Arsenic contaminated water. Chelation therapy for chronic Arsenic toxicity has been suggested as a specific therapy for relief of systemic clinical manifestations and reduction of Arsenic accumulates in the body, reducing subsequent cancer risk (Guha Majumdar, 2000).

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[1]Read more: https://www.lenntech.com/library/diseases/arsenicosis/arsenicosis.htm#ixzz6R3gFzpfe

3.2 Arsenicosis situation in Bihar

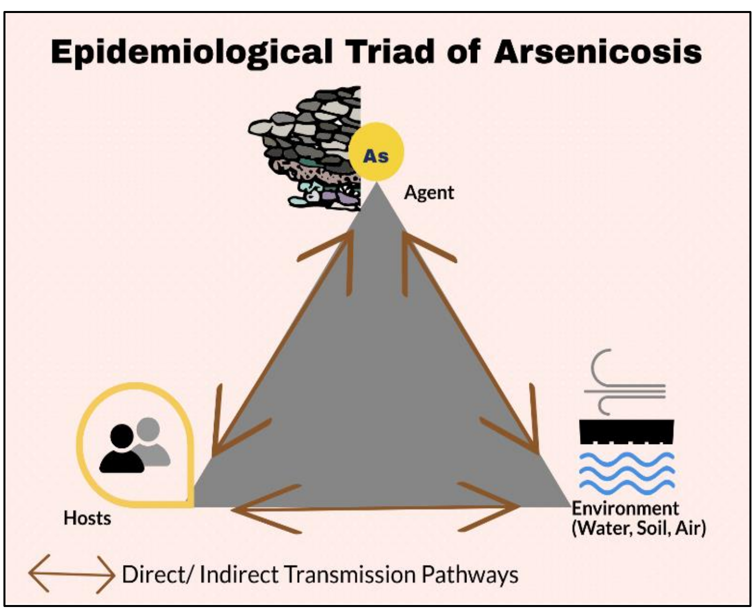
In Bihar, the manifestations of arsenicosis were first identified in the Semria Ojha Patti village of Ara in Bhojpur district in the year 2002 by the School of Environmental Studies, Jadavpur University, Kolkata, Department of Neurology, Medical College, Kolkata and Department of Obstetrics and Gynaecology, Institute of Post Graduate Medical Education and Research, S.S.K.M. Hospital, Kolkata (Chakraborty, et al. 2003). The current scenario of arsenic contamination in groundwater in Bihar is very critical. According to a recent study (Rahman et al., 2019) more than 10 million people are exposed to the Arsenic contamination in groundwater.

After West Bengal, Bihar is the second-worst affected state of India, and as per the latest reports the majority of the arsenic affected cases are from the district of Bhojpur, Buxar and Patna. The fact that few more districts (like- Bhagalpur, Samastipur, Vaishali, Saran) are enlisted as 'arsenic affected' has raised a major concern, taking the toll of the districts affected to 18. (Rahman et al. 2019). However, there is hardly any record of the numbers of registered cases of arsenicosis in different districts of Bihar. It has been found that epidemiological studies on arsenicosis in Bihar are very limited and mostly cross-sectional studies.

3.3 How people can get infected with arsenicosis?

Though Arsenic contaminated groundwater is the main reason behind arsenicosis, however the manifestations of the disease further linked with multiple factors. Epidemiological studies suggest that there are three components that need to interact with each other for any kind of diseases to occur. The gradual development of arsenicosis can be better understood using the causation model used in epidemiological studies, also known as 'epidemiological triads'(Fig 3.1).

Fig0.1:Epidemiological triad of Arsenicosis



Agent

In case of Arsenicosis, arsenic is the prime factor acting as an agent for the development of disease. As mentioned in section I, arsenic is a metalloid or semi-metal that exist in four oxidation states: elemental Arsenic (As 0), Arsenite (AsIII)), arsine (As -3) and arsenate (AsV).In general, inorganic forms of arsenic is more toxic to the environment than organic forms. Among the inorganic forms, the trivalent (arsenite) form is more toxic than the pentavalent (arsenate) forms. In Bihar, trivalent

Arsenic is found in 87 % of tested ground water sources (Ghosh, A. 2020). It is important to mention that concentration of arsenic depends on a number of factors, like- oxygenated water, the degree of biological activity, water source and the proximity of the water source to arsenic-rich geological formations and other anthropogenic sources (Ghosh, P. et al., 2008).

Host Factors

Exposed to soluble inorganic arsenic (>10 ppb) over a long period (such as 5-20 years) leads to arsenic poisoning or arsenicosis in human being. However, susceptibility of developing arsenicosis varies across communities with similar level of exposure.

- People from poor strata of the society are more susceptible of developing the disease due to their poor nutritional intake. The dietary status of the essential trace elementsis reported to be adversely affected by chronic ingestion of arsenic.

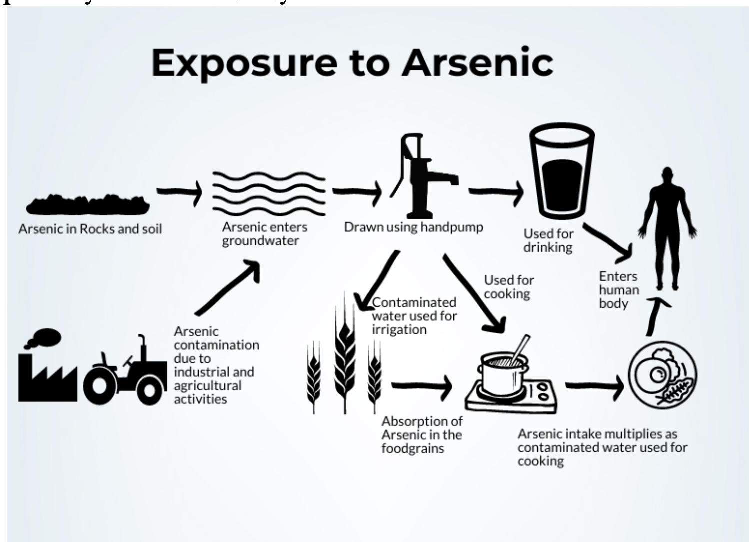
- Incidence of arsenicosis is higher among males compared to their female counterpart but simultaneously, studies showing the opposite results are also not rare.

- Age is also an important determinant of the disease. Chronic exposure for 10 years (range, 5-20 years) is usually necessary for expression of clinical manifestations. However, studies reported high occurrence of arsenicosis among the children (Rahman et al., 2019; Perry et al., 2015; Ghosh et al., 2008).

Environment

The third component is the environment that allows the disease to be transmitted. Arsenic may enter the food chain via different sources, through the 3 basic spheres: air, water, and soil. In all the 3 cases, sources of arsenic can be anthropogenic, geogenic or a combination of both. In case of Bihar, the source of arsenic is geogenic. In addition to these, the transmission pathways between each of these components allow the spread of the disease. The pathways can be direct or indirect. In case of arsenicosis, transmission happens indirectly through drinking of Arsenic contaminated water and food cooked using that water illustrated in figure 3.2.

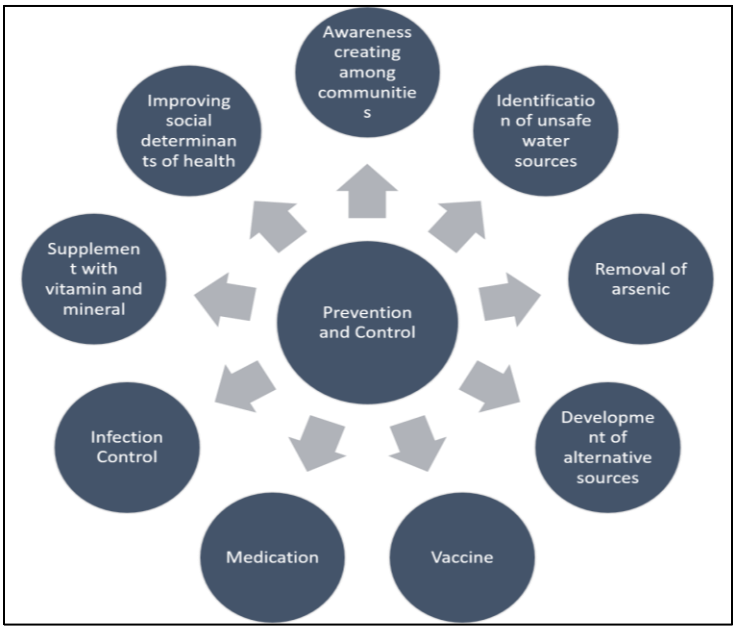
Fig 0.2: Arsenic distribution in the environment and its transfer pathways to human body



3.4 Prevention and control of Arsenicosis: The Bihar experience

Arsenicosis has emerged as a public health issue in recent years which does not have an effective treatment. Given the serious consequences of chronic Arsenic toxicity, it is important to address the preventive measures. Epidemiologists believe that disruption of links between the agent, the host, and the environment could stop continued transmission of the disease and suggested a number of preventive and control measures as shown in figure 3.3.

Fig.0.3:Preventive and control measures for Arsenicosis



In terms of the preventive measures, very recently the state has started taking different measures. Undoubtedly, providing arsenic free safe drinking water is the key to arsenicosis prevention in case of Bihar. The move is taken as a part of the Har Ghar Nal Se Jal scheme that envisages potable drinking water in all 17.87 crore rural households in the country by 2024. Apart from that, the state has focused few other measures, like- create awareness in the community about the contaminated sources through 'jal chaupal', provide facilities for water quality testing (water quality monitoring system), diagnosis of the disease in the field, and treatment and ongoing monitoring.

3.5 Key findings and recommendations

1. Very limited epidemiological studies/ research has been conducted so far in Bihar. Therefore, it is very important to have a comprehensive database for health impact of arsenic on exposed population. These data further can be used for risk assessment.
2. High concentration of arsenic in the groundwater has already done a lot of damage to the public health and if appropriate strategies and effective measures are not taken shortly, then the population of Bihar is going to witness another devastating health hazard.
3. More research is required to have an effective treatment for chronic arsenicosis.
4. As part of the arsenicosis prevention and control measures, it is essential to develop comprehensive arsenicosis management plan involving experts from various fields, like- epidemiology, engineering, social science within the umbrella of primary healthcare system.

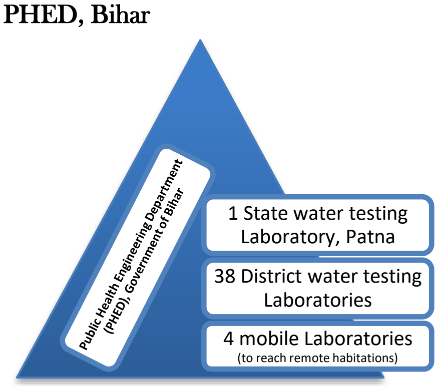
Section 4: Water Testing and Health Assessment Procedures

This section discusses the various water testing and monitoring methods for arsenic in water, variations and correlation between various detection techniques, and clinical testing parameters for health assessments of arsenic.

4.1 Water quality assessment in India

The issue of Water Quality Monitoring & Surveillance has been given due emphasis under Nation Rural Drinking Water Program (NRDWP). The monitoring and surveillance results from the habitations has been put on the database of the Department and monitored to ensure drinking water security at the household level. The National Rural Water Quality Monitoring & Surveillance Programme launched in February 2005 was merged with NRDWP and now subsumed under Jal Jeevan Mission (JJM). Quality monitoring receives 2% of annual JJM funds. Water quality monitoring involves testing of water samples collected from water sources by Department in water quality testing laboratories. Surveillance is undertaken by community using Field Test Kits (FTKs), sanitary inspection, etc. Under JJM, water samples will also be collected from Functional Household Tap Connection (FHTCs).

Fig 4.1: Number of laboratories under PHED, Bihar



Quality of water supplied to the habitations via hand pumps, piped schemes and other sources, is being monitored by PHED, Government of Bihar. In Bihar, a new Public Private Partnership (PPP) model was initiated to build a sustainable model for testing water quality and assessing its fitness for human consumption by strengthening water quality testing laboratories. It was taken under the Sector Wide Approach to Strengthening Health (SWASTH) programme.

As per latest JJM guidelines, the frequency of testing is as follows:

1. <u>Sub-divisional/ block lab</u>- 100% water sources under its jurisdiction; once for chemical parameters and twice for bacteriological parameters (pre and post monsoon) in a year,
2. <u>District laboratory</u>: 3,000 water sources/year, covering all sources randomly spread geographically
3. <u>State laboratory</u>: at least 5% of the total drinking water samples across all district level laboratories with random and uniform geographical spread

4.2 Arsenic detection methods

Arsenic is present in various forms/species depending on the chemical, physical, and biogeochemical conditions of the environment. These species can be broadly categorised into inorganic arsenic and organic arsenic species. Several different forms of arsenic can be found naturally in water: arsenite, arsenate, methylarsonic acid, and dimethyl arsinic acid - the methylated forms generally being in lower concentrations than the inorganic ones (Braman and Foreback 1973; Crecelius et al. 1974). All arsenic compounds dissolved in water are toxic—arsenic as two inorganic species arsenite and arsenate. Arsenite is generally more toxic than arsenate, and humans are exposed to both forms of inorganic Arsenic from water and food. Depending on the type of species, the technique used for the estimation of arsenic is unique. The most selective and sensitive methods for the determination of total arsenic and its species in water are coupled techniques including chromatography, optical methods, and mass spectrometry. There are several methods that are used for the estimation of arsenic in water or the solution form.

Box 4.1: A review of contemporary methods for arsenic and arsenic species determination in water
(Modified from (Rajakovic-Ognjanovic 2018)

Methodology	Detection	Detection limit ($\mu g\ L^{-1}$)	Advantages	Disadvantage	Reference
HPLC-HF-AAS	Arsenic speciation	0.05–0.8	Rapid, inexpensive. No need for sample pretreatment	–	(Hung et al. 2004)
IC-ICP-MS	Arsenic speciation	0.01	No need for sample pre treatment	–	(Rado et al. 1987)
HG-AAS	Total arsenic and arsenic speciation	0.6–6.0	Approved by US EPA	–	(Hung et al. 2004)
HPLC-HG-AAS	Total arsenic and arsenic speciation	1–47	No need for sample pretreatment	–	(Hung et al. 2004)
GF-AAS	Total arsenic	~0.025	Approved by US EPA	–	(Hung et al. 2004)
ICP-MS	Total arsenic	~0.1	Approved by US EPA	Spectral and matrix interferences	(Rado et al. 1987; Rajaković et al. 2012)
ICP-AES	Total arsenic	~30	Minimal sample volume; no sample pre-treatment and short measurement time	Expensive; handling requires expertise	(Hung et al. 2004)
HPLC-ICP-MS	Total arsenic	0.01	No need for sample pre-treatment	–	(Jeong et al. 2017)

4.3 Role of Field Testing Kits

In recent years field test kits (FTK) have been largely used to identify Arsenic levels in contaminated water sources in India. An Arsenic FTKs enables to detect the presence of Arsenic in water. The FTKs are popular because of the quick on-site test/ result methods with no infrastructure requirement. Most of the kits are working on the principal of reaction of arsine gas with any chemical agent which produces a colour complex. The intensity of the colour is compared visually with a colour-coded chart or measured electronically to calculate the concentration of Arsenic in the water sample. The samples from arsenic affected sources can be further sent to laboratory for verification and detailed analysis.

Correlation between results of field test kits and laboratory/ advanced instrumentation

To give an example of the verification and correlation of field testing kit data with laboratory methods, the following section presents some analysis based on water sampling carried out by SaciWATERs under its ongoing project funded by the EU in Bhagalpur and Buxar districts of Bihar. To know the correlation between the field test kits data and lab analysis, water samples were collected from two arsenic contaminated districts namely Buxar and Bhagalpur. Details of field test kits used in the estimation of arsenic are given in the **Annexure 1**.

Both ORLAB and Ffem Water testing kits have certain advantages and disadvantages over each other. The cost of testing per sample is more than double in ORLAB than Ffem Water test kits. The lab tests were conducted using Atomic Absorption Spectrophotometer. Testing of water samples in the Mahavir Cancer Sansthan & Research Centre (MCSRC) was done by using UV – Vis Spectrophotometer. The cost of this lab testing is approx. Rs. 500 per sample. The correlation between average values of the results (mg/l) of field testing kit and the lab results from Mahavir Cancer Sansthan & Research Centre (MCSRC) showed good correlations with $R^2 = 0.7291$ and $R^2 = 0.7386$ (**Annexure 2**). The difference between the actual testing values is due to differential sensitivity and detection limits of the instruments. Sometimes the handling of the samples and preservation can also lead to sharpening differences in test values. On the other hand the correlations between average values attained from the field test kits and those from Public Health Engineering Department (PHED) were weak.

Such correlations can help build confidence in testing methods, help selection of testing kits, and ensure that testing results are verified and robust assessments are provided. A variety of other available Arsenic testing kits in market is given in **Annexure 3**.

4.4 Clinical testing

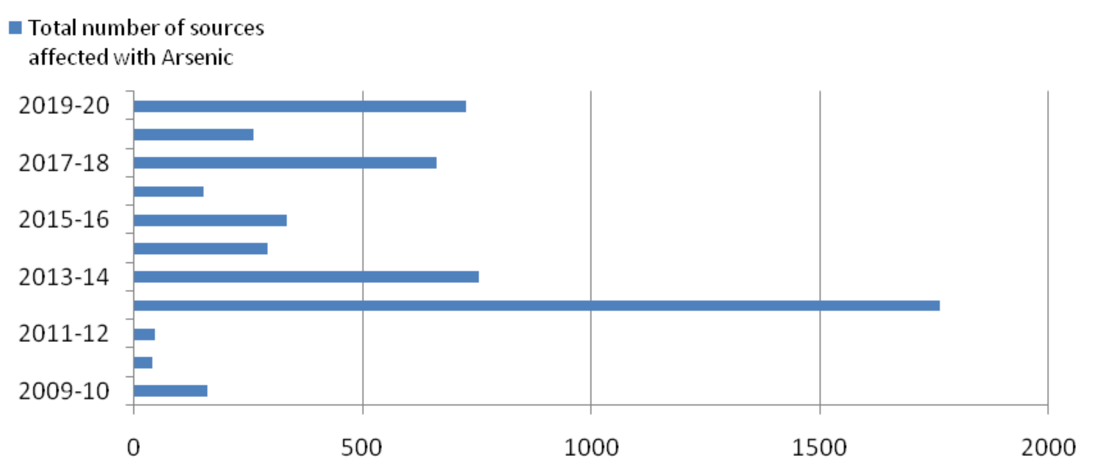
The physiologic effect of arsenic exposure includes gastrointestinal and hepatic effects, renal effects, cardiovascular effects, neurologic effects, dermal effects, respiratory effects, hematopoietic and hematologic effects, reproductive effects, carcinogenic effects, lung cancer, and other health effects (ATSDR 2011). Arsenicosis and its stage can be diagnosed by considering various parameters including symptoms identification visually and clinical testing. Once the stage of arsenicosis is diagnosed by the doctor it will help in the treatment and also help to figure out the underlying causes to limit the future exposure or change your lifestyle if needed. To switch the source of drinking water contains less arsenic or free from arsenic helps to improve the health. Biological samples including urine, fingernails, hair and blood are taken to measure high levels of arsenic in the body (ATSDR 2011).

Test like fingernails and hair long-term exposure at least six months while urine test is used to know the acute exposure that has happened within a few days. These tests only can measure high amount of arsenic in the body not imminent adverse effects of exposure.

4.5 Key suggestions

The Arsenic contaminated water sources data from Jal Jeevan Mission for Bihar shows highly fluctuating levels between different years. In the year 2013-14 the positive sources abruptly increased to 1763 from 44 in 2011-12. Fig 4.2 provides the information across years. Differences in levels captured may be owed to different testing methods, varied levels of accuracy arrived at, number and characteristics of water sources utilized for water testing, handling of samples, seasonality of water samples etc. Thus correlation of tested data with various methods of testing must be done to help arrive at more robust results.

Fig 4.2: Total number of sources affected with Arsenic in Bihar



The accurate geographical extent of Arsenic can only be traced through increased systematized testing for a number of sources at district and state laboratories. Correlating this data across different instruments and methods can help increase accuracy and accountability for the results. The temporality of testing also plays key role since seasonality can affect arsenic concentration. Repeated testing must be conducted at a given season. There should be repetition of a certain number of sources every time to capture a long term history of particular sources.

Section 5: Arsenic Mitigation Measures

This section focuses on the available arsenic mitigation technologies in Bihar in order to provide arsenic free safe drinking water to the rural population of Bihar. It also tries to explore the effectiveness and sustainability of the arsenic mitigation measures in the context of the state.

Since the arsenic was discovered in the groundwater of Bihar, a number of research and development activities have been conducted on means of providing arsenic free drinking water to the vulnerable areas of the state. The major source of Arsenic in groundwater in the central Gangetic plain of Bihar is of geogenic origin (Kumar et al. 2016; Shah 2008) and closely linked to the geo-hydrological condition of that region. Therefore, remediation is not possible without having a complete understanding of all physiochemical processes controlling its release from the sediments into the groundwater. In order to deal with the problem, various mitigation measures have been developed and implemented, ranging from in-situ reduction of Arsenic level within the aquifer itself, ex-situ removing of Arsenic from groundwater with the help of technologies, looking for alternative aquifers, and reduction of the contaminants (Arsenic levels) by artificial recharge of the groundwater, mixing with potable water, etc. Every mitigation option has its own pros as well as cons. Some arsenic-contaminated areas have seen introduction of one of these measures or a combination of more than one. In Bihar, as the responsibility of providing safe drinking water lies with Public Health Engineering Department (PHED), it also decides on the arsenic remediation measures.

5.1 Arsenic mitigation options adopted in Bihar

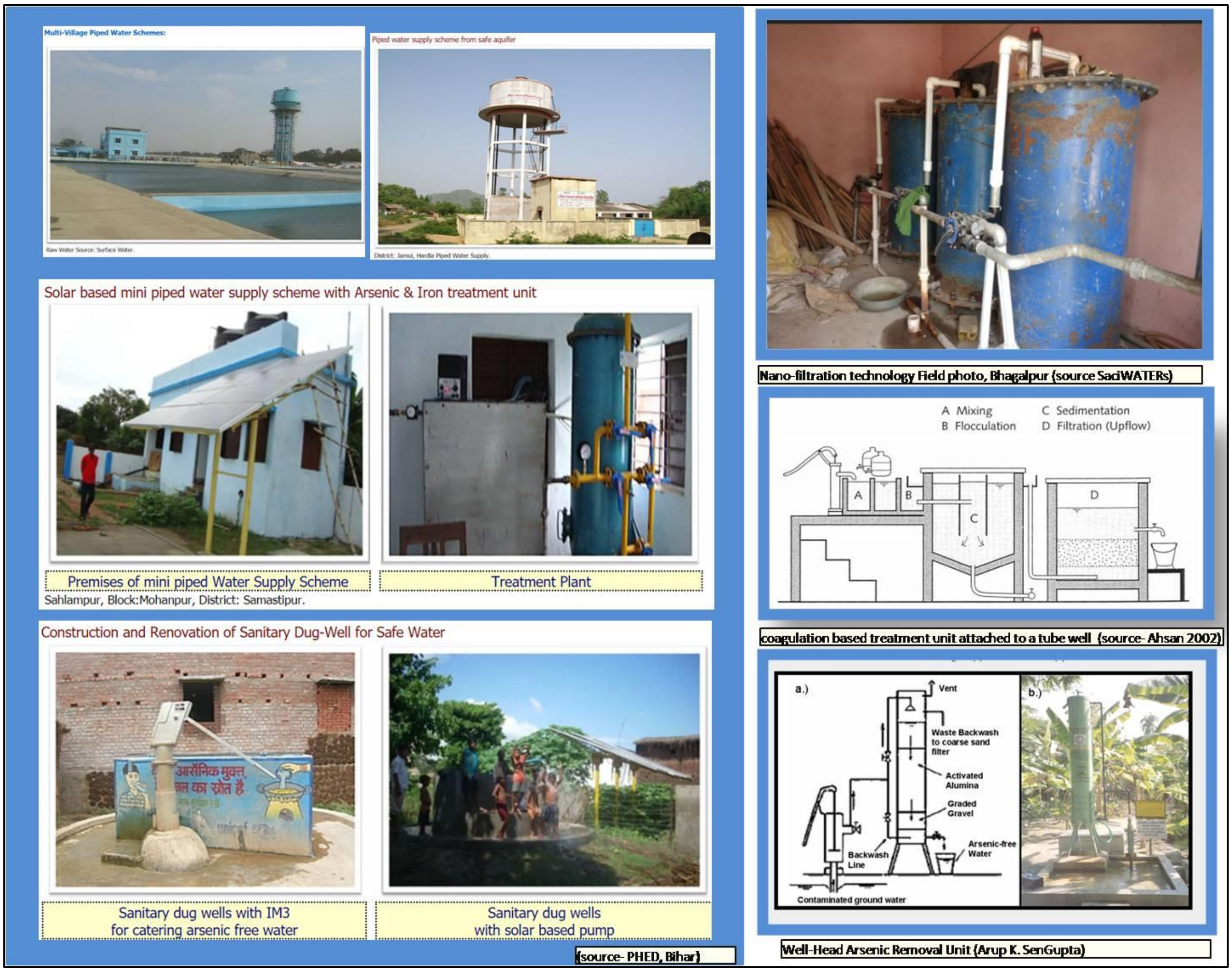
In the case of Bihar, PHED has adopted six types of solutions (both long and short term) for arsenic mitigation in the arsenic-affected areas of the state. The mitigation options have been taken up on the basis of hydro-geological conditions of the districts. These are mostly community level or large scale measures. Apart from these, few more mitigation options are being used in the rural areas of Bihar at the household level.

The challenges and effectiveness of the arsenic mitigation options are discussed in details in Annexure 4. Information on the challenges and feasibility has been taken from various studies and assessments. The following mitigation options have been compiled and assessed in **Annexure 4**:

- Multi-village piped water supply scheme by using conventional treatment plant
- Piped water supply scheme from safest aquifer
- Solar based mini piped water supply scheme with treatment unit
- Activated alumina (AA)
- Granular ferric (hydr) oxide
- Cerium oxide, Metallic iron or Iron-coated sand or brick dust
- Ion exchange media
- Coagulation + flocculation and Sedimentation/Filtration

- Micro-filtration (MF)
- Ultra-filtration (UF)
- Nano-filtration (NF)
- Reversed osmosis (RO)
- Deep Tube Well (Handpump attached with treatment unit)
- Sanitary dug well with IM3 handpump and with solar based pump
- Rainwater harvesting systems
- Sand Filters
- Sludge disposal

Fig 5.1: Arsenic Mitigation Options



The effectiveness of the arsenic mitigation measures have been evaluated using three criteria (Brouns et al., 2013):

- **Technical Feasibility:** Includes the factors that indicate whether the technical aspects of the filter are functioning or not. i.e. the filter capacity (in litre / day), the concentration of arsenic (in ppb), chances of contamination by other factors and the possibility for environmental impact of the filter.

- **Economic Feasibility:** It consists of installation costs, recurring cost and affordability.

- **Social Feasibility:** includes social acceptability, i.e. the total number of users and also whether people are excluded based on their social identity.

5.2 Key findings and recommendations

1. It is worth mentioning that finding out an efficient and sustainable technique to remove arsenic from solution remains a challenge task as most of the mitigation strategies have failed in Bihar.
2. Many cases, low levels of adaptation lead to the issue of social feasibility of the provided option. In terms of arsenic mitigation, the adoptability depends on user's perception on good quality of water which includes four physical properties - colour, odour, taste and freshness. These four criteria help the users to select their water sources. On the one hand, Arsenic is odourless and tasteless component and on the other hand treated water might change the physical properties of water. In that case there are chances that users may decide to continue with the contaminated sources if there is no initiative for capacity building and knowledge dissemination. Along with these, distance, of the water sources, accessibility and convenience of the technology affect user's decision.
3. It is also found that while some of the measures are socially viable, there are questions about the safety of deep aquifersin the long run.
4. For successful implementation and sustainability of any remediation measure therefore it is important to focus on the following issues:
    - Number of users covered
    - Social acceptability of the measure
    - Low installation and recurring cost
    - Satisfy the levels of four physical properties of water
    - The long term safety of deep aquifers and surface water

Section 6: Arsenic Mitigation Using Traditional methods

This section provides a range of traditional method can be used in order to reduce the health impact of arsenic contamination in the groundwater.

While the technology based solutions are more effective in reducing arsenic contamination from the groundwater, there found a lot of challenges as well. The deep tubewells or deep hand pumps that extract water from deeper uncontaminated aquifers is not very cost-effective and in the long term over consumption or improper installation might lead to their eventual pollution. Similarly, the government piped water schemes (Har ghar nal ka jal) too could provide safe water, however the large scale projects need a lot of time and resources for it.

6.1 Traditional Methods

In this context, there are few traditional practices could be used /followed by the communities in order to reduce the health impact of Arsenic contamination. Those methods are described as follows:

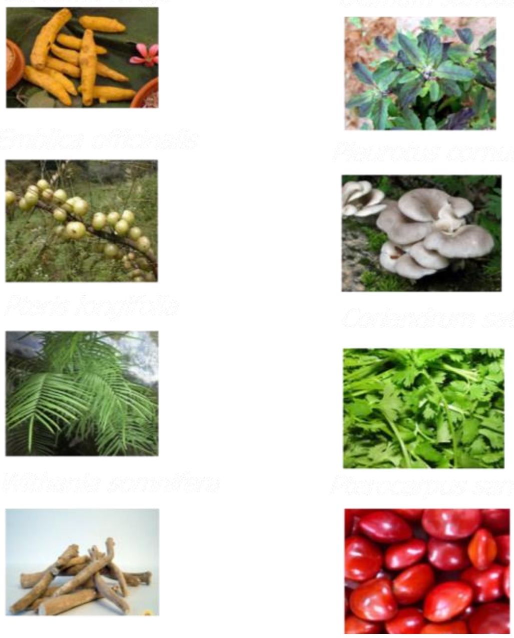
1. Restoration of existing dug wells

Fig 0.1: Restoration of dug well for drinking purposes in Buxar, Bihar

Before the pipeline project reaches to the communities the problem of arsenic contamination can be solved to some extent by simply discarding the use of shallow depth hand pumps and restoration of an existing dug well. In research (Mondal, P. et al. 2013), it is found that open wells are found to be an alternative for handpumps or tubewells for arsenic free drinking water. If the wells are constructed, so as to prevent leakage between the upper and lower aquifers, it is likely that they will be free of arsenic (and other undesirables) in future. It has been suggested that one should use deep open wells for drinking with strict adherence to the sanitary standards of the World Health Organization (WHO) and continue to use shallow wells for irrigation, lest the availability of water from deep open wells may cease. However, due to the ubiquitous presence of handpumps and also the ease of drawing water from it, open wells are being used scarcely.

2. Nutritional intake to cure arsenicosis

Fig 0.2:Antidotes against arsenic induced toxicity



The intake of arsenic-contaminated water and food causes the deposition of arsenic in the body. Sooner or later it shows the symptoms of arsenicosis. Arsenicosis has limited treatment procedures; a chelating agent is one of them. However, this is an expensive therapy to employ in arsenic intoxication. Several studies (Ghosh, P. et al., 2008) demonstrated the association between malnourishment and the growth of arsenic caused skin lesions, skin cancer and cardiovascular disease.Thus, it is important to develop a strategy for improving the health of people exposed to arsenic poisoning. Studies (Sharma and Flora, 2018) suggested that nutrient-rich food enhances the detoxification process of the body. Food rich in vitamins, protein and antioxidants helps to diminish the effects of arsenic poisoning by methylation. Methylation is the detoxification process which takes place via S-adenosylmethionine (SAM) triggered by a healthy diet.

3. Reduce the toxicity of Arsenic following certain cooking methods:

Traces of Arsenic in the food grains and vegetables have already been reported. The reason was identified as the use of Arsenic contaminated ground water for the purpose of irrigation. Studies have reported that arsenic concentration in boro rice is much higher than in aman variety because a much higher amount of water is needed for boro cultivation compared to aman cultivation. On the other hand, in a study (Kumar et al., 2016) conducted in north Bihar, it was found that twelve (80%) out of fifteen cooked rice samples had higher arsenic concentration than uncooked rice. The reason for this was ascribed to the presence of higher arsenic concentration in household water used for cooking. It was found in studies (Mwale et al., 2018; Ohno K, et al., 2009; Ohno K, et al., 2007) that cooking and boiling methods may alter the arsenic concentration in cooked food. If a household uses arsenic-free water for cooking (1: 6 ratio) and drains out the excess water after cooking, it can significantly reduce (20-30%) the arsenic toxicity in food. However, percentage arsenic removal using cooking techniques vary widely depending on the type of rice and its origin (Mwale et al., 2018).

6.2 Key findings and recommendation

1. Governments and NGOs need to work together in the arsenic affected areasin order to spread awareness regarding avoidance of shallow depth handpumps and increases use of alternative

options (like- water from sanitized dug well) which can minimise the susceptibility of the exposed population.

2. It is also important to mention that cooking rice in excess water (1:6 and parboiling) not only reduces the risk of As in food but also results in a reduction of essential elements, thus increases the risk of micronutrient deficiency, which might have severe impact especially in children, pregnant women, and the elderly population in Bihar as this region dependent on a rice-based diet. Therefore, dietary supplements need to be provided to the marginalized section of the society in order to reduce the risk of malnutrition as well as impact of As toxicity.

Section 7: Policy Interventions

This section focuses on the various initiatives (policies, plans, acts, strategies and guidelines) taken at state and national level in order todeal with the arsenic problem in the Arsenic affected areas of Bihar along with the sustainability, constraints and recommendations.

18 out of 38 districts of Bihar are affected by the presence of Arsenic in the groundwater. A substantial proportion of health issues in rural areas can be attributed to consumption of contaminated drinking water. Ever since the problem of arsenic contamination has been identified in Bihar (2002), a number of policy initiatives have been taken for the monitoring and mitigation of it as well as to ensure that adequate and contamination-free drinking water reaches the poor marginalized rural population. The analysis of the existing policies explores the extent to which water quality issues in groundwater, especially issues related to arsenic contamination are acknowledged, and responded to both at the state and national level.

This section is based on the various policy documents available at the state and national level, information provided by the state(Bihar) on the online IMIS on the website of the Public Health Engineering Department (PHED), Bihar State Water and Sanitation Mission, Ministry of Drinking Water & Sanitation (Government of India), initiatives of the Ministry of Drinking Water & Sanitation, Water Resources Department of Government of Bihar, reports on budget allocation, reports and guidelines of the ministry and discussions held in meetings of state officials dealing with rural drinking water and sanitation with senior officials of the ministry.

7.1 Arsenic Mitigation Policies

In India, water is a state subject and rural water supply has been included in the Eleventh Schedule of the Constitution, a subject that may be delegated to rural local bodies (Panchayats) by the States. Being a state subject, most of the initiatives regarding drinking water supply are taken by the state government and its agencies, while, the central government has been supplementing the work of state government through the centrally sponsored rural water supply programmes. The evolution of the policy initiatives in water at state and national levels are listed below in Box 7.1 and detailed out with their relevance to water quality aspects in **Annexure 5**. Water policies in India have been directed towards quality aspects to varying levels. While some policies not directly focussed on mitigating water quality issues may indirectly be focussed on safe water access for households.

Box 7.1 Evolution of National and State Policies in Water

Year	Policy/Act/Mission
1972-73	Accelerated Rural Water Supply Programme (ARWSP)
1970s	Minimum Needs Program (MNP)
1986	National Drinking Water Mission
1986	Environment Protection Act
1991	Rajiv Gandhi National Drinking Water Mission (RGNDWM)
1992-1997	Eighth Plan Five Year Plan
2002	Swajaldhara
2005	National Rural Water Quality Monitoring & Surveillance Programme (WQMSP)
2009	National Rural Drinking Water Programme (NRDWP)
2010	State Water Policy of Bihar
2012-17	12^{th} Five Year Plan
2015	Master Plan for arsenic mitigation
2016	Har Ghar Nal Ka Jal, Nischay scheme
2017	National Water Quality Sub Mission (NWQSM)
2019	Jal Jeevan Mission (JJM)

7.2 Key findings and Recommendations

1. The State Government of Bihar and the Government of India recognize arsenic contamination in the groundwater as one of the most critical problem especially for the middle and lower Ganga plain and Brahmaputra basin and has continued to prioritize water quality issues since the last two decades. The policies designed in the last two decades demonstrate increasing acknowledgment of arsenic contamination impacts in groundwater and include strategies for mitigation of arsenic and associated health issues. However, it is also true that successful implementation of those policies depend on proper planning and monitoring.

2. The way the arsenic related issues have been incorporated, shows a paradigm shift towards more demand driven, bottom-up and participatory approach in the management of operations and maintenance of drinking water services provided by the government.

3. In order to have a sustainable solution for arsenic mitigation, it is important to focus on multi-sectoral policies (like- irrigation, health policy etc.) as well.

Section 8: Institutional Mapping for Water Quality in Bihar

This section identifies and maps out the various cross sectoral institutional levels and networks that are involved in working on water quality issues in Bihar, with a special focus on arsenic issues. The section highlights the significance of the exercise of institutional mapping, the institutional setup, and their interlinkages.

8.1 The need of Institutional mapping

Mapping institutions (or institutional mapping) refers to a methodological approach attempting to conceptualize institutions related to a problematic of concerns in a particular place, at a particular time, and with a particular goal. Among other things, it is intended to produce an analysis of the functioning of institutions and assess the interactions of the key stakeholders engaged in those institutions (Aligica 2006). The involvement of active players in a particular object or project and their inter-linkages defines the success/failure of the project.

A formal mapping of various institutions has been done by a group of fellows from Delft University of Technology (2013). They have highlighted the important mitigation strategies and how these mitigation strategies have failed to provide arsenic free drinking water. SaciWATERs conducted an institutional mapping exercise under the "Arsenic Knowledge and Action Network" funded by Arghyam, pertaining to arsenic issue in Bihar. The chain of institutions involved in water quality in general and Arsenic in particular is further revisited because of changes in governance at the central level in the recent years which have caused some changes in institutions and their roles and responsibilities.

8.2 Government Institutions working for Water Quality at different levels

Jal Jeevan Mission (JJM), initiated by Central government under the Ministry of Jal Shakti in 2019, aims to ensure access of piped water supply of 55 lpcd of prescribed quality on a regular and long-term basis for every household in India by the year 2024. Finance Minister Nirmala Sitharaman announced *Har Ghar Nal Se Jal* programme in her Budget 2019-20 speech.

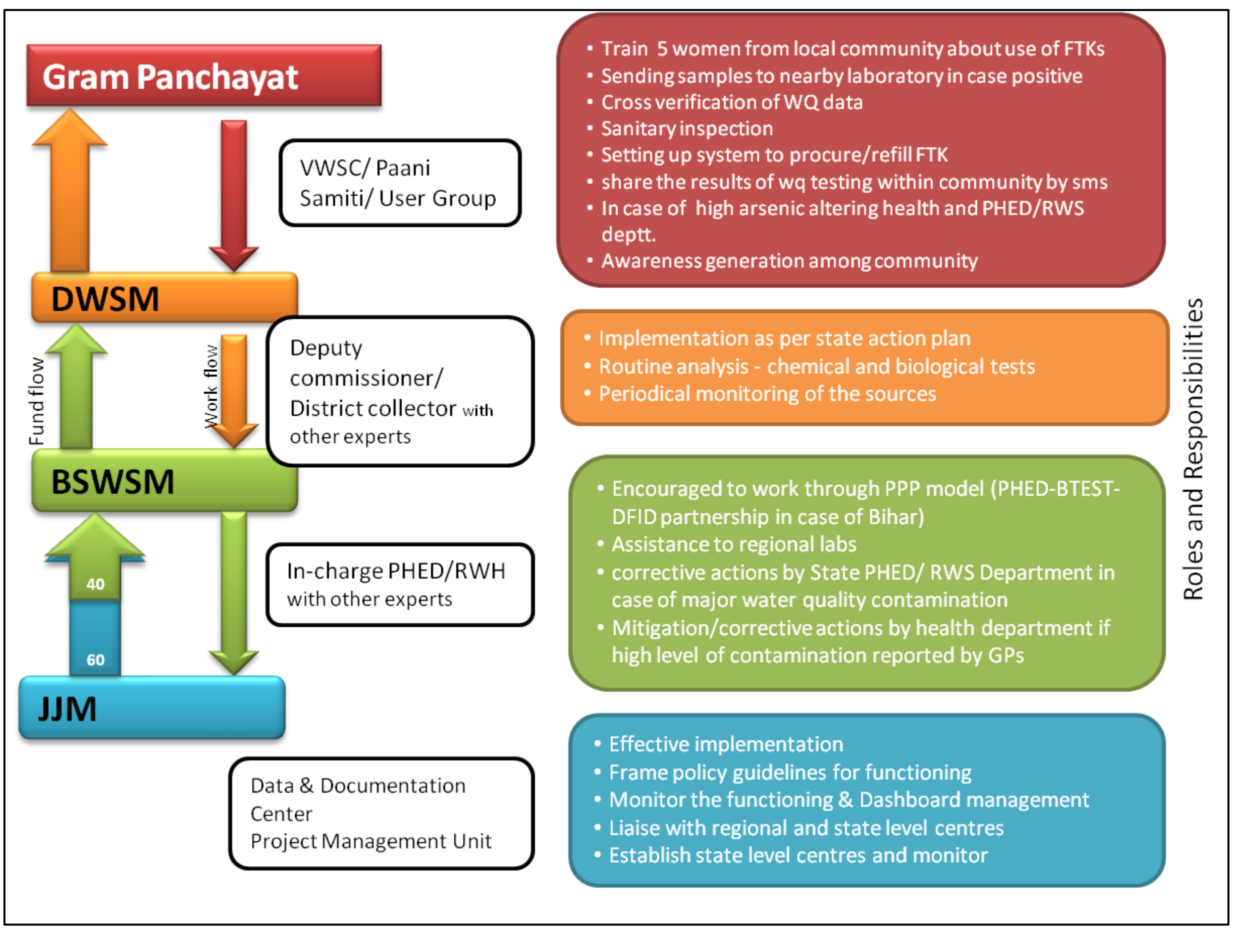
Water quality monitoring is an essential component of JJM. National Water Quality Sub-Mission (NWQSM) is now subsumed into Jal Jeevan Mission, has aim to provide safe drinking water to identified 27,544 Arsenic/ Fluoride affected rural habitations by March, 2021 as per existing guidelines. Water quality monitoring and Surveillance Mission (WQM&S) involves testing of water samples collected from water sources by Department in water quality testing laboratories. Surveillance is undertaken by community using Field Test Kits (FTKs), sanitary inspection, etc. Under JJM, water samples are also being collected from functional household tap connections (FHTCs). Water testing is important for monitoring the operation of water supply, verification of the safety of drinking water, investigation of disease outbreaks, validation process and preventive measures. All the components under JJM follow bottom-top, community driven approach (fig 8.1).

In water quality-affected habitations, especially with Arsenic and Fluoride contaminants, potable water is ensured on priority under JJM. Since, planning and implementation of piped water supply scheme based on a safe water source will take time, as a purely interim measure, Community Water Purification Plants (CWPPs) may be taken up to provide 8-10 lpcd potable water to meet drinking and cooking need of every household residing in such villages/ habitations..

8.3 Institutions and Stakeholder Setup in Bihar

The institutional setup in Bihar and the functions of the institutions are the same as mentioned under JJM guidelines. In Bihar, the registered society is the Bihar State Water and Sanitation Mission (BSWSM). This is the main body responsible for implementing the state level water supply and sanitation projects and works under the guidelines outlined by JJM. Roles and responsibilities at state level, district level and gram panchayat level has been elaborated in previous section.

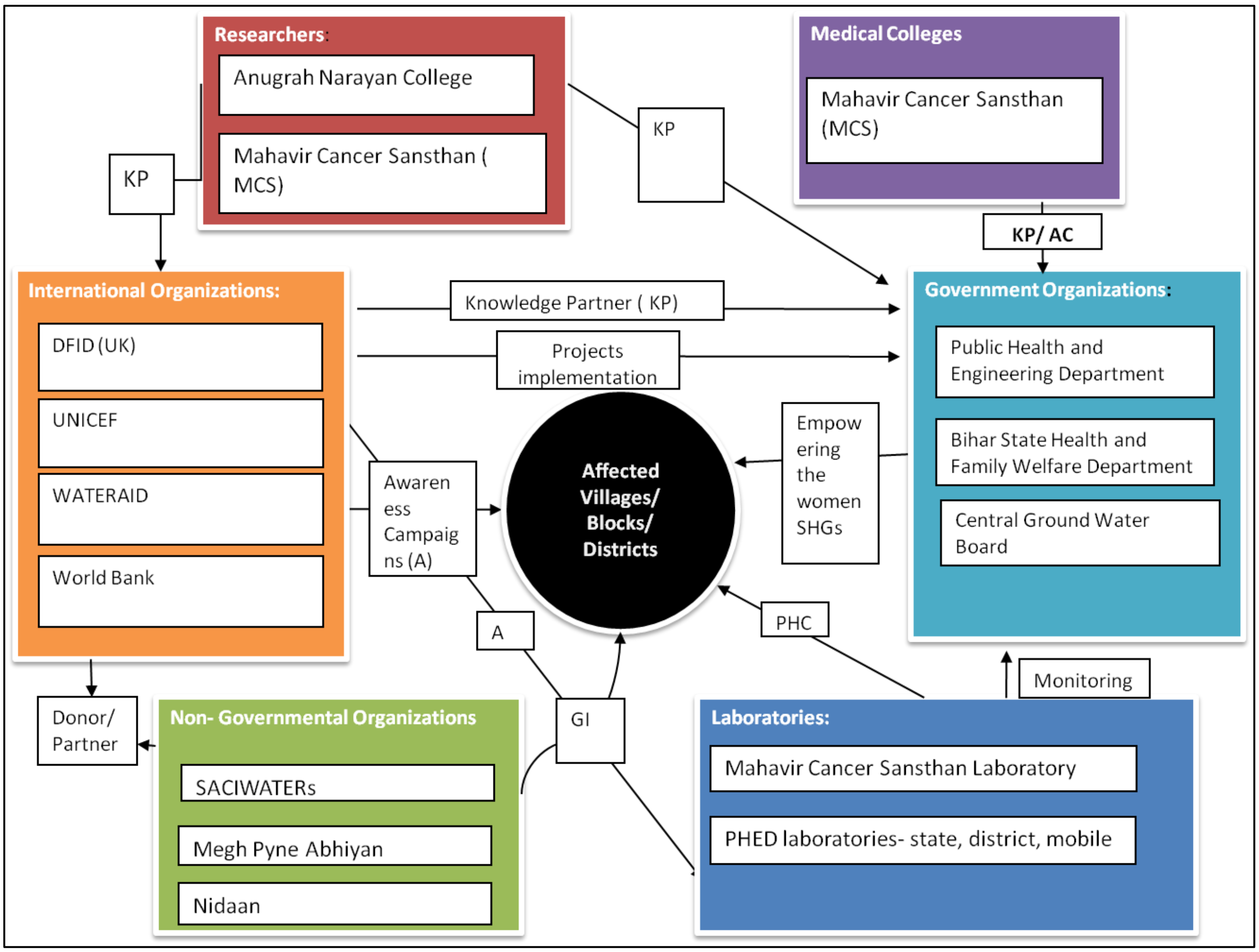
Fig 8.1: The four tier institutional mechanism of JJM (water quality) with their roles and responsibilities



Abbreviations for Fig 8.1:	
BSWSM- Bihar State Water and Sanitation Mission	JJM- Jal Jeevan Mission
BTEST- Bihar Technical Assistance and Support Team	PHED- Public Health & Engineering Department
DFID- Department for International Development (UK)	RWH – Rain Water Harvesting
DWSM- District Water and Sanitation Mission	VWSC- Village Water and Sanitation Committee

A modified and updated institutional mapping chart from prepared by SaciWATERs[2] gives a detailed picture of set all institution viz. Government, non-government, international organisations, academic and research organisations involved based on the literature review in Fig 8.2. The roles and responsibilities of each of the actor in the map is elaborated upon in box 8.1

Fig 8.2 Institutional Mapping for Arsenic issues in Bihar



Abbreviations for Fig 8.2:		
A- Awareness	AC- Awareness Campaign	GI - Grass root intervention
KP- Knowledge Partner	PHC- Primary Health Care Centers	

[2] http://www.arsenicnetwork.in/wp-content/uploads/2016/08/Internship-Report-Aishwarya.pdf

Box 8.1. Roles and Responsibilities of actors pertaining to the issue of Arsenic in Bihar

Stakeholder type	Institution	Roles and Responsibilities
Government Institutions	Public Health and Engineering department	• An apex organization that fosters the supply of drinking water and sanitation services in the districts of Bihar • Overall management and monitoring of water quality testing at state level • Establishment of laboratories, maintenance and data monitoring • Premier organization which has also been involved in the technology implementation to solve water quality issues
	Bihar state health and family welfare department	• SWASTH programme was designed to bring together different service delivery departments of Department of Health and Family Welfare, PHED and Social Welfare Department.
	Central ground water board	• CGWB is National Apex Agency entrusted with the responsibilities of providing scientific inputs for management, exploration, monitoring, assessment, augmentation and regulation of ground water resources
International Organisations	DFID (UK)	• The DFID is represented in Bihar by the Bihar Technical Assistance Support Team (BTAST) • The DFID-SWASTH is working very closely with the PHED department on the issue of water quality in an integrated manner. • The DFID acts as a knowledge partner to the PHED and they do pilot projects regarding arsenic awareness
	UNICEF	• UNICEF works as a knowledge partner and financer for the Public Health and Engineering Department of Bihar • After the discovery of arsenic in the tubewell water, UNICEF responded by constructing UNICEF was involved in constructing sanitary wells and rain water harvesting system
	WATERAID	• Water Aid works with the government as its knowledge partner and also works with the civil societies working at the grass root level on the issues of water quality and sanitation. • The organization mainly provides fund to the Non-Governmental Organization in carrying out grass root level projects in Bihar on Water Quality and Sanitation.
	World Bank	• Bihar Rural Livelihood Project, widely known as Jeevika is an initiative by the Government of Bihar to reduce poverty. This project is funded by the World Bank

Non-Government organisations	Megh Pyne Abhiyan (MPA)	• MPA is a campaign working with the grassroots organizations and professionals in five flood prone districts of North Bihar. • The institution is working to revive the traditional mitigation strategies practiced by the communities. • The dug wells have been found to be a source of clean drinking water in flood prone areas of North Bihar.Thus, the MPA came up with the initiative of constructing more dug wells as source of As free water.
	Nidaan	• Nidaan has been a partner with the WaterAid and works on various social issues amongst which is water quality. The role of Nidaan on water quality has been limited to the work that it carries out with WaterAid.
	SaciWaters	• SaciWaters, as a part of its Arsenic Knowledge and Action Network, is trying to form a network in Bihar • As an early initiative it is trying to bring in the active stakeholders and affected communities on a common platform to discuss the interventions needed
Medical colleges and hospitals	Mahavir Cancer Sansthan	• Mahavir Cancer Sansthan (MCS) was identified as a premier institution in identifying patients who have been affected by arsenic. • Many research works are being conducted by the competent researchers in MCS to identify and treat the patient sufferings from various forms of cancer. • Other local/rural hospitals and doctors are a very critical actor in dealing with arsenic issue, early diagnosis could be helpful in treating the issue better. Many studies suggest that there is a need to strengthen this system.
Researchers		• Prof. Ashok Ghosh who have immensely contributed in understanding and bringing the issue of arsenic to the forefront. Prof. Ghosh has a team of researchers working on the issue of arsenic and has also conducted many field visits to the affected regions in Bihar. • Dr. Arun Kumar of MCS has been an active researcher in finding out the effects of the dosage of arsenic on human body. Dr. Kumar has several cancer patients coming from the various arsenic affected districts to the MCS hospital.

Section 9: Way Forward

The objective of this situation paper was to highlight the different aspects of arsenic especially in the context of Bihar, from spatial distribution to vulnerability assessment, testing methods, mitigation technologies, and policies addressing arsenic issues in drinking water and role of different institutions mitigating arsenic issues. Many facts have been brought together in this report, yet there are number of issues that need to be addressed in the long run.

Firstly, arsenic in the groundwater was initially detected in 4 districts (Bhojpur, Patna, Buxar, Bhagalpur) along the banks of river Ganga. However, eventually the traces of Arsenic have been detected in 14 other districts of the state. Most importantly, Arsenic is not only accumulating in the human body by drinking of contaminated water but also through food chain. Therefore, the way the spread of Arsenic contamination is detected over the time period, it can be recommended that monitoring and testing of water sources is very important at a regular interval not only for the affected areas but also for those where the traces of Arsenic is not found yet. Through regular monitoring, it would be possible to detect the problem at the early stage and also can be easily avoided health hazard caused by the Arsenic contamination in the groundwater by using alternative safe water sources. It can also be recommended to monitor other water quality parameters (like- Fluoride, Iron, PH, BOD, etc.) along with the arsenic issue.

Secondly, Arsenic contamination is not only a water quality and public health issue but also a social issue as it brings social stigmatization and exclusion with it. Studies have reported that providing arsenic free drinking water and treatment for the arsenicosis disease is not sufficient for the communities, unless awareness can be created among them in order to reduce social discrimination. It is also found that it is the poorest section of the society faces the consequences more due to lack of awareness as well as lack of resources. It is not possible to solve the water quality issues separately unless it deals with the issues of poverty and illiteracy.

Thirdly, in case of testing it is very important to follow particular processes and guideline as little changes in the values can decide whether the water source is safe or unsafe. It has been reported that in some districts and sub-districts, water quality laboratories of PHED are not functioning properly due to ill maintenance and lack of trained staff. Therefore, more cautions are required in order to get accurate result of the water samples. Given the seriousness of the issue, it is also very important to train the staff of the testing laboratories. The correct results would help in taking right decision.

Fourthly, there found flaws in the existing mitigation measures taken for different areas of Bihar. For successful implementation of any mitigation measure, only technical viability is not enough as economic and social feasibility is equally important. Therefore, the recommendation would be to look for socially and economically viable options and then build the capacity and perception of the communities for adopting those measures.

Finally, in case of policy interventions, community participation and ownership should get utmost importance. Though the existing policies have mentioned about participatory approach in many places yet there found lack in the ground. Community engagement along with help from other stakeholders (like- NGO, Health Institutes, etc.) might solve many problems in the long run.

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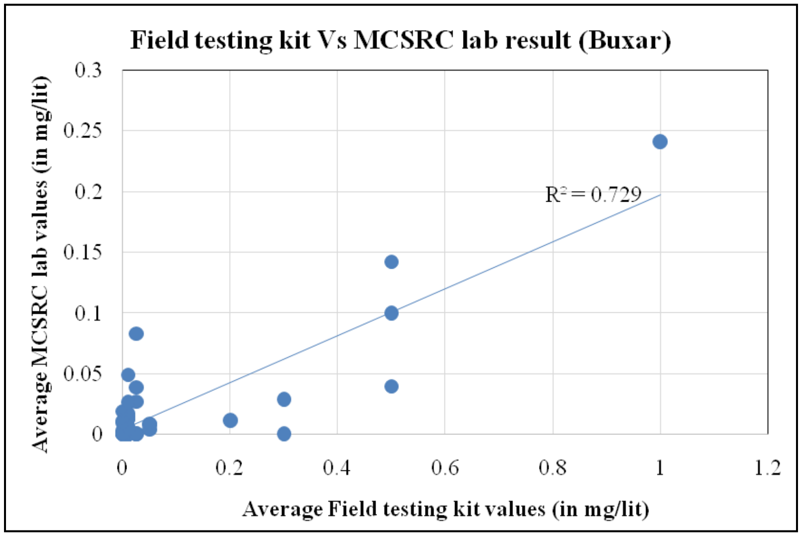
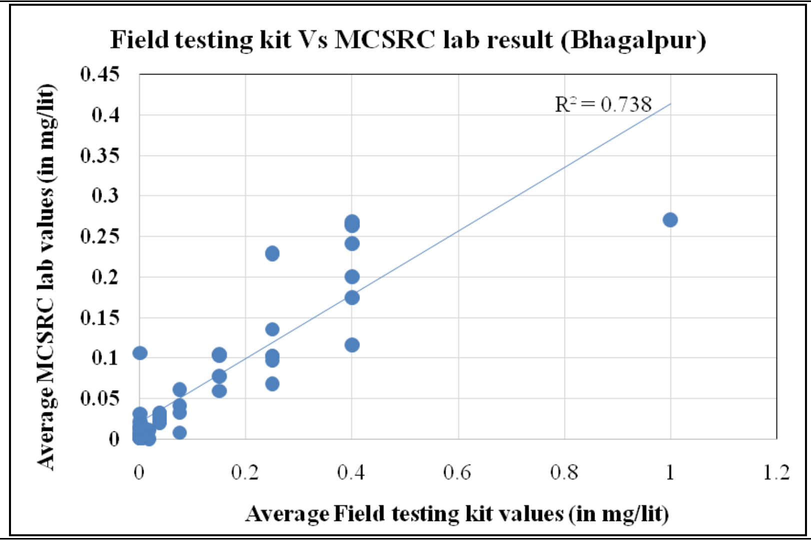
Annexure

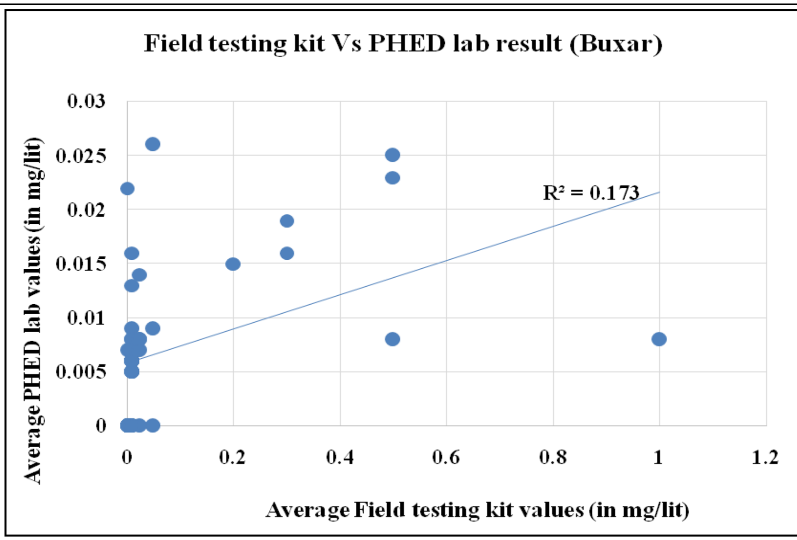
Annexure 1 – Comparison between ORLAB and Ffem Water Testing Kits

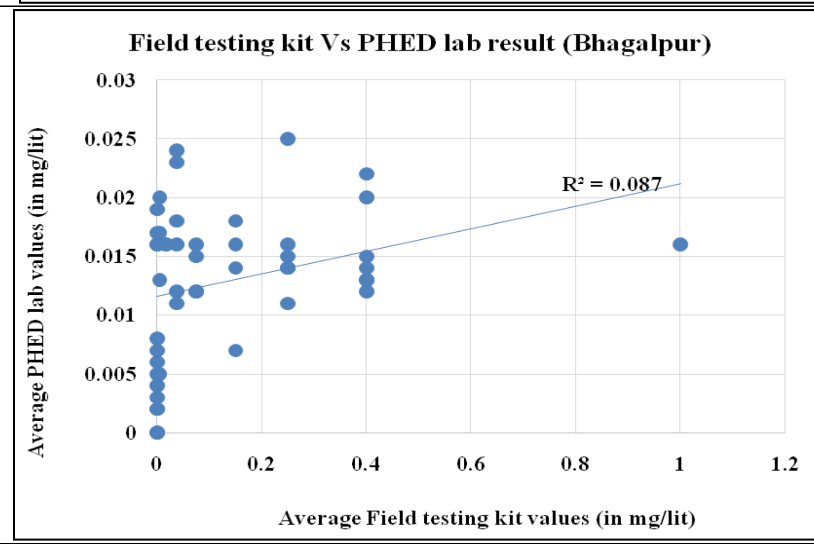
Parameter	Arsenic III and V	Arsenic III
Name of kit	ORLAB	Ffem Water test kit
Design	Compact and light box, easy to carry in the field	Tests are based on colorimetry. The device is an open source device.
Kit capability	Color metric results/ semi quantitative	Base testing kit, Arsenic Reagent, Iron Reagent, Calibrated Smartphone, 100 ml dropper bottles
Minimum detection level	0	0
Arsenic detection range (mg/l)	0.01,0.025,0.05,0.1,0.2,0.3,0.5 & 1.0 ppm (Note: also upto 5 ppm, when using 1/5 dilution method)	Range – (0 ppm to 0.3 ppm) (Note: can test for concentrations well above the limits mentioned in the ranges above, by diluting the sample with distilled or dionised water. The app allows for up to 5 times dilution. These dilutions do increase the error in sample measurement.
No of Tests	100 Tests per kit	
chemicals used	Zinc Dust, Tartaric Acid, Ferrous, Nickel Salt, potassium peroxymonosulfate are present in the form of Arsenic reagent 1, 2 & 3, Arsenic test strip's test pad4.	
Kit particulars	Arsenic reagent 1, 2 & 3, Arsenic test strip's test pad4.	Arsenic reagents A, B & C, Arsenic test strip, A Smartphone with the ffem apps installed, and an alignment sticker, Cuvette & pipe, 10 ml measuring tube
The time required for the test	10 minutes	Instant
Health hazard	Should not expose to eyes, skin, or clothing	
Cost per test in INR	Rs. 40-50	Rs. 20

Annexure 2 – Correlations between testing values of Water Testing Kits, MCSRC lab testing, and PHED testing









Source: SaciWATERs water testing and analysis data from Bhagalpur and Buxar district field sites

Annexure 3 –Arsenic Testing Kits available in the market

KIT name	company name	price	technology	range/accuracy	remark	Reaction time	Picture
Arsenic testing kit	Prerana Laboratories, Pune	4900	Test Strip colour comparison	10,50,100 ppb	400gms	11 m	
Jal Tara Arsenic Testing Kit	Taralife Sustainability Solutions Private Limited, New Delhi	6000	use colour comparison charts.	10, 20, 50, 200, 500 ppb	50 tests		
AQUASOL Arsenic Test Kit	Rakiro biotech systems private limited. R-466, TTC Industrial Area, MIDC Rabale, Navi Mumbai	3100	use colour comparison charts.	0.0, 0.05, 0.1, 0.2, 0.5, 1.0, 2.0, 3.0 mg/l	100 tests	10 m	
V tech Arsenic Test Kit	Instrumentation Tatabad, Coimbatore, Tamil Nadu	2900	Test Strip colour comparison	0.0, 0.05, 0.1, 0.2, 0.5, 1.0, 2.0, 3.0 mg/l	100 tests		
Arsenic test kits	Royal Enterprises, Chennai	5000	Test Strip colour comparison	0 to 200 micro gram/L		10 m	
Merit water testing kit	Advance Inspection & Testing Lab, New Delhi	3000		0.0 to 3.0 mg/l	100 tests		
Wastek Arsenic testing kits	Wasser Solutions Private Limited, Thane	not mentioned		0.05,0.1,0.2,0.5,1,2,3 ppm			

Hach Arsenic Test Kit	Hach DHR India Private Limited	30000	Test strip	0-500 ppb			
		12000	Test strip	0-500 ppb 0-4000 ppb			
Stainless Steel Visual Arsenic Test Kit	Analytical Technologies Chamarajpet, Bengaluru, Karnataka	45000	Test Strip color comparison	10,50,100 ppb	400 gms	11 m	
Lovibond from tintometer	The Bharat Instruments & Chemicals, Civil Lines, Ludhian	15000	use colour comparison charts	0 - 0.5 mg/l	100 tests	Rapid	
Arsenic testing kits	Saptagiri Water Solution, Bengaluru, Karnataka	A variety of kits available based on accuracy limits and number of test capacity- • Quick Arsenic Econo- 300 Tests, Quick Arsenic Econo II - 100 Tests, Quick Arsenic II Mini - 5 Tests Kit, Quick Arsenic Low Range Mini - 5 Tests, Quick Arsenic Low-Range II - 50 Tests Kit • Quick Arsenic Mini Kit, Quick Arsenic Ultra-Low II - 25 Tests Kit, Rapid Arsenic Test Kit • Quick Arsenic Scan					 
Arsenic Monitoring Kit	Chem-in corporation, Pune	not mentioned	As (III), and As (V)	10 ppb interval (0-100ppb)	1.13 kg		

Annexure 4 – Arsenic mitigation Options in Bihar: scale and characteristics

Sl No	Mitigation Options	Mechanism	Type of Solution	Scale of operation	Water Sources	Challenges	Advantage	Remarks
1	Multi-village piped water supply scheme by using conventional treatment plant		Short Term	Large Scale (Multi-village)	Treated Surface Water	Expensive, Lack of infrastructure, Pollution, Require cleaning at regular interval		needs research on river morphology, because the Ganga shifts away from the plants
2	Piped water supply scheme from safest aquifer	In-situ	Short Term	Large Scale	Groundwater from deep aquifers	Expensive, Lack of infrastructure	Would be a better option as can easily adopted by the society	Might be a good solution for the future.The state has taken the initiative through 'Har ghar Nal ka jal' scheme.
3	Solar based mini piped water supply scheme with treatment unit		Short Term	Community level	Groundwater (Arsenic contaminated)		Cost effective as solar energy is used	Generally found in the isolated places with few households
4.1	Activated alumina (AA)	Ex-situ (Adsorption and Sedimentation/Filtration)		Community level	Groundwater (Arsenic contaminated)	Low efficiency as pre-treatment required to remove iron, Strict maintenance is required with time interval to avoid microbial contamination, not cost effective as the filter needs to be replaced after 3-4 regenerations, AA can cause kidney problems, and can lead to cancer		Though a lot of installation has been done in Bhagalpur, however not very efficient and needs more research on it
4.2	Granular ferric (hydr) oxide	Ex-situ (Adsorption and Sedimentation/Filtration)		Community level	Groundwater (Arsenic contaminated)	Pre-treatment is required that increases the cost	highly effective to remove the arsenide and arsenate (and phosphate) and produces relatively small amounts of residual spent media	Found in small number in Bihar
4.3	Cerium oxide,	Ex-situ		Community	Groundwater	it needs (just like the	high selectivity for	effective in removing

	Metallic iron or Iron-coated sand or brick dust	(Adsorption and Sedimentation/Filtration)		level	(Arsenic contaminated)	others) iron removal by sand filtration to avoid clogging as a pre-treatment	arsenic ions, does not need pre-treatment or adjusted pH-conditions	both As(III) and As(V) and common used in adsorption units in Bihar, mostly because of the easy way of regeneration
4.4	Ion exchange media	Ex-situ (Adsorption and Sedimentation/Filtration)		Community level	Groundwater (Arsenic contaminated)	Cause interference with other ions and get easily blocked	Effective technique to remove arsenic (V) if exchange resins are available. Resins fit for arsenic removal (selective) are important to provide high efficiency. Hybrid solution is excellent technology	Not very common in Bihar. Suitable technique if selective and sensitive chemical agents are used in ion-exchange process
4.5	Coagulation + flocculation and Sedimentation/Filtration	Ex-situ (Adsorption and Sedimentation/Filtration)		Community level	Groundwater (Arsenic contaminated)	Chemical and pH adjustment is required. Generation of sludge in large volume as by-products	Efficient to remove arsenate from the wastewater generated in the industries	Not a suitable technique for removal of arsenic if problem of groundwater of Bihar is concerned
5.1	Micro-filtration (MF)	Ex-situ (Membrane and Filtration technology)		Community level	Groundwater (Arsenic contaminated)	the filter accuracy is much less compared to the other filtrations		Not found in Bihar
5.2	Ultra-filtration (UF)	Ex-situ (Membrane and Filtration)		Community level	Groundwater (Arsenic contaminated)	Cannot filter the arsenic properly without the arsenic is adsorbed to other particles. the filter accuracy is much less compared to the other filtrations		Not feasible and not found in Bihar
5.3	Nano-filtration (NF)	Ex-situ (Membrane and Filtration technology)		Community level	Groundwater (Arsenic contaminated)	needs enough electricity to perform the high pressure, therefore not cost effective	Does not always make use of chemicals, it also can remove odours and bad tastes due to the small pore size.	Not feasible yet found in some places of Bihar

5.4	Reversed osmosis (RO)	Ex-situ (Membrane and Filtration technology)		Community level	Groundwater (Arsenic contaminated)	a RO-system is not sufficient as it needs extra filters for iron removal, high cost and wastage of water	Does not always make use of chemicals, it also can remove odours and bad tastes due to the small pore size.	Not feasible yet found in some places of Bihar
6	Deep Tube Well (Handpump attached with treatment unit)		Long Term	Community level	Groundwater (Arsenic Contaminated)	• Maintenance of the treatment unit • Expensive		Low
7	Sanitary dug well with IM3 handpump and with solar based pump	Oxidation technology	Long Term	Community level	Groundwater	• Chances of bacterial contamination • Acceptability • Accessibility • Cleaning required at certain interval	Better and cost effective	
8	Rainwater harvesting systems		Long Term	Household level/ Community level	Rainwater	Suitable roof structure, Collection, Preservation, Seasonal variability, Maintenance	Reduces the extraction of groundwater, easy to build	
9	Sand Filters	Ex-situ	Short Term	Household level	Groundwater (Arsenic contaminated)	The big issue is the disposal of the arsenic contaminated sand, lack of awareness	In the case villagers live such a distance from the centre of a village that it is not profitable to get water each day, an own filter is very welcome. Preferred by those households living away from the water sources	To perform this on household level is very difficult in Bihar.
10	Sludge disposal	Bioremedia tion		Household level	Groundwater (Arsenic contaminated)	Difficult to implement due to lack of knowledge among the people	the only disposal option so far	observed in Maner, Not a feasible option at present

Annexure 5 – Water related policy initiatives at the National level and state level in Bihar

Year	Policy/Act/Mission	Level	Major issues	Remarks on water quality aspects
1972-73	Accelerated Rural Water Supply Programme (ARWSP)	National	to ensure that sufficient drinking water reaches the rural community through the Public Health Engineering System	the water quality issues were not highlighted
1970s	Minimum Needs Program (MNP)	State	to ensure the supply of sufficient drinking water to the rural areas	
1986	National Drinking Water Mission	National	Similar to ARWSP	a modified version of the Accelerated Rural Water Supply Programme launched with a need-based missionary approach
1986	Environment Protection Act	National	the Water Quality Assessment Authority (WQAA) was constituted with the aim of formulating water quality management plan	
1991	Rajiv Gandhi National Drinking Water Mission (RGNDWM)	National	Identification of water quality related issues, monitoring of sources, addressing the problem with the application of science and technology to ensure that the available water is of acceptable quality and ensure that the quantity and quality of water can sustain at the long term through proper water management technique and implementations of management information system.	1. ARWSP was renamed as RGNDWM. 2. More resources were allocated to those states having more quality affected habitations in arid and hard rock regions
1992-1997	Eighth Plan Five Year Plan	National	Sub-missions to deal with the water quality problem, i.e. habitations exposed to the problem of Arsenic, Fluoride, Iron, salinity were taken up	during that period the Arsenic problem in the groundwater of Bihar were unknown
2002	Swajaldhara	National	It emphasized on the need for an increase in people's participation, treatment of water as a socio-economic good and the use of 20% of available funds for states promoting reforms along these lines. Sub-Mission projects were taken up to ensure safe and sustainable water supply, through rain water harvesting, artificial recharge, etc. particularly to the rural habitations which are suffering from water quality problems like Arsenic, Fluorides, Iron, etc.	The RGNDWM was later scaled up as Swajaldhara

2005	National Rural Water Quality Monitoring & Surveillance Programme (WQMSP)	National	to institutionalize community participation and involvement of PRIs for water quality monitoring & surveillance of all drinking water sources.	
2009	National Rural Drinking Water Programme (NRDWP)	National	to enable all households to have access to and use safe & adequate drinking water within premises to the extent possible in order to meet the SDG goal by 2030.	The National Rural Water Quality Monitoring & Surveillance Programme (WQMSP) were also merged with NRDWP
2010	State Water Policy of Bihar	State	close review and Monitoring Measures	
2012-17	12th FYP	National	the state proposed priority measures for Management of shallow and deep aquifers particularly in arsenic prone area.	
2015	Master Plan for arsenic mitigation	State	short/immediate, medium/ intermediary and long-term interventions	
2016	Har Ghar Nal Ka Jal, Nischay scheme	State	to provide clean drinking water to every citizen of Bihar, without any discrimination with a view to end their dependence on Hand-pumps (chapakal) and other sources of drinking water.	implemented jointly by the Public Health Engineering Department and the Panchayati Raj Institutions
2017	National Water Quality Sub Mission (NWQSM)	National	to make provision of safe drinking water to Arsenic and Fluoride affected habitations by March, 2021	Under the revised guidelines of NWQSM, there was a provision for the states to utilize funds up to 67% of the total state allocation to address water quality problems.
2019	Jal Jeevan Mission (JJM)	National	in partnership with States, to enable every household in villages to have Functional Household Tap Connection (FHTC) in the next 5 years (by 2024). It is predicted that with FHTC, each household will have potable water supply in adequate quantity of prescribed quality on regular and long-term basis.	restructured and subsumed the ongoing National Rural Drinking Water Programme(NRDWP)