Dealing with arsenic in rural Bihar, India

Evaluating the successes and failures of mitigation projects and providing a long-term mitigation strategy

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Abstract

Arsenic is a toxin that is commonly found in the ground water of shallow aquifers in the Ganges River Delta. Long term consummation of arsenic contaminated water will among others cause skin diseases, skin and bladder cancer and cardiovascular diseases.

Since its discovery, much research has been done on the subject of arsenic and how to provide arsenic free drinking water to rural areas. Based on this research, many arsenic filter techniques have been developed and implemented. However, many of these filters have not been successful in providing safe water to everyone who needed it. Many problems arose regarding the awareness of the affected communities, maintenance of the filter installation and the power required for providing the filtered water.

This research focused on the social and economic factors that have influenced the successes and failures of different arsenic mitigation projects and will provide a strategy on how to handle the arsenic issue in the upcoming years. The main goal of this research was:

To provide further insight in the successes and failures of different arsenic mitigation techniques and provide a strategy for handling the arsenic issue in the upcoming years.

This has been done by evaluating different arsenic mitigation projects in the Bihar districts of Bhojpur, Bhagalpur, Maner, Vaishali and Buxar. For evaluating these projects interviews have been conducted with villagers, NGO's and different government parties.

Most of the issues related to arsenic mitigation can be put into four categories. These are: Insufficient awareness of local population, insufficient maintenance of mitigation structure, Social conflicts and Negligence during installation.

Many people in rural Bihar still do not know about arsenic and the need for mitigation. For any mitigation structure to work, overall awareness is necessary. Integrating drinking water safety and sanitation in the school's curriculum would be an important first step in achieving overall awareness.

Proper maintenance is also a huge issue regarding mitigation structures. Maintenance strategies have often been neglected in constructing village level mitigation projects. The current trend is that communities themselves should be responsible for the maintenance and that a caretaker should be assigned and paid by the villagers.

Some of the filters that were tested started showing arsenic levels over the allowed limit of 10 ppb. Until proper guidelines on replacement of the filter media are set up, governmental agencies should regularly visit the mitigation facilities to determine whether everything is running smoothly and to determine the status of the filter media.

The third major issue regarding arsenic mitigation projects are social conflicts. With many of the filters that were visited, the owners of the land where the filter was installed excluded other villagers from the use of the filter.

Lastly there have been many issues regarding negligence in the installation. Issues that have come forward are for example improper transfer of the land where the filter is installed, which causes social conflicts as described above, no facilities for the disposal of sludge and backwash, which contaminates the area around the filter even more and there has been very little attention to after-care service and maintenance.

Because of the many issues with small scale filter units it is recommended to use source water that is not contaminated with arsenic. Since the long term safety of deep aquifers cannot be guaranteed if large quantities of water are extracted, the only feasible alternative is to use surface water. Most of the arsenic affected areas in Bihar are relatively close to the Ganga River. Large scale multi-village surface water supply plants are therefore a viable option for supplying many districts of Bihar with arsenic-free water. One of these plants has been constructed in Mozempur and this should be monitored carefully in order to find out possible issues.

For villagers that cannot viably be supplied with surface water the only option at the moment seems to treat the ground water using filters, since the long term safety of deep aquifers cannot be guaranteed.

When using filters the following aspects need to be carefully dealt with:

- Social conflicts;
- Exclusion;
- Distribution of filtered water;
- Sludge disposal;
- Backwash disposal;
- Maintenance;
- Filter media replacement.

Social conflicts and exclusion can be minimized by creating a finely-meshed grid for the distribution of the filtered water. Since people have many choices on where to get their water and do not have to share it with as many people, exclusion and vandalism have less effect than with a non-finely-meshed grid.

Sludge and backwash have to be stored in sealed tanks until a proper way of disposing of it is available. Future possibilities for disposing sludge and backwash are through bioremediation and making bricks out of the sludge. More research into sludge disposal methods is necessary.

For maintenance it is especially important for the entire community to be aware of the mitigation project so that there can be social control on the maintenance. For the replacement of the filter media it is necessary for governmental agencies to regularly check on the filter and whether the filter media is saturated.

Preface

This study has been done as a part of the minor International Entrepreneurship & Development of the Technology, Policy and Management faculty of Delft University of Technology.

In conclusion, this report will give a description of the current status of arsenic mitigation in Bihar and will give a strategy regarding arsenic mitigation for the upcoming years.

Much research has been done on the technical aspects of different arsenic mitigation projects; however the social aspects that contribute in the successes and failures of these projects have so far been mostly neglected. Therefore, the main scope of this research is regarding social aspects of these projects. For this research we have limited ourselves to the Bihar state of India.

For this project, our research group has spent two months in Bihar for conducting field visits to several arsenic mitigation projects and take interviews from involved stakeholders after doing a two month literature study from the Netherlands.

This report consists of a general introduction on the arsenic issue and the need for this study. This is followed by an analysis of the stakeholders involved. After the stakeholder analysis our field observations will be discussed. Based on these field observations, the conducted interviews and literature studies, different arsenic mitigation projects are then elaborated upon and compared in a multi criteria analysis.

Transcripts of the interviews and questionnaires conducted can be found in the appendices.

Since solving the arsenic issue in Bihar is not a feat that a single stakeholder can achieve, the advice from this report is directed to all involved organizations.

We would like to express our thanks to all the people we met in connection with the making of this report for the kind support and valuable information received.

We would like to especially thank Dr. Ashok K. Ghosh for providing us with invaluable information and accommodation during our stay in Patna, Dr. Rajeev Kumar for his guidance during the field trips, Dr. Nurpur Bose for her knowledge about the social aspects regarding arsenic mitigation projects and Dr. Otto Kroesen for granting us the possibility to participate in this research.

Patna, February 2013

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1. Introduction

India has suffered, both in the past and present, from problems regarding drinking water. The three major sources of drinking water in India are surface water, rainwater and groundwater. Up until around 1970, most inhabitants of rural India used surface water for their needs since surface water is abundant in all regions of India.

A large problem regarding the use of surface water is bacterial and viral contamination. These provided a major health hazard and diseases such as cholera and diarrhoea were very common. Therefore, around 1970 (UNICEF, 2011), NGO's and international development agencies such as UNICEF started promoting the use of ground water for rural India. Ground water was a safer alternative to surface water since it always provided fresh water without bacterial and or viral contamination. Nowadays, most households in rural India have a privately owned tube well or have direct access to a government owned tube well.

Several years after these tube wells had been installed, a portion of the population started developing skin diseases such as black and/or white spots. These skin diseases turned out to be caused by arsenic contamination in a part of the shallow aquifers in India. The main affected regions are Bihar and West Bengal. Other affected areas around the world are Bangladesh, parts of China, Mongolia, Nepal, Cambodia, Myanmar, Afghanistan, Korea and Pakistan (Amitava Mukherjee, 2006).

Since its discovery, much research has been done on the subject of arsenic and how to provide arsenic free drinking water to rural areas. Based on this research, many arsenic filter techniques have been developed and implemented. However, many of these filters have not been successful in providing safe water to everyone who needed it. Many problems arose regarding the awareness of the affected communities, maintenance of the filter installation and the power required for providing the filtered water.

This research will focus on the social and economic factors that have influenced the successes and failures of different arsenic mitigation projects and will provide a strategy on how to handle the arsenic issue in the upcoming years.

The main goal of this research is:

To provide further insight in the successes and failures of different arsenic mitigation techniques and provide a strategy for handling the arsenic issue in the upcoming years.

This will be done by evaluating different arsenic mitigation projects in the Bihar districts of Bhojpur, Bhagalpur, Maner and Vaishali. For evaluating these projects interviews will be conducted with villagers, NGO's and different government parties.

By doing this research we hope to contribute to assessing the arsenic issue and put it on the agenda. On the long term, we hope this research will contribute to the arsenic awareness of rural India, Governments and international aid agencies.

2. Arsenic contamination in Bihar

This section gives general information about arsenic problems and water usage in India. First the historical water usage in India will be elaborated, then general information about the presence of arsenic and its health effects will be discussed. Lastly the differences between Bihar and other arsenic affected regions in the world will be elaborated.

2.1 Water usage in India

The Republic of India has always had a huge problem with getting clean water for safe and clean drinking water supply. Because of the industrialization the demand for water has increased, especially in Tamil Nadu and Karnataka in South-India. Other areas with lot of water shortages are Punjab, Haryana and Rajasthan all located in the northern part of India (Cullet & Gupta, 2009).

India has three types of water resources: surface water, rainwater and groundwater. In the first place, the surface water was the most obvious resource. Rivers like Ganga in the north and Krishna in the south seems to be the good sources for drinking water. However, due to lots of industrialization and other sources of pollution throughout India, many problems appeared. Beside the rivers, sources like ponds, small rivers and dug wells used to cause many diseases and epidemics, such as cholera and diarrhoea. These water sources were and continue to be, contaminated with lots of bacteria.

Besides surface water, some parts of India used rainwater. Rainwater can be used for drinking purposes only during the annual rainfall. However, during the Monsoon season, (May-August) melting water from the Himalayas in the north can be used. Rainwater harvesting was mostly done in regions that suffered from surface water shortages during the dry seasons. Since Bihar does not suffer from these shortages, rainwater harvesting systems have not been used here much. However, southern parts of India are using rainwater for drinking purposes with great success.

Beside these two drinking water resources, there is only one alternative left: use of groundwater. Many fresh water aquifers are easily available in India's surface. Since ground water provides water that is safe from bacterial contamination, many (international) organizations and the community welcomed this new alternative. From 1970 water that comes from the tube well was the important and new water resources that are also bacteria-free. By the time of partition of India and Pakistan in 1947, there were around 50000 tube wells available in Bangladesh. So this technology is not a new one.

International organizations like UNICEF and the World Bank started constructing tube wells to serve the community for their need of daily drinking water. After many years, government organisations like the Public Health Engineering Department (PHED) and Western organizations installed many hand pumps in almost every part of the country.

2.2 Presence of arsenic

Unfortunately, this solution proved to have a devastating impact on public health. Many hand pumps were and continue to be, contaminated with arsenic, poisoning millions of Indians especially in the areas along the Ganga River.

In the eighties and nineties scientist detected presence of arsenic in ground and groundwater, this contaminates the hand pumps. Seven states namely West Bengal, Jharkhand, Bihar, Uttar Pradesh, in the flood plain of the Ganga River is contaminated by arsenic (Chatterjee & Das, 1995). Assam, Chhattisgarh and Manipur in the flood plain of the Brahamaputra and Imphal rivers have so far been reported affected by arsenic contamination in ground and groundwater, above the permissible limit of 0.01 mg/l. the permissible limit is a guideline set up by the World Health Organization (WHO) (Howard, 2003).

If we talk about Bihar, where arsenic in the groundwater was first reported in Bhojpur in 2002, after many years the authorities recognize this problem and take responsibility for it (Ghosh A. , 2010). They are reporting contaminated hand pumps. Hand pumps, which are contaminated by arsenic above the permissible limit of 0.01 mg/l, were painted red, indicating that the hand pump is unsafe to use, regarding arsenic. Hand pumps, which are contaminated by arsenic, but under the permissible limit of 0.01 mg/l, were painted green. That indicates that the water source is safe to use.

Bihar is one of the worst affected areas regarding arsenic in India. Affected patients have never been registered as arsenic patients. In addition, there is also not a cure, or hospital that is specialized regarding arsenic. The nearest hospital that can help the arsenic patients is located in Kolkata. For the most people in rural India, they are not able to travel to Kolkata due to lack of knowledge about arsenic, and money to travel to Kolkata. A map of arsenic presence in Bihar can be found in Figure 2-1.

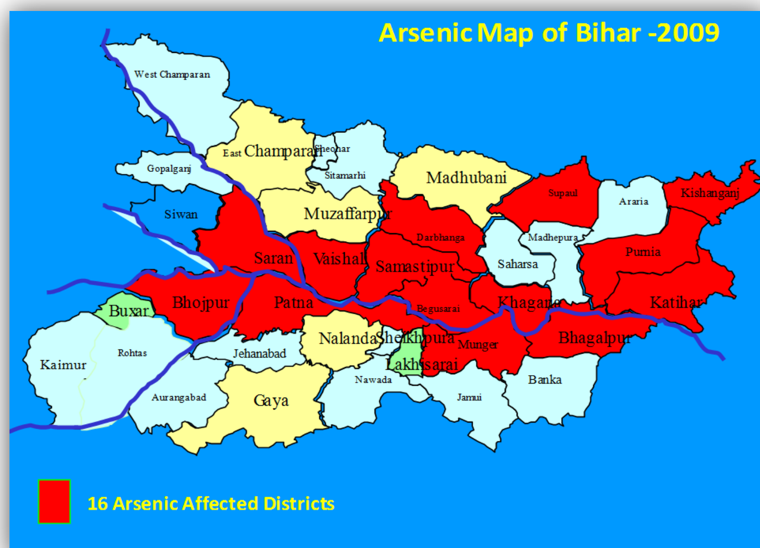

Figure 2-1: Arsenic presence in Bihar (Ghosh A. , 2011)

2.3 Health effects of arsenic exposure

It took many years to know that arsenic is a toxic for human-being and animals. Nevertheless, it has been used for several thousand years. Arsenic in drinking water at 60 mg/l or more will kill immediately. The limit of 0.01 mg/l was set primarily to be sure to avoid these acute toxic effects. As mentioned earlier, the permissible limit is set by the WHO at 0.01 mg/l. Some countries which suffer from arsenicosis raised their limit to 0,05mg/l. Bangladesh is one of the country that raised the limit, because they have no mitigations options for arsenic.

Long-term exposure to high levels of arsenic in drinking water may cause dermatological consequences, like black spots, thickening and discoloration of the skin, numbness in the hands and feet, black-foot diseases, keratosis, but also mental diseases like depression, decreasing of production of blood cells, abnormal heart rhythm and digestive diseases. In addition, liver, kidney, lung and skin cancer may also be found sooner or later, depends on how long someone is exposed to arsenic. Generally it takes 20 to 30 years to have cancer, with a concentration of 500 ppb (parts per billion) (Abernathy, Liu, & Longfellow, 1999).

Skin manifestations are commonly observed. There are 4 kinds of stages: preclinical, clinical, complications and malignancy.

The first stage starts at the moment when people begin taking contaminated water. The body tissues start to show higher arsenic concentrations, but no skin diseases can now be observed. The second stage, various effects on the skin, such as hyperpigmentation and keratosis can now be observed a little. It takes at least 5 to 10 years until manifestation of this stage. Complications occur after the second phase. Different complications beside skin are now affected like lungs, eyes, liver and kidney.

At the last phase cancer affect skin or other organs in the body. Sometimes self-amputations occur in limbs. Death will probably follow after all.

Figure 2-2: Keratosis (left, middle) & Melanosis (right)

2.4 Bihar in relation to other arsenic affected areas

There are many regions in the world affected by arsenic. In this section the differences between Bihar and other affected regions will be uncovered, in order to provide explanations for certain mitigation technologies working in some parts of the world, but not in Bihar.

2.4.1 Water availability

In the previous paragraph, we mentioned that Bihar has 3 types of water resources: rainwater, surface water and groundwater (Kumar & Singh, 2005).

The average annual rainfall in Bihar is 1200mm. Therefore, especially during the Monsoon period, there is no water shortage. This water might be used for drinking purposes after treatment by, for example, using chlorine or boiling the water.

The second water resource is surface water. The Ganga River flows downstream from the Himalaya to the Bay of Bengal. This river divides Bihar into south and north. Although the WHO and UNICEF told to the people not to make use of surface water due to bacterial contamination, surface water is a great source for drinking water. Just like rainwater, it requires treatment before use.

The third source for drinking purpose is groundwater. After people have been told not to drink surface water untreated, people switch their water sources to groundwater. Unfortunately, groundwater in Bihar is affected by arsenic, fluoride of iron.

Compared to other areas in India, South-India in particular, Bihar has no water shortage. In South-India, people also make use of surface water and, if available, they might use groundwater. During the summer season the temperature can raise up to 40 degrees and little rain is forecasted. The rivers and many other surface water sources are getting dryer. In that situation, people are forced to make use of groundwater. In the recent years, farmers get subsidies for power supply to pump up the water from the ground. Because of the enormous use of groundwater, groundwater levels in most of India are decreasing rapidly. Bihar seems excluded from this problem so far.

Seeing all these problems, storage of water could be a better option. Rainwater harvesting is a common method used in southern part of India, like Tamil Nadu and Andhra Pradesh. Rainwater harvesting is storage of rainwater before it can reach the (deeper) aquifer. For example, sloping roofs can catch up the rain before it reaches the ground. Same as surface water, rainwater can also be used for all kind of purposes and it requires treatment before drinking use.

Since Bihar does not cope with water shortages, people have not found it necessary to invest in water harvesting solutions. Also, people have never dealt with water issues before since water has always been abundant. They therefore see it as a gift of god and are mostly not willing to pay for their drinking water.

2.4.2 Caste system

The caste system had officially been abolished in 1949. For more than 2500 years, this phenomenon still plays a big role in the daily lives and it can be experienced in the field of marriages, job-hunting and especially in rural areas.

In the state Bihar with over 80 million inhabitants, an unknown number of people suffer from social exclusion and severe poverty as a result of their origin from a lower caste. Especially the lowest caste, the 'untouchables', suffer the most (Gupta, 2001).

Bihar belongs to one of the poorest and least developed states of Bihar, both economically and socially. Even though the economy in Patna region has grown in the past few years, farmers benefit very little from it. Bihar also stagnates in the field of education. Around 55% of the children in the countryside get education (Population Census India, 2011).

Media sometimes show that Dalit (untouchables) are excluded from water sources as they are meant for people from a higher caste. An article in the Belgian newspaper shows that an 'untouchable' unsuspectingly took a drink of water from a source that is only meant for the higher caste. As a result, he got punished unmercifully and abused for this offense and ended up severely wounded.

This is only one of a range of examples that shows violence against the lowest caste. Compared with a country like Bangladesh, the caste issue does not play a role there. The reason is because they are predominantly Muslim. Other parts of India, such as state West-Bengal, the caste system played a big role. Due to community awareness created by NGO and foreign organizations, villagers gradually accept the 'untouchables'. This is however a long process, as the caste system has not yet disappeared in people's lives.

Next to the limited media attention in both foreign countries as well as India, we have experienced the great caste problem ourselves. Villagers with a better living standards (can be seen on the outside: clothing, land pieces and the condition of their house) have a filter installation near the house. Villagers with lower living standards complain about the fact that they have no access to arsenic-free water.

Compared to West-Bengal, no awareness is built among the people. Even though the caste system does not exist anymore (officially), it is hard to convince these people not to focus on the caste issue as they live in a discriminating and religious environment. This is a result of lack of community participation and awareness.

From our experience with the Indians (from a higher caste) that we have spoken with during our trips in the bigger cities such as Bhagalpur, Patna and Kolkata, we have learned that they find the caste issue is no longer a problem. However, when it comes to religion, respect and status they will eventually choose and support their own caste and drop the lower castes. They even do not take the initiative to banish the caste system.

2.4.3 Education

The education rate in Bihar is one of the lowest in India. The total literacy rate is around 63%. Overall male and female literacy rate is 72% and 53% respectively. Total rural literacy rate in this state is approximately 44% (Population Census India, 2011).

In comparison with Uttar Pradesh, another state that suffers from the consequences of arsenic, the literacy rate is a bit higher than Bihar. The total literacy rate is around 70% as per 2011 population census. Overall male and female literacy is 79% and 60%.

The literacy rate in West-Bengal are higher than in UP and Bihar. The rate is 77% and is above the national average of 74%.

By intensive literature research and our field observations, people in the rural area of West-Bengal are more aware of arsenic, fluoride and iron in drinking water. Different arsenic removal technologies have been successfully implemented.

We also compare India with other (developing) countries where arsenic is present: People's Republic of China and Bangladesh.

Country	Total literacy rate
P.R. China	96%
India	74%
Rural Bihar	44%
Bangladesh	54%

Table 2-1: Literacy in Arsenic affected regions

People in China, Bangladesh and India are all suffering from the consequences of arsenic. The problems are greatest in India and Bangladesh. The mitigation of arsenic contamination in China has been more or less completed. This can be due to the high literacy rate (so better awareness) and good management regarding arsenic in drinking water. Problems in Bangladesh are still present, despite the work that has been done by many NGO's.

3. Problem description

Presence of arsenic in ground and groundwater has been discovered in many countries: Canada, japan, USA, China, Hungary, Chile, New Zealand, Mongolia and in Bangladesh. Measures to remove the arsenic of drinking water supply are generally known. The mitigation of arsenic contamination in the previous listed countries has been more or less completed, except for Bangladesh. Even in the Netherlands arsenic is present. Arsenic in Holland is found in the Schelde Estuary, in the south-western part of Holland.

Even though arsenic contamination in groundwater has been detected in many countries, still little is known about the underlying processes behind the contamination. With the fact that the processes behind the contamination are unknown, each water resource from groundwater might be contaminated in the future.

In the Ganga delta, where Bihar is situated, arsenic has been transferred through natural geological processes over thousands of years. Up until now and as earlier mentioned, the main reason for the presence of arsenic in groundwater is still being hypothesized. In a report from the BGS (British Geological Survey) says: ‘an unfortunate combination of three factors: a source of arsenic that is present in the aquifer sediments, arsenic is released from the sediments to groundwater and arsenic is flushed away in the natural groundwater.

Generally five directions of arsenic mitigation can be observed: treatment of arsenic contaminated water, installing deep Tube wells, surface water treatment (in India Ganga River or dug wells) and rainwater harvesting. Cultural, economic, geographic and many other differences between regions and communities within India have made the assessment of strategies difficult.

For our research, we will focus us on Bihar, a state in northeast India. The northern part is divided by the southern part of Bihar through the Ganga River. However, parts are affected.

The extent of the arsenic problem seems to be huge in India. In Bihar, 22 districts out of 38, Tube wells have been found providing drinking water, in some worse than in others, that contains arsenic above the permissible limit. For a while, Bihar has raised the permissible limit for arsenic at 0.05 mg/l. The WHO changed their limit a few years later back to 0.01 mg/l. In the time that the limit was raised to 0.05 mg/l, serious diseases appear.

Around 28000 hand pumps have been tested so far in Bihar. Almost 27% of these tested hand pumps had arsenic contaminated water: above the permissible limit of 0.01 mg/l. it is hard to say how many people are suffering from arsenicosis. Only a small amount of the potential patients has been diagnosed. Thus, it could also be possible that thousands of Bihari already died due to arsenic. Though, their actual death cause will never be uncovered. More research to the total number of fatalities is necessary.

The highest value that has been reported so far is around 1.9 mg/l. This value is found by A.N. College Patna, in the Bhojpur district, one of the worst affected areas in Bihar. Other worst affected areas are: Bhagalpur, Buxar, Vaishali, Rural Patna, Samastipur and Munger.

Since arsenic has been discovered, the Public Health and Engineering Department (PHED) tried to tackle this problem by constructing many hand pumps with arsenic, fluoride and iron filters. Later they realize that these small arsenic removal units are hard to maintain, so they try to install (mini) water supply scheme, which provides water for more than 1 household. Sometimes it can provide water for an entire village, depending on storage capacity.

It is clear that safe drinking water and hygiene environment are essential for the welfare of all human life and development. Due to lack of above, many water related illnesses are prevalent in villages and affecting the rural population. Though the (state) government has planned and executed many water supply schemes, spending huge amount of Rupees in providing safe drinking water to the community in rural Bihar. Despite huge investments made on water supply, many schemes are non-functional due to improper operation and maintenance of the system. Sometimes it is clear that corruption plays a role for not providing clean drinking water. The community, which did not own the system, felt that the government should be responsible and hence their sustainability became a big issue. In Bihar, apart from the piped water supply schemes, many schemes are designed and under construction under the mitigation programme of in the arsenic, iron and fluoride affected areas to undertake the challenge of providing clean drinking water to the community in rural India. Since arsenic, fluoride and iron has been discovered in Bihar, the next challenge is their operation and maintenance, to make it cost effective and sustainable.

4. Research methodology

In the previous paragraph we have shown the problem definition, which will be used to describe our main goal in our research in order to deal with the problem. As a result of the problem definition, a general question is stated in this paragraph.

This research will focus on the social and economic factors that have influenced the successes and failures of different arsenic mitigation projects and will provide a strategy on how to handle the arsenic issue in the upcoming years.

The main goal of this research is:

To provide further insight in the successes and failures of different arsenic mitigation techniques and provide a strategy for handling the arsenic issue in the upcoming years.

This will be done by evaluating different arsenic mitigation projects in the Bihar districts of Bhojpur, Bhagalpur, Patna, Buxar and Vaishali. For evaluating these projects, interviews will be conducted with villagers, NGO's and different government parties.

Because this research question has a general character, we divide it into several more sub-questions. Using these sub-questions, we try to provide more specific information on our main goal of this research. The sub-questions are as follows:

- Which parties are involved and rate their involvement;
- Which measures are promising to mitigate the effects of the arsenic poisoning;
- Have these measures already been implemented;
- If there are some measures implemented, in what way was the local community involved;
- Are there any on-going projects, if yes, rate the successes and failures of these projects;
- Which factors were decisive for the successes and failures for the mitigation measures and the on-going projects regarding arsenic;
- What are the main differences between Bihar and any other areas in the world regarding arsenic in groundwater;
- What are the important features of the named measures, considering costs, sustainability (long –and short term), willingness of the local community and socio-cultural and social-economic effects;
- Are there decisive factors for successes and failures of (on-going) projects in Bihar and in general for India where arsenic is present in groundwater;
- What are the possibilities to make both a short –and long-term strategy assessment for a successful implementation of measures with the support, coordination and collaboration of the local community in order to mitigate the adverse effects of the arsenic contamination of groundwater in Bihar?

This research will be restricted to the rural area of Bihar and will focus on necessary conditions for implementation of measures in the future, both in long-term and short-term. The cause and the effects of arsenic contamination will not be the main issue in this particular research. It will focus on all parties, which are involved, that will work on options for save drinking water supply in rural Bihar. If necessary, we will make some comparisons with other areas those are affected by arsenic.

As mentioned earlier, research to the cause and effects of arsenic contamination and develop a sustainable mitigation techniques will not be the main goal of this research. Nevertheless, lots of literature studies are required to understand the problem of the different solutions.

Through interviews, we try to have a complete overview of actors who are involved in the issue regarding arsenic. The most important actors to meet are the villagers, state level government, non-governmental organizations and research institution.

With the use of involved actors in the context of the arsenic issue, several development projects are determined. The selected pilot projects are thoroughly investigated in order to reveal the critical points of those projects on the different levels. It might engage an investigation of coordination, within and between several higher and lower level actors, the capability, efficiency and effectiveness of these actors. It is very important to have a thorough understanding of the structure, processes and relations across the different levels of the actors.

In addition, the mitigation measures, which are available are/will, be identified within the different projects, in order to investigate the stages of participation and awareness of the local community. According to the strengths and weaknesses of the different mitigation measures, we will suggest, in our opinion, the best solution considering the socio-economic conditions of Bihar. This strategy will be addressed to the grassroots level and might be a useful guideline for organizations involved in arsenic, present in the field.

5. Actor analysis

In order to get a complete image on the arsenic issue, and to give recommendations on the direction that should be headed, it is vital to correctly assess all the actors involved in the arsenic issue. No solution can be successful unless there is support from several parties, such as governments and in particular the local community.

The following actors have been identified:

1. Villagers
2. Teachers & Central Board for Secondary Education (CBSE)
3. Researchers
4. Local hospitals & rural doctors
5. World Bank
6. UNICEF
7. Village Government (Gram Panchayat)
8. Public Health and Engineering Department (PHED)
9. Department for International Development (DFID)
10. Local contractors

5.1 Actor description

In the following sections, each of the above identified actors will be described and elaborated. Firstly their needs and interests will be defined and their main resources regarding arsenic will be analysed. Lastly based upon their interests and resources, the importance of each actor will be determined.

5.1.1 Villagers

The villages of the Bihar state are by far the most important actors in the arsenic issue. Before around 1970 most villagers in rural Bihar used surface water as their main water source. Since surface water is often contaminated with viruses and bacteria, development organizations such as the WHO and UNICEF started recommending other water sources, such as tube wells.

Rural villages quickly adopted these tube wells as their main water source since they provided a clean and tasty alternative to the previously used surface waters.

The main interests of rural villagers in Bihar regarding arsenic are to have a clean, tasty and simple to use water source. This water source cannot be very far away from their homes, since the women, who provide the water, cannot leave their homes unattended for extended periods of time. Many observations, literature studies and interviews made clear that the position of the woman seems essential in this regard. It is her who plays a central role in household’s water management. This has, as earlier mentioned, implications for both location of drinking water source and the distance between place of collection and consumption.

The (large) distance seems to be problematic. Women have a busy schedule: cooking, cleaning, to take care of the children, animal feeding are just a few of their daily task. The walk to a nearby, often contaminated water source, can save a lot of time. This is either the case for a woman with lacking physical abilities, which is very common in India.

Furthermore, Indian villagers are used to water being free. It is seen as a government responsibility to provide clean water for free. This means that the arsenic-free source should be free or very cheap. We can conclude that almost every villager we have spoken with lack a sense of (community) responsibility. It is observed that operation and maintenance of several arsenic mitigation systems are rather poor. On one hand this can be subscribed due to lack of education or lack of awareness. In areas where organizations built awareness and provide safe water sources (Project Well/AWS, West-Bengal), community participation in general seems to be better.

On the other hand, it is observed that relatively few villagers are willing to take the initial step towards rural development and in particular arsenic mitigation. Structural lack of financial resources and education made the inhabitants of Bihar in general learn how to stand up for their selves and even to give individual interest higher priorities. People are hardly willing to contribute in tackling several development problems: it is either too much capital intensive or too much labour intensive.

Villagers can also sabotage arsenic mitigation facilities. On one of our field trips we spoke with a family that has had access to filtered water that was piped from a major drinking water plant in Bahrar. This connection has been destroyed however by villagers of nearby, oppressing communities. (Sing & Singh, 2012)

5.1.2 Religious institutions

Religious institutions can play an important part in raising awareness on the health effects of arsenic and the need of mitigation technologies. The major religions in Bihar are Hinduism and the Islam.

Religious institutions can also prevent mitigation technologies from succeeding. The caste system for example, makes it very difficult to implement solutions for entire communities. The caste system is built out of 5 layers. Especially the 5^{th} and lowest layer cannot use public water sources, since the water source will then be considered contaminated by members of higher castes. Since Hinduism is the largest religion in Bihar the caste system is still very topical. (Gupta, 2001)

Muslims are a minority in India. On almost every field they are behind Hindu Indians. Muslims are treated similarly as the lowest caste Hindu's and providing clean water for them can therefore also be problematic. However, Muslims usually live in more isolated groups and therefore have fewer problems regarding community based solutions than Hindu's.

It is clear that religious institutions provide both possibilities and problems regarding arsenic mitigation and are therefore a very important actor.

In an interview with a supervisor of the Bakhorapur temple in Bhojpur, it became clear that he is very aware of the arsenic issue in his block. He did not however, feels it to be the temple's responsibility to educate the villagers regarding arsenic or to provide possibilities for mitigation, also because there are not any funds available for doing this (Singh K. K., 2012).

5.1.3 Teachers & Central Board of Secondary Education

Although school attendance in rural Bihar is the lowest in the country, still more than 50% of the children attend school on a daily basis (ASER Centre, 2012). This makes incredibly powerful in building awareness regarding arsenic and safe drinking water in general.

Teachers do not seem to be especially aware of arsenic or the possibilities for mitigation. Many are not able to tell the effects of arsenic and the need for mitigation.

Most schools follow the educational program as set by the Central Board of Secondary Education (CBSE) (CBSE, 2012). Currently, the CBSE has no material regarding arsenic and therefore it is not taught in schools in rural Bihar. Requests for integrating arsenic in the educational program have been done by the Department for International Development (DFID) to the regional office of the CBSE in Patna. However, changing the educational program is a long and slow process and no progress has been made in this field so far (Kumar P. , 2012).

5.1.4 Researchers

There is a lot of research going on about arsenic around the world. A.N. College Patna for example is working on bioremediation, Lehigh university in Germany has recently installed a reverse osmosis filter in Maner, Berkeley University USA is working on new absorption materials such as zirconium and Delft University of Technology in the Netherlands is trying to predict underground arsenic flows using mathematical modelling and geographical information systems (GIS) software.

All this research is critical in order to provide long term, arsenic-free water since there are still a lot of knowledge gaps regarding the mitigation of arsenic.

The main knowledge gaps regarding arsenic currently are regarding:

- The presence of arsenic in surface water
- The long term safety of deep aquifers
- The saturation rate of absorption filter media
- The most viable filter media
- The correct disposal of backwash, sludge and saturated filter media

Most universities and research institutions do not see themselves as organizations that should be actively involved in arsenic mitigation projects (Ghosh A. K., 2012). Universities do not get financed for this type of work and their main goal should be research. However, professor Choudhary of Bhagalpur University thinks that universities should be actively involved in checking arsenic mitigation projects and making villagers aware of arsenic issues.

He pleaded that there should a lot of small scaled mitigation technologies installed. These technologies implementation need some time. In the meantime the PHED should tell the villagers after they pumped up their water to wait and let the arsenic oxidize and thereafter drink it. At the assumption the people do not drink the water due to the coloration by iron; he responded they would drink it because they are aware enough of the arsenic problem (Choudhary, 2012).

5.1.5 Local hospitals & rural doctors

In the state of Bihar there are no hospitals that specialize in the treatment of arsenicosis. Furthermore, many of the local doctors in the rural areas are not able to diagnose arsenic related issues or treat them properly (Ghosh A. K., 2012). Educating rural medics on the effects and treatment of arsenic could mean a significant decrease in the health effects of the rural population since simple nutritional improvements such as eating garlic (Chowdhury, Dutta, Chaudhuri, & Sharma, 2008) can drastically decrease the effects of arsenic on the human body.

Therefore local hospitals and doctors are a very critical actor in dealing with arsenic.

5.1.6 World Bank

The World Bank is an international development organization that provides loans to developing countries. The main goal of the World Bank is to reduce poverty. Since around 2000, the World Bank has spent about $45 million on arsenic mitigation projects in Bangladesh (World Bank, 2013). However, the World Bank is currently not active on arsenic mitigation in Bihar. Involving the World Bank could provide the state government with more funds in dealing with the arsenic issue.

5.1.7 UNICEF

UNICEF is an organization that is a part of the United Nations. UNICEF focuses mainly on child welfare.

UNICEF is one of the organizations that were actively involved during the 1970's to make the transition from surface water to groundwater (UNICEF, 2011). After the discovery of arsenic in the tube well water, UNICEF responded by constructing sanitary wells and rainwater harvesting systems. During our field trips we have found all of these systems to be currently defunct due to various reasons.

Currently, UNICEF works as a knowledge partner and financer for the Public Health and Engineering Department of Bihar (Santdasani, 2012).

5.1.8 Gram Panchayat

The Gram Panchayats are local self-governments on the village level in rural India. The main responsibilities of the Gram Panchayat are to provide services to the village like roads, education, sanitation and drinking water.

In order for an arsenic mitigation project to be started in a village, permission and cooperation of the local Gram Panchayat is critical and required.

5.1.9 Public Health and Engineering Department (PHED)

The Public Health and Engineering Department (PHED) is a state government organization that is responsible for providing safe drinking water to rural areas. The main goals of the PHED are: (PHED, 2012)

- Ensuring the supply of drinking water to rural areas and the development of sanitation facilities
- Constant monitoring of quality of drinking water supply
- Ensuring participation of communities in schemes involving drinking water supply and sanitation
- Reforming water supply and sanitation sector

Over the last years, the PHED has installed a lot of different arsenic mitigation projects. Many of these projects have currently become defunct due to various reasons that will be discussed in the "Field Observations" section.

Currently, the PHED is focussing on two different mitigation technologies. These are multi village surface water supply schemes using pipes and for regions where surface water is not available small solar panel based absorption filters. However, the PHED feels that this last solution is not maintainable for the future and therefore they focus on big water treatment plants with household connections. The building of these large scale plants however, is a very time intensive process (Singh E. , 2012).

Based on interviews with other organizations and the conducted field work, we have found that the PHED is mainly focussing on the engineering point of view regarding arsenic mitigation. (Santdasani, 2012) (Singh E. , 2012) (Ghosh A. K., 2012) (Kumar P. , 2012)However, since a lot of problems originate from social aspects, we believe that more attention for the social aspects from the PHED would help in overcoming a lot of problems regarding mitigation projects.

5.1.10 Department for International Development (DFID)

The Department for International Development (DFID) is a department of the United Kingdom Government. The goal of the DFID is "to promote sustainable development and eliminate world poverty. The main areas of work are Education, Health, Social Services, Water Supply and Sanitation, Government and Civil Society, Economic, Environment Protection, Research, and Humanitarian Assistance (Department for International Development, 2013).

The DFID is represented in Bihar by the Bihar Technical Assistance Support Team (BTAST). This team is in close contact with the Department of Health and Family Welfare, the Department of Social Welfare and the Public Health and Engineering Department along with other Governmental organizations of Bihar. Regarding arsenic mitigation, The DFID acts as a knowledge partner to the PHED and they do pilot projects regarding arsenic awareness (Kumar P. , 2012).

5.1.11 Local contractors

Implementing the arsenic mitigation projects is not done by the Public Health and Engineering Department themselves. Instead, they hire local contractors to build and maintain the mitigation structures.

Some of these local contractors are DNA Infrastructures, WaterLife, BluePlanet and Mahesh. In the past there have been troubles regarding these local contractors. These are mostly due to, what in political science is referred to as, the principal-agent problem. This dilemma concerns the difficulty of motivating the agent, in this case the local contractors, to carry out what is in the best interests of the principal, the PHED, instead of their own (Grossman & Har, 1983).

5.2 Formal mapping

To provide a clear overview of the actor field, a map has been created of all involved actors and the formal relations between them.

In this map, actors are depicted using a stick figure. Actors that are part of the same paternal organization are grouped in boxes and relations are depicted using one or two sided arrows with text explaining the essence of the relation between the actors. The map can be found in image Figure 5-1: Formal Map

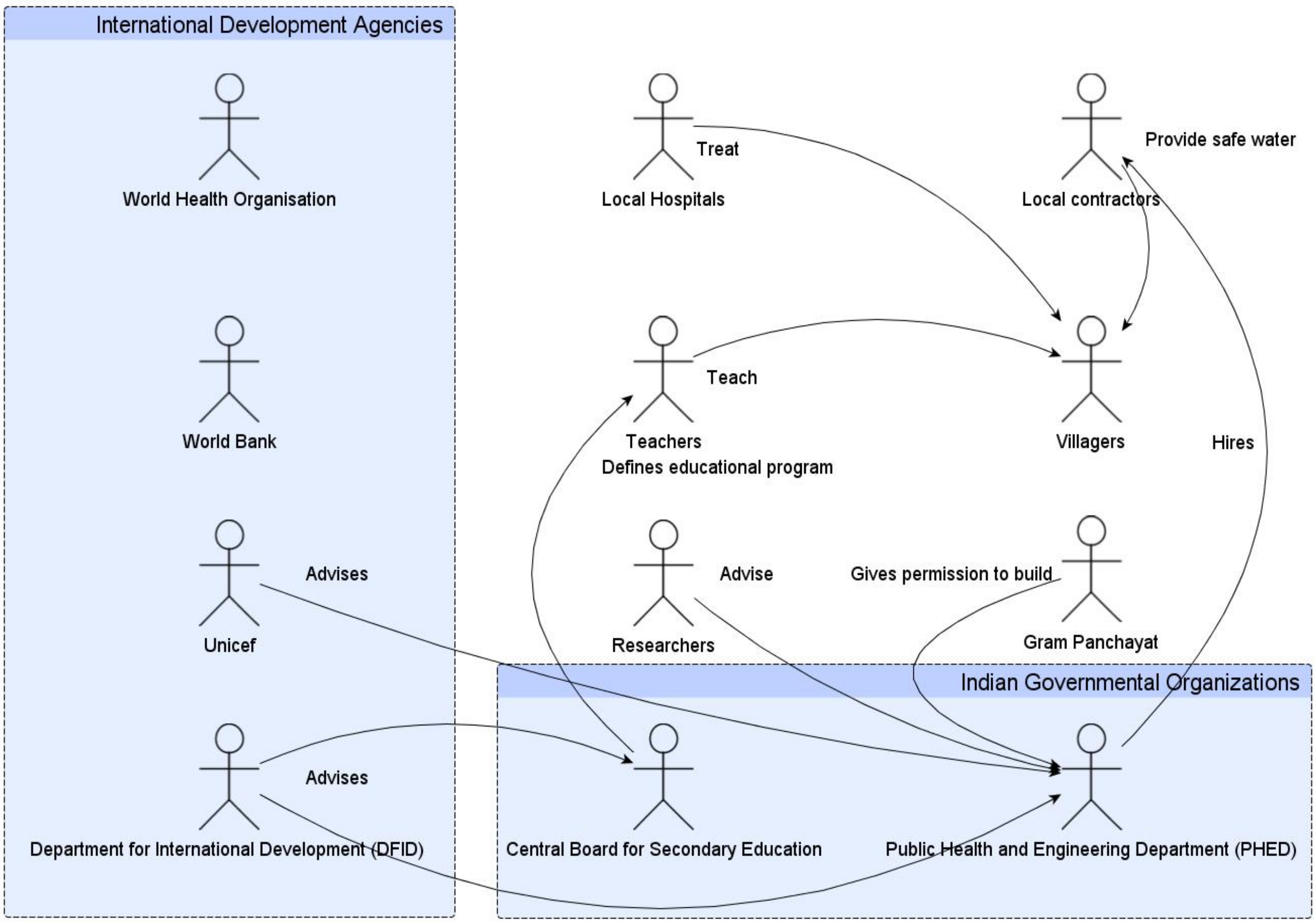

Figure 5-1: Formal Map

6. Field observations

Besides the technical studies on the different arsenic mitigation systems, the socioeconomic conditions regarding the arsenic issue have also been studied. This can be regarded as a very important issue when implementing an arsenic removal system in a rural village, because of the uselessness of installing any mitigation unit when nobody is able or willing to use or maintain it.

Hardly any projects on arsenic have been completed in the past and even fewer projects are on-going nowadays. This chapter about field observation reflects the results of visits to 6 project areas: Patna, Bhojpur, Buxar, Vaishali, Bhagalpur and West-Bengal. A selection of projects had been made, mainly extended to one block, according to several phases of arsenic mitigation and the applied methods of mitigation.

The results of these visits will be presented in this chapter and they are based on interviews with local villagers. We have tried to select the respondents from various social layers to gather information about their lifestyle. Some very interesting facts occurred during the interviews with the villagers. The questionnaires we used and a summary of the conducted interviews are enclosed in appendix A.

6.1 Bhojpur

Bhojpur district is situated on the west side of Patna. According to the 2011 census, Bhojpur district has a population of around 2.8 million inhabitants. (Population Census India, 2011)

Our field trip has only covered the Barhara block, which has more than 170000 inhabitants. During our literature study in The Netherlands regarding awareness of arsenic in rural Bihar, we have concluded that almost everyone knows what kind of adverse effects arsenic may result in.

What we have seen during the field trip in this area, we can conclude that knowledge regarding arsenic in groundwater and arsenic removal systems depends on the area, concentration found in a particular area and the education rate.

Whether you are Hindu or Muslim, religion plays an important role in the daily life of every Indian. The involvement of a religious institution can be very important. If such an institution can convince the people to be more aware of drinking water and hygiene, the behaviour and attitude may change. Unfortunately, our hypothesis is not right for this particular area. The supervisor of the Hindu temple we have visited is very aware of this problem. However, he did not take any responsibility because he thinks that it is not his duty. Apart from that, the temple lacks funds and knowledge about the arsenic issue. Furthermore, he told us that almost everyone is aware of this problem, but they have no alternatives for safe drinking water.

When we visited the first family in the same block in the village of Sinha, we took water samples from the hand pump for testing in the lab. Those people did not know what arsenic is, and what adverse effects it may cause. Not far away, but in the same village, the second interview was taken. With the same education rate (metric) and almost the same monthly income (around 6000 Indian Rupees) as the previous family, this person has more knowledge about arsenic. This can be explained by the fact that because other people have shown him the adverse effects due to arsenic. After all, he still uses a tube well and he does not know if it is affected by arsenic or not.

The highest concentration of arsenic was found in an adjacent village called Sinha-Pandey Tola. With a concentration of 1861 ppb, people have been suffering from arsenicosis. Symptoms are visible on the body of the patients.

Lot of work has been done in this area. Awareness building by academic institutions such as A.N. College and Kolkata University has resulted in a positive effect. People know about the problems and the existence of remedial options.

PHED and UNICEF collaborated and worked on a solution. UNICEF installed rainwater harvesting which is non-active now, because it is not really accepted by the villagers as a water source and does not provide water during the dry periods of the year. Furthermore, UNICEF came once to this village to build awareness among the people.

Since a couple of years, PHED has provided drinking water from the Ganga River. That means that the drinking water is arsenic free. Two problems with this form of water supply are that water is always running out of the tap, therefore wasting water and that the water supply requires power. Power supply is also a big problem in India. During the day, the villagers experience several blackouts. However, they found a great solution. A villager constructed an open well nearby the village. If there is no power available, people may use his open well.

200 meters away from the last village, a family is living in the village of Chanda. One woman has been suffering from the consequences of arsenic. She was unfortunately not willing to show us her symptoms. Just as the previous village, the government has provided safe drinking water through pipe. However, other people from another village has broken or stolen the pipe. Now they will have to use the hand pump again, which may contain high concentration of arsenic. After the pipe was destroyed, no one of the PHED came to solve this community problem. In the previous village, where the highest concentration of arsenic was found, they excluded this family for using their water.

A water treatment plant was built in this district 2 years ago. It was a great complex with an installation that purifies water from the Ganga River. Natural surface water does not contain arsenic. However, factories upstream of the Ganga River dump arsenic in the river. Despite the fact that the river may contain arsenic, this treatment plant does however not filter arsenic.

The cost for this enormous water treatment plant was around 64 million Indian Rupees, and the maintenance costs around 10 million Rupees per year. PHED built this plant and will be responsible for only this plant in the future. Villagers have to pay around 10 Indian Rupees per month per family for the use of this water. Pictures of the plant and its distribution can be found in Figure 6-1.

Figure 6-1: Mozempur water supply plant (left) and distribution (right)

6.1.1 Bhojpur summary

Water sources

Functioning:

- Tube Wells
- Open Well
- Surface water (Water treatment plant)

Not functioning:

- Rainwater harvesting

Disputed water sources due to social difficulties/acceptance:

- Tube Wells
- Open Well
- Surface water
- Rainwater harvesting

Other important points

- Not everyone is aware of the arsenic issue due to lack of awareness building and low literacy rate;
- Social difficulties in the community (caste system);
- Villagers exclude other villagers to let them make use of their (arsenic free) water source;
- Both the government and the community do not take care of the social problems;
- Every family should be responsible for their own water source;
- There are no medical facilities for arsenic patients.

6.2 Maner

Patna district is situated in the southern bank of the Ganga River. According to the 2011 census, Patna district has more than 1.6 million inhabitants. Despite the state Bihar is one of the poorest of India, the city Patna is ranked the 5th fastest growing city in India. But it has yet some enormous hurdles to overcome (Population Census India, 2011).

Our field trip has only covered the rural area of Maner block, which has more than 200000 inhabitants.

Our purpose in this block is to see the arsenic removal system that has been installed by the Berkeley University USA (Figure 6-4). It is an iron adsorption filter that has been constructed in front of a house of a well-educated family. With that information, they were designated to be responsible for the maintenance. The maintenance only consists of backwashing the entire system. That mitigation system provides arsenic free water and everyone is allowed to tap water from it, according to the words of the caretaker. Afterwards, we heard from Dr. Nupur Bose that not everyone can make use of the tap. The main reason the caretaker gave was: 'what will happen if the system is destroyed or broken? Who should pay for that?'

Despite the awareness of this family regarding arsenic, they still exclude people from this water source. People who are excluded from the tap are children (because they lack the knowledge of how to use the filter) and villagers from a lower caste.

Another arsenic mitigation system, an aero-filter, was also installed in front of their house. The whole system is stored in a shelter, while the pump is connected with this system in front of their house. This system requires a skilled person who is not always present there.

Dr. Rajeev Kumar (2012) told us that the water sample he tested in July 2012 contains a high concentration (around 40ppb) of arsenic that exceeds the permissible limit. Now (December 2012, tested by A.N. College) the concentration of arsenic is 14 ppb. This could be a result of bad maintenance or failure in a part of the system.

Apart from those two removal system, we have visited an open well that is solar-panel based (Figure 6-2) and which is located approximately 500 meters further away in the same village. This open well requires power in order to operate. Actually, nobody knows how the system works. They only know if they need water, they have to press a button. This open well does not contain water in the dry periods.

If the solar panel is broken, no one knows how to repair this. Neither do they know what will happen if it is broken, because the PHED installed this and left without any information. Fortunately, if the solar panel breaks down they do have an alternative: they can always make use of their own hand pump. Despite the small distance to the above stated adsorption filter, they have no idea what arsenic is.

A few kilometres away from the visited village in this block, we interviewed random villagers to check what is known regarding arsenic in general. The main water source is an open well which is installed for the entire community.

The people we have interviewed know hardly anything about arsenic. Only a boy, student at the Patna University, Department of Geosciences, has heard about it. He knows some adverse effects due to arsenic but has no idea what kind of remedial option is available.

Then a woman, who did not join the interview, showed up and showed us her damaged skin. It can be caused by arsenic, but nobody knows exactly the cause. She drank water from another tube well from another village, which could contain arsenic. Due to lack of knowledge and awareness, no one can ensure what kind of disease this is and it seems that no one really cares about this problem.

6.2.1 Maner summary

Water sources

Functioning

- Tube Wells
- Open well
- Open well with solar panel
- Adsorption filter

Not functioning

- Aero-filter

Disputed water sources due to social difficulties/acceptance

- Adsorption filter

Other important points

- Not everyone is aware of the arsenic issue due to lack of awareness building and low literacy rate;
- Social difficulties in the community (caste system);
- Caretaker excludes people to let them make use of 'their' water source;
- Both the government and the community do not take care of the maintenance and the social problems;
- Many water sources are available for the entire community (tube wells, open wells)
- There are no medical facilities for arsenic patients;
- Even though distance to the Ganga river is short, the river is not used as a water source;
- Despite the adsorption filter, the concentration of arsenic is still too high.

Figure 6-4: LeHigh Adsorbtion filter

Figure 6-3: IIT Mumbai Iron filter

Figure 6-2: Solar based sanitary well

6.3 Vaishali

Vaishali district is situated on the north side of the capital of Bihar, Patna. According to the 2011 census, Vaishali district has a population of more than 3 million inhabitants. (Population Census India, 2011)

Our field trip has only covered the Hajipur block which is near the Ganga River and has more than 120000 inhabitants. According to the research that has been done by the A.N. College, Vaishali district is one of the worst affected regions in Bihar. The exact number of patients with arsenicosis is unknown. This can be explained by the fact that there are hardly any registrations of arsenic patients.

During our field trip, we have spoken with 3 people regarding arsenic: principal of a public school, an official-in-charge and a Mukhiya.

The first interview was conducted with a principal of a elementary public school, named Gyan Deep Public School (Block: Bidulpur, Village: Pakri). The only water source that this school has is an open well next to the schoolyard. According to the principal, the entire village can make use of it. But the reality is that only the surrounding families make use of the open well, because of the large distance. The principal is also the caretaker of the open well. He puts chlorine in the water once a month.

Beside the open well, the pupils do not make use of the open well quite often. The reason is that the pupils usually carry their own drinking water from home.

Another water source, a hand pump, was installed by UNICEF in 2006. Although the A.N. College found arsenic in 2004, UNICEF installed the hand pump without testing the water and without the use of any filters. Unfortunately, the hand pump is broken and it has never been repaired by any organizations.

It has to be said that after the water samples were tested by A.N. College, they never came back to provide the villagers and the school the results of the taken samples.

The school has not received much information about arsenic and thus there is a lack of knowledge and awareness. A meeting for awareness building has never been organized by organizations concerned or whatsoever. The school is willing to teach the pupils about arsenic, but the reality shows that the teachers have not enough knowledge about that issue. The guidelines for the courses that should be followed are composed by the CBSE (Central Board of Secondary Education). These guidelines do not oblige teachers to inform the pupils about sanitation and hygiene, so that is why there is no attention for this matter.

The next person we met was an official-in-charge at the department of Development Authority at village level. He is well-educated and has a government job. He knows about the arsenic problem in general and so does the entire village (block: Bidulpur, village: Chik Sikander). This entire village belongs to a higher caste (Kumar R. , 2012).

The main water source is a tube well, which has never been tested on the presence of arsenic. Certain villagers can afford to buy bottled water if they worry about arsenic in drinking water. They pay 25 rupees for a 20 litre bottle of treated water.

It is remarkable that he and/or the entire village know(s) about the arsenic issue in general. Only an unknown NGO came to tell them a little bit about arsenic, but after that, nothing has done against contaminated drinking water.

The next meeting was with a Mukhiya, also known as the head of the village. There is an adsorption filter present in his village; however it requires power that can only be activated through the solar panel. This arsenic removal system was constructed by DNA Infrastructure. They built it on a piece of ground which belongs to a villager named X. This villager however excludes other people to let them make use this water source. He did not say this honestly, but we were informed by the Mukhiya. That ground belongs to him, so does the filter installation, said the Mukhiya

PHED, responsible for providing sanitation and safe drinking water in rural areas, was informed about this problem during a meeting with the villagers. UNICEF attended this meeting as well and noted this problem, but they have never responded.

Eventually, the entire village is assigned to use their own tube well or a community open well as they are not given the permission to make use of the adsorption filter.

Figure 6-6: PHED Adsorption Filter Exterior (left) & Interior (right)

Figure 6-5: Surface water supply scheme under construction

6.3.1 Vaishali summary

Water sources

Functioning

- Family tube Wells
- Open well
- Adsorption filter
- Bottled water

Not functioning

- School tube well donated by UNICEF

Disputed water sources due to social difficulties

- Adsorption filter

Other important points

- Not everyone is aware of the arsenic issue due to lack of awareness. Even though A.N. College came to the village of Pakri and tested water samples, they never came back to present the results or built awareness;
- Social difficulties in the community (caste system);
- One family excludes the entire village to let them make use of ‘their’ adsorption filter;
- Government (PHED) and UNICEF are not interested in tackling the social problems. They are only focused on the technical part;
- Despite the lack of meetings regarding arsenic in the village Chik Sikander, the villagers know well about the problems regarding drinking water;
- Courses about hygiene and safe drinking water are never taught due to lack of knowledge in the school.

6.4 Buxar

Buxar district is situated on the west side of Bhojpur district. According to the 2011 census, Buxar district has a population of around 1.5 million inhabitants. (Population Census India, 2011)

Our field trip has only covered the Brahmpur block, which has around 110000 inhabitants. This entire district is known for the many visible symptoms of arsenicosis. It is a very poor district, which perhaps is related to the arsenicosis symptoms due to malnutrition.

The first village was near an important road through Buxar. We first met with a local reference of the PHED in Buxar. They guided us through the Brahmpur block.

This local guide of the PHED told that they have been providing safe water by working with a small water supply scheme. 5 villages in this block have already been adapted to these small schemes. Regarding these small units, he only says that the response from the villagers to maintain and operate is very low. This can be explained by the low literacy rate in this district (72%, below the national average).

In Jaunhi Jagdishpur village we saw the first tube well with an arsenic filter next to it (Figure 6-9). Unfortunately, this filter was demolished. According to the PHED, the water quality will be checked every 6 months. Community participation and skilled people are needed for maintenance and operation, of which both is lacking. Consequently the media of the filters are overused, which resulted in a higher concentration of arsenic in filtered water. There were no signs of arsenicosis, which was a positive observation.

The filter we saw was an iron filter, which was installed by IIT Mumbai, financed by DST, a government of India undertaking (Figure 6-8). This system only filters iron and it was based on iron nails. Unfortunately there was neither a maintainer nor an operator assigned and thus has this system left unsupported. This water that was supplied by the iron filter has a very bad odour/taste, so the villagers do not make use of this and they also do not see the use of maintaining it.

Not far away from the iron filter, we met the Mukhiya of this village. Within a few minutes, people who showed us serious symptoms due to arsenic surrounded us. Our PHED guide has never observed this in this village before. The guide said that a small water supply scheme will be constructed within a few months. This supply scheme will provide water through pipe.

The people who are suffering from the consequences of arsenic have never heard of arsenic before and it was the first time they were informed about it. We asked if they had seen a doctor, but they did not. The hospital that is specialized in arsenicosis is not nearby, but located in Kolkata, West-Bengal (More than 600 kilometres away).

As mentioned earlier, PHED will install a small water supply scheme for this village within a few months. During the installation, a maintainer and an operator will be assigned and he or she will receive training for his or her job.

A few kilometres further away, we visited a small supply scheme (Figure 6-7). The first thing we heard is that somebody takes care of this unit. He was also present at that time and he allowed us to visit the filters inside the shelter. In the shelter we saw 4 filters, all financed by PHED. The filter was from DNA and the contractor was WaterLife. One of the 4 filters was a sealed box, which vibrates. We later heard that due to lack of maintenance these sealed box filters, which were installed by DNA Infrastructures, have become defunct and have been replaced by the other filters by the WaterLife firm (Kumar P. , 2012).

Also the sludge was disposed in a concrete box outside the building. Unfortunately the box was leaking, so the sludge was disposed in the ground water.

6.4.1 Buxar summary

Water sources

Functioning

- Some of the tube wells with arsenic and iron filters
- Tube wells without any filters
- Open well
- Small water supply scheme

Not functioning

- Some of the tube wells with filters were not functioning

Disputed water sources due to social difficulties/acceptance

- Small water supply scheme

Other important points

- Hardly anyone knows about the arsenic problematic;
- We have not experienced social conflicts among the communities;
- PHED was very nervous and tried to avoid our questions;
- In the small water supply scheme, there is no use of having 4 filters. One of them was sealed in a box, which vibrates. When A.N. College came to see the filter, some accessories were replaced or removed. All these actions are rather suspicious and we presume that there is corruption going on;
- We saw many symptoms due to arsenic. Unfortunately, they did not know that this was caused by arsenic in water and they have continued to use the affected sources;
- There are no medical facilities for arsenic patients. Although they want to see a doctor, they cannot afford it. The nearest hospital that is specialized in arsenicosis, is located in Kolkata, West-Bengal;
- There is a lack of community participation for maintaining or operating small units.

Figure 6-9: Well head adsorption filter

Figure 6-8: IIT Mumbai Iron based adsorption filter

Figure 6-7: Interior of PHED solar based adsorption filter

6.5 Bhagalpur

Bhagalpur district is situated on the eastside of Patna and the southern gang bank of the Ganga River. According to the 2011 census, Bhagalpur district has a population of around 3 million inhabitants.

During our 2 days field trip, we have covered several villages. On the first day we visited Ranidiyara, Nayanaar, Ranidiyara, Subbanagar. On the second day, our field trip has only covered Singhnan. Radgir, a student of Bhagalpur University, was our guide during our trip.

Radgir told us that arsenic is also present in the nature. The concentration of arsenic in the Ganga River has increased, because factories throw away arsenic in this water. Nowadays, water of the Ganga River has been used as drinking water. The only obvious way to keep the concentration of arsenic low is to make sure that arsenic is not dumped in the river. However, the main problem is that factories do not care about the nature and it is most often the inexpensive way to get rid of wastewater.

The first village we visited was Subbanagar, where a primary was located. To our surprise, there are 3 hand pumps of 20 meters in total in a row (installed by the PHED) (Figure 6-10). These tube wells are all the same: the depth of the tube wells is 110 ft., and had an iron contamination. Three of them have neither arsenic nor an iron filter. 10 years ago, the first tube well was installed by a private contractor and financed by a local funding agency. The second tube well was installed by PHED. Radgir delivered in this case a report to the PHED about these failures (3 pumps in a row). The result was an installation of the third pump. It has to be said that the third pump is not functioning anymore. This pump was financed by the MLA funding and it was installed in November 2012, during the Diwali festival. At that time, nobody was present who could provide us any information about what happened and why they installed the third pump.

As mentioned earlier, he wrote a report regarding those 3 pumps. He is fully aware of this matter and does not feel the necessity to do something about the broken pump. That is where his report/research ended. This is also one of the major problems regarding arsenic in Bihar: many reports and researches have been written and done, but nobody is able or willing to take care of it after all.

The next village we visited was Nayanagar Ranidiyara. This is the first community based filter plant that provides water (250 litres per day) for people who live in a range of approximately 250 meter from this scheme. This filter method was based on activated alumina. The groundwater contains a concentration of 250 ppb arsenic. Now that the filter works, the concentration of arsenic after filtering is around 100 ppb. This still exceeds the permissible limit of 10 ppb. The backwash water of the filter, which has a high concentration of arsenic, is directly poured into the ground again, thereby contaminating surrinding tube wells (Figure 6-11). Nowadays, there is a caretaker and maintainer who keep an eye on the filter plant and take necessary actions if needed. However, this caretaker has not enough skills in order to act properly in case of high concentration of arsenic in the water. He does not seem to be worry about this entire issue. It is possible that the filter contains too less activated alumina, or the activated alumina does not work effectively. The fact is that the problem has not been solved yet and there is also no solution for the future.

The contractor of this scheme is Mahesh, who is hired by the PHED. The system regarding maintenance and operating works as follows: PHED decides to build a small water supply scheme with an arsenic filter in this area. It has to be said that this area was never tested on arsenic before constructing this scheme. After all, arsenic was found accidently. PHED only cares that money has to be spent. PHED hires a contractor, a private company that is willing to build the scheme, and pays the caretaker via Mahesh. That means that Mahesh receives lot of money from the PHED. The caretaker told us that he did not receive wages in the past few months. So Mahesh holds lot of money back. Mahesh claimed that the PHED did not pay him for a long period, which can be the reason for the presence of high concentration of arsenic.

The maintainer is a local villager who lives near the scheme. Inside the scheme we found a logbook, where he notes down the concentration of arsenic, date of backwash and the amount of water that has been used. The suspicious thing is the fact that the last date in the logbook he registered was two days after tomorrow and all the results were exactly the same. This indicates he does not do his work properly.

After visiting this scheme, we visited another water supply scheme in the village of Ranidiyara, which is exactly the same as the previous one. It was financed by the PHED and built by a private company. Mahesh is also the contractor of this place. It was remarkable that the tap next to this scheme was demolished. According to Radgir, he said that it was a plastic tap so it is easy to damage it during usage.

Another tap, 100 meters away from the scheme, was also broken. The concrete where the tap is connected with has broken. It is unlikely that that happened during usage.

There could be two reasons for that, where neither Radgir nor the operator had a clear explanation for it:

- Perhaps the oxidation of arsenic caused such an expansion, which broke the concrete;
- Vandalism by locals as a consequence of boredom, sturdiness or refusal of implementation techniques.

The field trip has only covered the village Singhnan on our second day. We all focused on fluoride in drinking water and bioremediation plants.

Before we went to this field trip, we did some literature studies and we knew that this area has no arsenic in groundwater, but it has fluoride. The first location was near a road. A hand pump was installed by the PHED next to this road with a fluoride filter. The concentration fluoride of this pump is 20 ppm and this was found by Radgir. The permissible limit of fluoride is 1-1,5ppb. Like many other hand pumps with filters that we have seen, this was also not well-maintained and the pump did not even supply water.

The next stop was a primary school. Dr. Rajeev Kumar (A.N. College), who accompanied us during our trip, took water samples from the hand pump and the open well, which are both next to the school.

There was also a tube well present in the schoolyard. The concrete surface was all brown. We have observed the water, and the iron particles were clearly visible.

Then Radgir tried to be smart in front of all those pupils and teachers. Radgir wanted the names of all pupils who are suffering from the consequences of fluoride. He gave a professional impression and acted like an expert. He checked the teeth of all the pupils, and when he saw damages of all kinds, he noted down their names.

He said that he collects this information for an article, but we assume that he only wants to impress people and get positive attention.

6.5.1 Bhagalpur summary

Water sources

Functioning

- Family tube wells without any filters
- Open well
- Small water supply scheme, based on activated alumina
- Tube wells with arsenic filter
- Surface water (Ganga river

Not functioning

- Community tube wells with fluoride filters
- 3 School tube wells on a row, financed by PHED without filters
- Community tap that is directly connected with the small supply scheme

Disputed water sources due to social difficulties/acceptance

- 3 School tube wells on a row, financed by PHED without filters
- Small water supply scheme, based on activated alumina
- Ganga river (pollution)
- Community tap that is directly connected with the small supply scheme

Other important points

- Hardly anyone knows about the arsenic problematic;
- The logbook we saw in the water supply scheme was very suspicious: the information was fake;
- There are no medical facilities for arsenic patients;
- Remarkable was that PHED gave command to install 3 tube wells on a row, without any filters
- PHED hires the corrupt contractor Mahesh;
- Mahesh holds money back;
- Water supply scheme that uses activated alumina can cause cancer, but PHED still uses this method;
- There is lack of community participation
- The primary school we visited has never taught pupils about hygiene and safe drinking water due to lack of knowledge;
- Lots of tube wells with fluoride filters were destroyed and it has never been repaired;
- It is possible that the information Radgir gave us is not always right. We suspect that he tried to look like an expert and has not always the knowledge regarding this entire issue.

Figure 6-10: Three hand pumps without filter

Figure 6-11: Sludge dispopsal of PHED Adsorption Filter

6.6 Kolkata

North 24 Parganas district is a district in southern West-Bengal state, of eastern India. In our research we limited ourselves to the Bihar state of India, but we want to compare Bihar state with West-Bengal state, regarding arsenic in drinking water and awareness/knowledge about this problematic.

According to the 2011 census, North 24 Parganas district has a population of around 11 million inhabitants. The Baduria block we visited has more than 240000 inhabitants. (Govt. of India: Ministry of Home Affairs, 2011)

If we compare Bihar with West-Bengal in general, the average literacy rate is in West-Bengal 77% and in Bihar 63%. All statistics are as per 2011 population census.

Despite the fact the majority in both states are Hindus, the mind set of both states are different. According to Dr. Ashok K. Ghosh and Supriyo Das (A.N. College, Project Well 2012), people in West-Bengal are more aware of the arsenic issue. There is more community participation in West-Bengal than in Bihar. This can be explained by the fact that the literacy rate in West-Bengal is higher.

Our field trip has only covered the Baduria block, which the majority of the people are Muslim. So the problems in the community are different compare to the Hindus. For example: in the Muslim society there is no caste system.

We have visited 3 dug wells (out of 250), that have been installed by Aqua Welfare Society (AWS) and Project Well. The funder of those dug wells is Blueplanet. Those 3 wells were installed in January 2011 and the cost of 1 well is around 50000 Indian Rupees.

After installation of those wells, AWS is responsible for the maintenance in the upcoming 2 years. They put Theoline (10% chlorine) in the well water, which happens three times a month. Furthermore, twice a year, AWS takes water samples and bring it to the state government lab to test the water.

The first and the third open well are used by around 100 people per well. Most of them are the Muslim people. Because those people belong to the same community and within the Muslim there is no caste system, we have not experienced any social difficulties so far.

The second well we visited was not working properly. This well was also used by the Muslim community. AWS, responsible for maintenance and operating, could not give us a clear explanation why this well is not functioning anymore. They assume it is broke due to improper installation. The nylon net which should protect the sand filter in the ground contains a hole and it is probably clogged with lot of trash. The maintainer has never tried to repair this and they think it cannot be repaired due to lack of skilled people.

6.6.1 Kolkata summary

Water sources

Functioning:

- Surface water
- 2 Dug wells with hand pumps

Not functioning

- 1 Dug well without hand pump. This hand pump is removed and is used at another dug well

Disputed water sources due to social difficulties/acceptance

- None

Other important points

- According to Supriyo Das, around 90% of the entire village has access to clean drinking water without arsenic;
- For the other 10%, except surface water there are no alternatives;
- Lot of work regarding arsenic mitigation has been done. After 2 years, the filter installation will be handed over to the community and they will become responsible for the maintenance;
- Around 20 families make use of 1 well. The distance between their houses and the well is short, therefore almost everyone comes to the well to tap water;
- There are no symptoms due to arsenic;
- The dug wells are meant for drinking purposes. For irrigation the villagers use groundwater which may contain arsenic. In this case, the food chain is most-likely contaminated with arsenic.

7. Comparison of mitigation technologies

Using the conclusions from the actor analyses and the field observations, it is now possible to start comparing the different arsenic mitigation technologies.

To do this, the different criteria an arsenic mitigation project has to meet will be defined. Second, the different arsenic mitigation technologies that are being used and can be used in the Bihar region will be elaborated. Of these mitigation techniques the pros and cons will be discussed using the defined criteria. Finally, the results of this comparison will be summarized in a multi criteria analysis.

7.1 Criteria definition

In order to clearly define the criteria an arsenic mitigation project should meet, a goal tree is used. A goal tree is a criterion definition method that starts with a main goal. In this case the main goal is to have successful arsenic mitigation methods. This main goal is then split out into sub criteria until measureable criteria have been formed. This goal tree can be found in **Error! Reference source not found.**.

A well-functioning arsenic mitigation system consists of three aspects. It has to be socially viable, technically viable and economically viable.

Social viability includes two factors. These are the total number of users and the percentage of the village that is covered by the mitigation system. This second factor includes whether people are excluded based on race, religion, wealth or caste and is a very important factor to consider.

Technical viability encompasses all the factors that indicate whether the technical aspects of the filter are functioning or not. These are the total filter capacity (in litre / day), the concentration of arsenic (in ppb), the concentration of iron (in ppb), the bacterial and viral concentration (in ppb) and the possibility for environmental impact of the filter (scale 1-5)

Economic viability deals with two aspects. One of those aspects is the costs, which consists of single costs and monthly maintenance cost. The other aspect is on how future proof the mitigation structure is. This encompasses the availability of spare parts, the difficulty of maintaining the facility and whether or not viable plans have been made to maintain the facility.

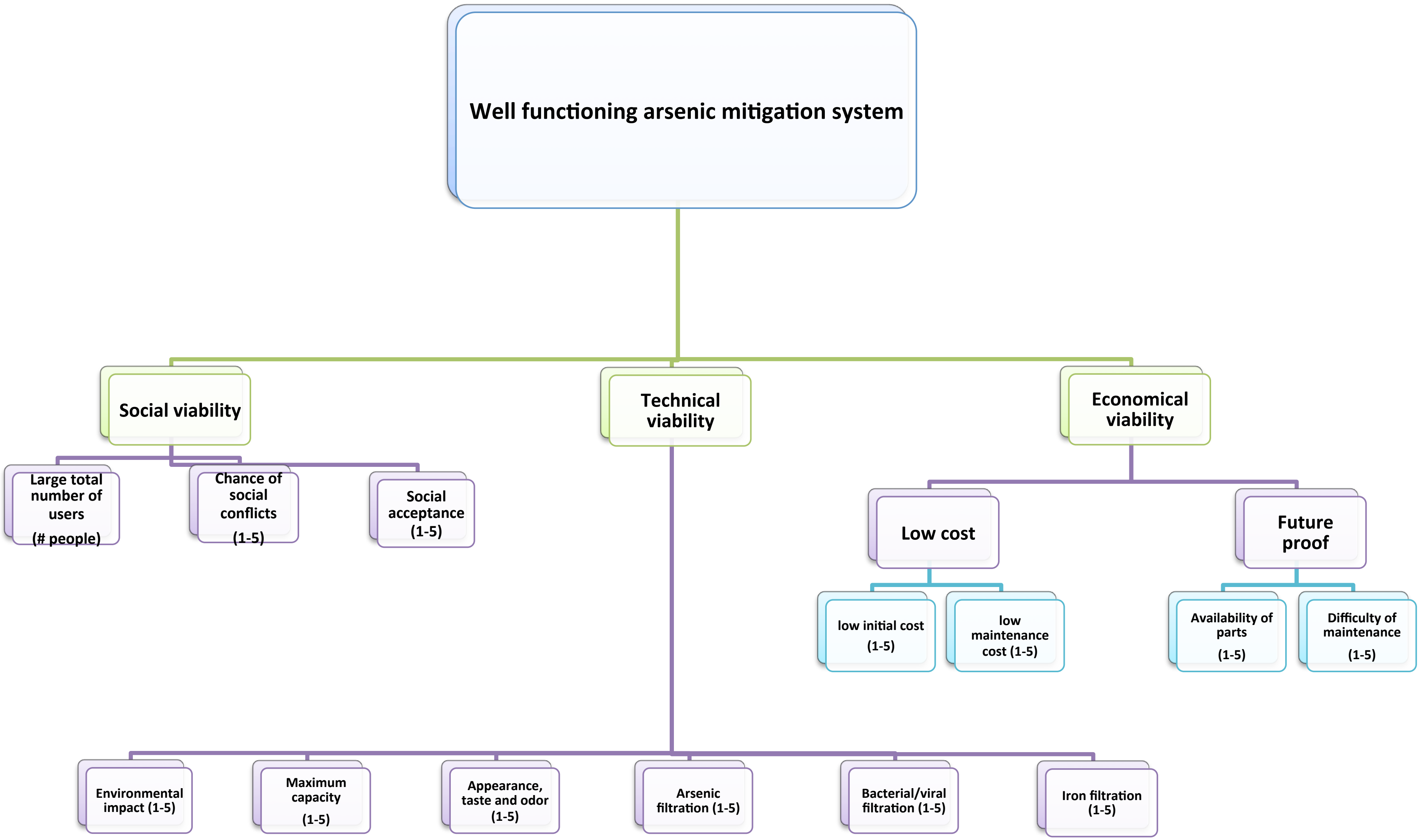

Figure 7-1: Goal Tree

7.2 General arsenic chemistry

To know about the different mitigation techniques which can be implemented to obtain arsenic free water, it is necessary to have knowledge about what arsenic actually is and in what kind a forms it occurs in the groundwater. Reports from the Central Ground Water Board have pointed out that in Bihar the arsenic contaminated aquifers is found at a depth of approximately 50 m. The deeper, not affected aquifers are at a depth of around 120-130 m. The concentration is here around 3.5 ppb, which is below the guidelines of 10 ppb (Saha, Suhu, & Chandra, 2010).

The origin of the arsenic can be attributed to the subsurface sediments derived from mountains in the Himalaya. Here the arsenic is fixed in the sediments as long as the groundwater contains sufficient dissolved oxygen. Due to microbial activity the oxygen is slowly depleting in the groundwater, which causes the detachment of the arsenic out of the sediments and the contamination of the groundwater.

One of the chemical characteristics of arsenic is that it is a redox-sensitive element. That means it easily gains or losses electrons in the right conditions (pH-value). To which form it oxidizes of reduces is dependent of the other chemicals which also are present in the groundwater. Under oxidizing conditions arsenate, As(V), is usually predominant. In this state it can gain electrons. In reducing conditions arsenide, As(III), is dominant. These are the two most common forms of arsenic in groundwater. Under the pH conditions of the groundwater, As(V) is negatively charged as $[H_2AsO_4^-]$ or $[HAsO_4^{2-}]$ and As(III) as $[H_3AsO_4]$, so uncharged (USGS). This fact plays an important role in some separation techniques. The presence of iron may also influence the chemical reaction of the arsenic. Because when the iron oxidizes (in contact with air) it can adsorb the arsenic. This is important in adsorption techniques.

The main technical issues of arsenic are a better understanding of the source of arsenic and the way it is released, the sludge disposal and filter formations which should be easy to operate and maintain (adaption to local willingness).

To qualify the different mitigation techniques in rural Bihar it is useful to subdivide the methods by scale: household, community and large scale plants. Each scale needs a different setup, extent and perhaps other chemicals.

7.3 Household level projects

In Bihar there were very few household level mitigation installations found. That is probably due to the lack of awareness and thus preparedness of the villagers. They are not educated enough and do not know enough about arsenic and its health effects and way of occurrence. Building their own well or filter is too much effort for something they do not even realize what it actually is.

The most installations we found were meant for more than one household, so these will be divided with the community level projects. In contrast to projects in Bangladesh (Hoorens & Koenders, 2010) there are very few sand and chemical filters which families only use for their own purpose to avoid drinking arsenic contaminated water. Hereby must be notified that some projects, which were meant for a community, are now only used by the operator of the filtration unit. This case was observed in Maner. The operator was more educated than the rest of the village. Therefore he maintained the unit, but also denied access to other villagers, because it will otherwise increase the risk of being defect and he should pay to repair it.

Different types of household level filters will be elaborated in the following paragraphs.

7.3.1 Sand filters

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. That is also what observations confirmed in among others Bhojpur, because they used their own hand pump. Unfortunately these families were not aware enough of arsenic (some did not even know of the problem) to also install a filter. However, some sand filters also filter iron, which would reduce the discoloration of the water and thus it is not necessary for people to be aware (Berg, Luzi, Trang, Viet, Giger, & Stuben). They still need to know about the existence of such a filter. The requirements for this kind of filters are:

- Concrete construction for the sand filter and for the water storage tank
- Hand pump, which almost every family who lives on a distance from the centre have one.
- Locally available sand
- Small diameter sieves to prevent sand muddles the purified water

Not only can this filter be used with groundwater, but also with surface water. However, in Bhagalpur there were significantly higher concentrations found in the river branches of the Ganga River. The explanation could the run-off of affected tube wells or the dumping of waste water by industry. In Khagaria district, there were a few pilot programs for household level sand filters. An example of household level sand filter with surface water is the home based pitcher-filter. It is a formation of different size granular and sand grains above each other. The bottom jar contains the finest graded sand. It is possible to add some alum to kill bacteria. However, this can give a lot of problems, that this method is considered to be almost impossible to implement in rural Bihar. The people are not aware and educated enough. Besides it is too much effort and water is also used for other purposes, like fishing (Kolkata observation).

The big issue is the disposal of the arsenic contaminated sand. To perform this on household level is very difficult in Bihar.

7.3.2 Rain water harvesting

This is a unit that accumulates and stores the water in tanks or increases the groundwater table. In the tank it is stored and used for drinking and cooking purposes (or non-potable supply). First it has to be treated with chlorine or the so called SODIS-method against contaminants. A rainwater harvesting unit needs to meet some geological and technical conditions to work properly. These are:

- There have to be a significant rainfall, which provide enough water. This also includes the storage of the water in dry periods.
- A sloping roof is required for the small scale units. For larger units also a flat roof may be sufficient, if it meets the right conditions to transport the water to the storage tank.

In Bihar most of the houses have a flat roof, which means the way to collect the rainwater is difficult. Other reason could be that there are better options, like dug- and tube wells. This goes along with the observation the people are not aware enough about the arsenic and do not feel any necessity to build such an installation on their roof.

Period of year	Rainfall Bihar (mm/month)	Possible storage (L/month)
Monsoon	200	4800
Post-monsoon	30	720
Winter	5	120
Summer	20	480

*Table 7-1: Rainwater harvesting water availability (Storage = rainfall * surface area)*

Assuming a rooftop surface of 30m^2 and a waste coefficient of 20%, the given possible storage is shown in Table 7-1: Rainwater harvesting water availability. When the average size of a family in Bihar is around 8 members and each needs around 5 L per day for drinking and cooking purposes, their monthly requirements are around 1200 L. This is sufficient in the monsoon and perhaps in the post-monsoon, but after that it is not enough.

So in rural Bihar there are only a few rainwater harvesting units. At our fieldtrips we only saw one, namely in Bhojpur. This one was defunct, due to lack of maintenance. The villagers also have a tube well connected with the Mozempur treatment plant and an open dug well, so there is no need for this solution.

Despite of the fact this unit will not provide sufficient water for only drinking and cooking purposes in Bihar throughout the year, it could be a good alternative. It reduces the extraction of groundwater. Extensive extraction of groundwater can cause a higher level of arsenic. That is because groundwater contains usually organic material and in case of too high extraction (mostly for irrigation purposes) it can stimulate microbial activity and thereby accelerate the oxygen depletion and thus the arsenic release. The rainwater harvesting unit is also easy to build. Finally it is a way to prevent the houses from flooding in the monsoon period, to just catch it up and store is. The reason it has not been implemented yet is because of the lack of awareness to create an alternative water supply method and lack of knowledge about the arsenic occurring in the ground water.

7.4 Community level projects

7.4.1 Oxidation

7.4.1.1 Open dug well

To understand why a dug well is an option for mitigation, knowledge about the processes is necessary. When the water is in contact with the air, the As(III) part oxidizes to As(V). In the groundwater iron co-occurs with arsenic, due to the sediments they belong to, namely a formation of arsenic and iron (Clifford, D.; Ganesh, 2011). Also the iron oxidizes in an aerobic environment. The arsenic and iron in their oxidized state precipitate together and co-precipitate to the bottom of the well. This takes some time and it is also not a guarantee the water is arsenic free due to recharge of new arsenic contaminated water from the groundwater or the concentration of arsenic is just too high for total precipitation within an acceptable period of time. That was also found in Bhagalpur, where there are dug wells with a contamination level above the 10 ppb.

Before installing a dug well it is important to know at which location and depth to dig. These needs to follow the next conditions (Akvo, 2012) (Smith, Hore, Chakraborty, Chakraborty, Savarimuthu, & Smith, 2003):

- At a location were layers of sand and gravel provide a natural filter.
- At a location were the recharge of the water is guaranteed
- At a location were villagers live, who show the symptoms of arsenic intake.
- At a location were actually arsenic was found in tube wells
- At a location were any other source of arsenic free drinking water is absent within a distance of 200 meters from their houses
- At a location were the potential user population is around 200 villagers.
- At a location higher than the surrounding area with no toilet or agricultural field within a distance of about 100 feet. The travel time for pathogens to go from the contamination location to dug well should be around 25 days, to be certified as ‘’low risk’’.
- At a depth the well is stable and the ground pressure will not get too high.
- At a depth above reducing conditions, so in the oxidizing zone.

Looking at these requirements, dug wells in Bihar and West-Bengal should be dug at a depth of approximately 9 meters (30 feet). In spite of its dependence of the hydrological conditions of the area, it should be in an unconfined aquifer.

7.4.1.2 Oxidation (chemicals and aeration) and sedimentation

The main focus of this mitigation technology is based on the formation of insoluble compounds. So a chemical is added or the water is exposed to air to react with the soluble arsenic, which causes a precipitate. The difference between precipitation and adsorption is that adsorption is based on the electrostatic binding of arsenic to metal hydroxide surfaces (Vu, Kmainski, & Nunez, 2003).

This principle is about the same as open dug well. However, there is the oxidation process natural when the groundwater is exposed to the air. Here there will be added some chemicals to accelerate the process, which is preferred by villagers. Though, some chemicals can give a bad odor, bad taste or strange color to the water, which makes it less attractive to drink.

The process is based on the geological phenomenon that arsenic occurs when there is also iron (Fe) present. Fe removal involves oxidizing soluble ferrous iron (Fe^{2+}) to insoluble hydrous ferric oxide (HFO) and then removing the HFO by filtration. Arsenic can adsorb to this HFO and, as a result, some arsenic will be removed during Fe-removal (Holm & Wilson). The oxygen is called an oxidant in this case. Aeration is the artificial process of accelerated oxidation process. Other oxidants are [$KMnO_4$], potassium permanganate, or [$NaOCl$], sodium hypochlorite. These should be added manually, but iron co-occurs naturally with arsenic in groundwater.

To oxidize the Fe^{2+} to HFO and the As^{5+} to As^{3+} there is oxygen required. Here the aerating process plays a role. To accelerate the oxidation process it is useful to add a sprinkler installation. Here the water is sprayed in a container, which causes a higher surface to the oxidation process. After this the solid particles will be filtrated by sedimentation.

Results had showed out that the efficiency is poor with iron. So adding the [$KMnO_4$] or [$NaOCl$] might be an option. This, however, can cause health problems if it is not used in the right manner. It is also difficult to implement in the society of the illiterate people of Bihar. They have no knowledge about adding the chemicals. Also training them is a labor-intensive process, while there are better and easier mitigation technologies. It can also cause some bad taste or odor, which discourages the people to drink the treated water (Smith, Hore, Chakraborty, Chakraborty, Savarimuthu, & Smith, 2003).

7.4.2 Deep tube well (DTW)

The deep aquifers from Bihar have found to be relatively free from arsenic contamination. The main reason for the deep tube wells to be safe is probably because sediments are older and any arsenic present was flushed out thousands years ago. The depth of the deep aquifers should be around 120-130 m in Bihar. Here the arsenic content is around 3.5ppb (Saha, Suhu, & Chandra, 2010). From reports of Bangladesh it was found that some deep tube wells did seem to be contaminated by arsenic. This was due to improper installation, some contacts with the arsenic contaminated and non-arsenic contaminated aquifer or a small amount of natural occurring arsenic (Hoorens & Koenders, 2010). Research by the CGWB has find out that this is not the case in Bihar. The aquifers are here divided by a 15-32 thick clay layer.

Regarding the possible failures for a deep tube well as long term sustainable option this method should be considered carefully. Firstly, to install the DTW at a good chosen location, namely where it cannot harm the environment and provide safe water for a very long period. Also the DTW have to be monitored during the use of it, to avoid extensive extraction (no irrigation) and pollution of the deep aquifers. It would be a disaster if also these aquifers will be depleted or polluted after a few years and the whole scenario will repeat.

A big advantage of this method compared with others is that the local villagers are used to the pump system, because they now use tube wells. So it is easily to adapt on these method and they do not need extra training, besides they handle the aquifer with caution.

7.4.3 Adsorption and Sedimentation/Filtration

First of all, there have to be knowledge about adsorption before implementing it in an arsenic affected area. Adsorption includes the phenomenon that molecules of a gas or a liquid attach to a surface of a solid or a liquid and covers it with a layer. It can be used on suspended particles, after coagulation (and co-precipitation), oxidation and on a fixed media. Here applies that when the media has a larger surface, the capacity is also larger. The chemicals that can be used are:

- Activated Alumina
- Granular ferric (hydr)oxide
- Cerium oxide, Metallic iron or Iron-coated sand or brick dust
- Ion exchange media
- Coagulation + flocculation and sedimentation/filtration

These will be discussed in the following paragraphs

7.4.3.1 Activated alumina (AA)

This method is very effective in removing As(V), but low in removing As(III). Here must be notified that the As(III) is more toxic than the As(V). AA is known about its high porosity, large surface area and is used mostly as filter for fluoride. If there is more AA, low temperature of the water and low pH (high pH decrease the efficiency due to negative charge, which can electro-statically repel anions) the filter is effective. (Jurenka, 2010) (Wikipedia, 2008)

The presence of iron plays a double role. On the one hand is has a negative effect on the performance of the AA, because it can clog the bed. On the other hand it can be beneficially used to remove the arsenic by adsorption and co-precipitation. Pretreatment can increase the capacity of the filter, by oxidation of the As(III) and removal of the iron (the positive effect of the iron is retained, while the negative effect is eliminated) (Jalil & Ahmed). The pretreatment contains the oxidation of As(III) to As(V) and the removal of iron.

By oxidizing the As(III), the harmful concentration of As(III) decreases and the efficiency of the filter increases, because it can remove the As(V) more easily than the As(III). By adding $[KMnO_4]$, potassium permanganate, the oxidizing process is accelerated (see ‘’oxidation’’). This, however, produces a color to the water, which can cause such a low preference of the villagers to drink the water, they will use other (perhaps contaminated) sources. A sand filter can remove the color (also micro iron flocks) (see ‘’sand filter’’). A dose of 1.0 mg/L should be enough to oxidize 500 ppb As(III).

The pretreatment to remove the iron contains aeration, flocculation and sedimentation. It performs well on removing the macro iron flocks, but less on the micro iron flocks.

The maintenance must be strict to avoid microbial contamination or, after a period of time, to high concentrations of arsenic in the purified water. Periodically, the media is backwashed resulting in high-arsenic-contaminated waste water. This was observed in Bhagalpur were one of the backwash pipes dumped waste water with concentration arsenic of 179 ppb, which flows back into the ground water. It also contains many microbial contaminants and activated alumina particles. This reduces the capacity of the filter by 30-40%. That is why the filter needs to be replaced after 3-4 regenerations (Extension, 2010).

The PHED has built a lot of installations with AA in Bhagalpur around June 2011. In these installations were no signs of pretreatment like stated above. This means the AA is not working on full capacity and its efficiency is low. What also was notable is the fact that at the backside of the buildings was a pipe dumping water, which is perhaps contaminated with arsenic. Also these installations did not purify the water enough. That may also be caused by improper maintenance. Another notable fact is that us during an interview was told that actual research pointed out that AA can cause kidney problems, and can lead to cancer. However, no sources were found to support this claim. More research on the safety of using activated alumina is therefore necessary.

7.4.3.2 Granular ferric (hydr) oxide

Granular ferric hydroxide is highly effective to remove the arsenide and arsenate (and phosphate) and produces relatively small amounts of residual spent media. Just as with AA it is recommended to conduct a pretreatment. This includes aeration and pre-filtration to remove iron flocks (Ahmed).

There are methods implemented with Granular ferric (hydr) oxide in Bihar. However, this is a very small amount and also in this research no such installations were found during the field work.

7.4.3.3 Cerium oxide, Metallic iron or Iron-coated sand or brick dust

In Bangladesh a lot of pilot programs were set up. These consisted for a great part of adsorption filters. Cerium oxide was one of the used adsorption media. Like the READ-F, developed in Japan, implemented in Bangladesh. This method displays a high selectivity for arsenic ions. The advantage of this adsorption method compared with the other adsorption methods, is that this one does not need pretreatment or adjusted pH-conditions. However, it needs (just like the others) iron removal by sand filtration to avoid clogging as a pretreatment. It can be regenerated by adding sodium hydroxide and then sodium hypochlorite and finally wash it with water.

One of these metallic iron adsorption units is zirconium. This method is effective in removing both As(III) and As(V) and common used in adsorption units in Bihar, mostly because of the easy way of regeneration.

7.4.3.4 Ion exchange media

This method is much different than the methods stated above. It shows similarities concerning the fact it will pass through a filter, but differs when it comes to the adsorbent criteria. In this case arsenic ions will exchange with ions of the media. This technology is very selective in which ions to be exchanged, due to the different charge of the ions. So can it be very efficient in removing arsenate and arsenide without removing other chemicals. This increases the capacity for removing the arsenic.

Also in this technology the media must be regenerated periodically.

7.4.3.5 Coagulation + flocculation and Sedimentation/Filtration

The coagulation is the process in which heavy metals are adsorbed by coagulants in order to separate these metals from the water. Hereby the results are flows. The colloids are destabilized by adding a chemical, the coagulant. It differs with precipitation on the part that in coagulation the colloids are suspended in a liquid and not dissolved. The process in which the small flocks are accumulated to large flocks is called flocculation. After forming the large flocks, they can be eliminated from the water by sedimentation or filtration. Alum and iron(III) salts are the most common coagulants (Fields, Chen, & Wang, 2000).

Also here a pretreatment concerning oxidation of As(III) is suggested. The factors which affect the coagulation process are the coagulant dosage, pH, turbidity, natural organic matter (NOM), anions and cations in solution, zeta potential and temperature.

7.4.4 Membrane and Filtration

The membrane technology can be subdivided into two forms which are used in gaining arsenic free water. These are the high- and low-pressure membranes (Foundation). Compared to many other filtration techniques this one does not always make use of chemicals, which is an advantage in the underdeveloped rural areas of Bihar. On the other hand it needs to make use of electricity, which is not always available. Therefore this technology is often used in combination with solar panels.

The principle of the methods contains pressurizing the contaminated water against a membrane. Depending on the kind of membrane it obstructs the access of specific contaminants and passage the water. This method makes use of high pressure, maintenance of a concentration gradient on both sides of the membrane and electric potential (Lenntech).

Another advantage of this filtration is that it also can remove odors and bad tastes due to the small pore size.

In Bihar only installations of Nano filtration and Reversed Osmosis are found. No micro- and ultrafiltration were observed. This is probably because the filter accuracy is much less compared to the other filtrations.

In the following paragraphs the four types of membrane filtration will be discussed.

7.4.4.1 Micro filtration (MF)

The pore size of this low-pressure filtration is around 0.1 micron, which is small enough to filter bacteria and suspended solids. However, this method is not always reliable in filtering the arsenic. To solve this there are two ways developed. One is to fix the membrane with a negative charge. This is more effective in removing the anionic arsenate than a membrane which is uncharged. The other way is to precipitate the arsenic into larger particles, so it cannot pass the microfiltration membrane. This can be done by adding a chemical that accelerates the oxidation (iron or mangese) (Caniyilmaz, 2003)

7.4.4.2 Ultra filtration (UF)

This is also a low-pressure filtration. This filtration method uses pressures up to 10 bars. It filters solutes of molecular weight greater than 1000. The permeate contains low-molecular-weight organic solutes and salts. The pore size is around 0.01 micron. With this size it can remove also viruses compared to microfiltration. However, also ultrafiltration cannot filter the arsenic properly without the arsenic is adsorbed to other particles. So also this method needs oxidation.

7.4.4.3 Nano filtration (NF)

The pore size used with nano-filtration is 0.001 micron. Besides viruses, bacteria and suspended solids this high-pressure method can also filtrate multivalent ions, like arsenate and arsenide. That means an oxidation is not needed. So it is not necessary to let a bucket of water alone for a few minutes. It needs enough electricity to perform the high pressure.

7.4.4.4 Reversed osmosis (RO)

The last membrane technology is RO. The basic principle of the flow of solvent is if two solutions are separated by a semi permeable membrane. The natural flow is from low concentration solution to high concentration, trying to reach a stable situation (the osmosis pressure). The reverse osmosis process reverses the previous process by placing the concentrated solution of the membrane under pressure. Only water can flow through the membrane (0.001 micron) and the (arsenic) particles stay behind in the membrane (Schmidt, 2010).

In Maner was a pilot program conducted two years ago by Karlsruhe University. This system did also contain an aeration tank and granular media filter to get rid of the high amount of iron. These were necessary, which means only a RO-system is not sufficient.

Also in Buxar a RO-system was observed, which was installed by DNA Infrastructure. This one was a lot smaller than the system we saw on pictures of the Karlsruhe University. The filter in Buxar was not working anymore.

7.5 Large scale projects

Large scale projects are projects that use non-arsenic contaminated water as a source. They remove other contaminations from the water such as bacteria and other microbes and supply it through pipes to multiple villages.

There are currently two types of large scale projects possible. These are surface water supply plants and deep water supply plants. These will be discussed in the next paragraphs.

7.5.1 Surface water supply plants

The last scale contains the big surface water treatment plants. These were observed during the fieldtrip in Mozempur and Vaishali. Here the water is pumped up from the surface of the Ganga and treated to eliminate microbes and other contaminants. After this it will be distributed with pipes to the adjacent villages.

Here must be notified that this also needs research on river morphology, because the Ganga shifts away from the plants.

7.5.2 Deep water supply plant

There were no deep water supply schemes observed in Bihar. That does not mean it could not be a proper option. However, this will need some research, because, just as with deep tube wells, one should be cautious with the clean arsenic free deep water.

If it may be a good solution for in the future, villages which suffer from arsenic and are far away from a large surface water area, can make use of these installations.

7.6 Sludge disposal: Bioremediation

Probably the biggest technical issue of arsenic is the disposal of the sludge, after purifying the water. It does not matter which way the water is treated, there will be always arsenic. It is just not possible to vanish is. What is possible is a new technique coming up: bioremediation. As so far this is the only disposal option so far. First the water with the high arsenic concentration is put in a concrete box, where there is no option for leaking. Thereafter bioremediation including microbes and phytoremediation provides a sludge and contrite treatment option. After the plants and microbes assimilate the arsenic, they will be burned in a safe environment and the ash will be used for bricks. Important is that the bricks should be used in a dry environment, to prevent the arsenic from leaking out of the bricks into the groundwater.

Unfortunately, this method has not been developed so far to be integrated in the purifying methods and the local community. However, one concrete box with the plants was observed in Maner, at the Layheigh filter. We were not able to see the process after the plants are burned, but probably it will be done properly, because it was a pilot program by the A.N. College and the owner seemed to be a man with enough knowledge about arsenic. To meet such conditions in a random village with people, who do not even know about arsenic, is a difficult objective.

7.7 Multi criteria analysis

Now that all mitigation technologies have been described, it is possible to summarize the findings in a Multi Criteria Analysis. In a multi criterion analysis all the different alternatives are summarized in one chart and are rated based on the criteria that were defined earlier.

The left-most column consists of the ratings for a regular tube well. This is not an arsenic mitigation technology but it is the most common water source for rural villagers in Bihar. It is therefore useful to compare other technologies to a regular tube well.

In the bottom row an overall rating for each of the projects is given. This overall rating is based on the individual ratings of the criteria, but is not a (weighted) addition of these. It is a rating of the general overall quality of the technology.

Unit is a scale 1-5 if not mentioned otherwise	Household			Community										Large Scale	
	Tube Well	**Sand filter**	**Rainwater harvesting**	**Open dug well**	**Oxidation**	**Deep tube well**	**Activated Alumina**	**GFH/GFO**	**Ce, Metallic Fe**	**Ion exchange**	**Coagulation**	**Nano filtration**	**Reversed Osmosis**	**Surface water**	**Deep water**
Users (#people)	8	8	8	200	1,125	200	1,125	1,125	1,125	1,125	1,125	1,125	1,125	125,000	50,000
Chance of social conflicts	1	1	1	4	3	4	3	3	3	3	3	3	3	3	3
Social acceptance	5	2	1	3	4	5	4	4	4	4	4	4	4	4	4
Initial cost (INR)	1	1	2	2	3	2	3	3	3	4	3	4	4	5	5
Maintenance cost (INR/month)	1	1	2	2	2	2	3	3	3	3	3	3	3	5	5
Availability of parts	5	3	4	4	3	5	3	3	3	3	2	2	2	4	4
Difficulty maintenance	1	1	3	3	3	1	4	4	4	4	4	3	3	4	4
Maximum capacity (L/person/day)	5	5	3	4	5	5	5	5	5	5	5	5	5	5	5
Appearance, taste and odor	4	2	3	2	4	5	4	3	2	3	5	5	5	5	5
Arsenic filtration	1	3	5	2	3	5	4	4	4	4	4	5	5	4	5
Bacterial/viral filtration	4	2	3	2	4	5	5	5	5	5	5	5	5	4	5
Iron filtration	1	2	5	1	3	2	5	3	2	3	5	5	5	4	2
Environmental impact	1	3	1	1	1	3	3	3	3	3	3	3	3	2	4
Overall	1	2	2	3	4	3	4	3	3	3	3	3	3	5	1

7.8 MCA analysis

In order to make a clear overview of which possible solutions there are, we removed some options like micro and ultrafiltration, because we are considering them as not possible to implement in Bihar. Also we are not sure about the existence of large-scale deep water supply plants, but add it as a possible solution for in the future.

7.8.1.1. Users

In this criteria there have to be a separation between the household, community and multi village scaled option. Assuming that an average family in Bihar consists of 8 people, there sand filter and rainwater harvesting unit will be meant only for them. The open well and deep tube well will provide water for a community, however these have their side effects. The open well should be built for around 200 villagers. Not more, to prevent social conflicts. The same case is for deep tube wells and the fact that this one should not be installed in great numbers, to prevent extensive extraction from the limited deep water aquifers.

The adsorption schemes will provide water for significantly more villagers, distributed by pipes to a community tap.

And of course the large scale surface water plant will provide more water, than the other options, because of the huge amount of water in the Ganga River. On the other hand, the deep water aquifers for the deep water supply is limited like stated above and this also limited in its distribution.

7.8.1.2. Chance of social conflicts

This criterion gets a low mark, when it is positive, so the risk on social conflicts is low. These are the cases in all the household mitigation options.

Like stated in the part ‘users’, the open well option and limited amount of deep tube wells have a larger chance of social conflicts compared with the other community mitigation technologies, because the villagers use it on a central place, there where the possibility of different ethnical groups and different castes is the highest. They also can pollute their common water supply, which increases the chance. The option which provides water with a community tap have a average chance, because there will be enough taps and supply the water to small amounts of users.

7.8.1.3. Social acceptance

Here the will by the villagers to use a new mitigation option is graded. A tube well is an option there are using now for a couple of years, so they now how to operate it. That’s why the tube well and deep tube well have the maximum mark here. The other taps, connected with a large scale plant or a purifying scheme has graded 1 point lower, because it is a new installation and people may find the taste, smell or appearance different than they are using now (this does not mean it is better appearance, smell or taste, because these terms are relative and subjectively). To gain water from an open well, that could be a labor-intensive process, if there is not a hand pump connected to it. In Kolkata it was also noticed that at a random moment nobody was using the open well anymore, because someone spread the rumor of some kind of animal, which lives at the bottom of the well. In an open well, you have a big dark hole, where you can’t see the bottom. This makes it more sensitive for such stories like Kolkata. We consider the sand filter as a very labor-intensive option, which is way too much effort for the uninformed and ignorant villagers of Bihar.

7.8.1.4. Initial cost

It is very hard to gain the exact numbers of the initial cost, that's why we also scale these criteria from 1 to 5. The household scale options are the cheapest and the large scale the most expensive. Ion exchange, Nano filtration and reversed osmosis are considered to be expensive technologies due to the complex buildings and filters they require. The rainwater harvesting unit (RHU), open dug well and deep tube well is cheap, but also these need more initial cost than tube well and sand filter, because of the equipment and building materials. Of course the construction of large scale plants requires a lot of money (Mozempur was INR. 64 million)

7.8.1.5. Maintenance cost

This includes the use chemicals, required manpower, needs for backwash or regeneration and complexity of the maintaining process. The tube well and sand filter have low cost, because it requires not much effort nor materials, besides the local available sand (sand beds river). The RHU, open dug well, oxidation and DTW also have low maintenance costs, because of the simple installations. The methods where chemicals are used are considered to have higher maintenance costs, also because they require stricter monitoring. The large scale plants have very high costs, because they need much manpower, chemicals and strict operating (Mozempur has annual costs INR. 10 million). On the other hand it provides water for many villagers.

7.8.1.6. Availability of parts

The two kinds of tube wells have a high availability of parts, because they need their pipes to dig in the ground, which are easily to gain. Namely, in all villages there are many tube wells.

The RHU and open well does not require complex parts and are also easy available, just as the two large scale plants. The different community mitigation technologies, except for the deep tube well and open well; they need chemicals, equipment or parts, which are less easy to gain. For the coagulation, Nano filtration and RO that is even harder, because they need more different chemicals, electricity or very fine sieves (semi-permeable membrane).

7.8.1.7. Difficulty maintenance

The tube wells don't even require maintenance and the sand filter is also very easy because of his primitive installation and locally available sand (Sand Pond Filter). Other installation may have scored lower because they need chemical treatment, backwash, regeneration and proper use of electricity.

7.8.1.8. Maximum capacity

Only the RHU and the open dug well can provide less water compared with the other techniques, because they rely on the amount of rainwater.

7.8.1.9. Appearance, taste and odor

The risk of a bad appearance, taste or odor can be caused by the occurrence of bacteria, iron, pollution or other contaminants. Depends on the way of filtration some of these occurrences can be removed or not. It is also possible that there are no contaminants present in the raw water, like deep water or surface water. To filter water with chemicals, it is possible that the water gets a bad smell or taste, which makes it less attractive for the villagers to drink.

7.8.1.10. Arsenic filtration

The most important criteria are of course arsenic filtration, where the tube well scores very low. According to samples we took and report we have read, we were able to give the criteria a different mark. Deep tube well provides arsenic free water until now, but also RO and Nano filtration are very effective. The household scale options seem to have higher contents of arsenic, because of their primitive way of filtering. Also oxidation and open well aren't always reliable to remove all the arsenic. Different adsorption techniques have a significant lower amount of filtered water, but also here it is possible that some arsenic particles go through the filter, without being adsorbed. This only works when there is a good maintenance and monitoring. Unfortunately, this was lacking in many districts, which is put into the other criteria indirectly.

7.8.1.11. Bacterial/viral filtration

To prevent the villagers get ill from bacteria, these also should be removed from especially surface water. This is the lowest at deep water. Water from other aquifers are likely to have a little higher amount. However, with good pretreatment this should be removed. The surface water and ground water, which are stored for a period, are likely to have more bacteria than ground water. It requires intensive treatment with chlorine or other chemicals, like the surface treatment plants are doing.

7.8.1.12. Iron filtration

This is only the case in groundwater. That's the reason why the RHU doesn't have iron content. Both of the high-pressure filtration techniques have low iron, because the filter is very fine and it will also remove iron. Open well; on the other hand, is very likely to have a high amount of arsenic, because this water is not treated against the water. That is the reason the villagers don't always make use of this option, because it will get brown in a very short time.

7.8.1.13. Environmental impact

This is the largest with using deep water. This water is namely thousands of years old and limited in its storage. Extensive extraction could seriously damage the environment and perhaps contaminate the water due to high pressure differences between the different layers. Using rainwater and the upper layer of the soil does not harm the environment, because of is regular recharge. However, filters can harm the environment by its high arsenic concentration in the sludge in combination with improper disposal of it. It is also possible that the added chemicals can do harm to environment. This should definitely be included before implementing it, because otherwise it might create a big issue for the future.

7.8.2. Explanation of overall number

To check the MCA and consider certain criteria more important than others, it is possible to develop an overall number, which provide the best option. The most important criteria is of course the arsenic concentration. Then it is also from importance to pick up some social criteria. One of these criteria is the appearance, taste and smell, because this can make the water more or less attractive to the villagers to drink the water. If there is enough awareness among the people, maintenance may not be the biggest issue. However, the situation in Bihar is different than this and the villagers' first priority is gaining enough food. They don't want to spend too much time operating and maintaining their installation each day.

Here comes forward that the surface water treatment plants are the best solution for the long term. Than oxidation and AA are options for villages far from surface water. However, it must be taken in consideration that AA can cause kidney problems, but this requires more research.

8. Common issues with arsenic mitigation

Based on the results of the field trips and the conducted interviews it has become clear that a lot of the issues arising with arsenic mitigation are due to four factors. These are the awareness and mind-set of the local population, the lack of maintenance of the installed mitigation units, negligence in the correct instalment of mitigation facilities and community based social conflicts. These issues will be elaborated in this section and possible solutions will be proposed.

8.1 Maintenance

Many of the issues that were found with arsenic mitigation projects are due to a lack of maintenance. Common issues that were found regarding maintenance will be discussed in this paragraph.

One of the first things that became clear on the field trips and during the interviews was that all involved organizations are aiming at community maintenance of most of the arsenic removal units. When asked about this, most actors responded that since rural Bihar is so vast and difficult to reach, it is not feasible for governmental agencies to do the daily maintenance of these plants (Updhyay, 2012) (Kumar P. , 2012) (Dwivedi, 2012). It is difficult to accurately determine the workload of the PHED. More research in this field is necessary to determine if this workload is indeed too high to be active in the maintenance of the arsenic mitigation projects

Some of the absorption filters that were visited and tested already started showing arsenic levels above the legal limit. This can be due to improper backwashing or due to not replacing the filter media in time. Since the time to replace the filter media is very dependent on the daily water outtake and the (fluctuating) source arsenic levels, it is not possible to determine a guideline on when to replace this medium. The only way to ensure the filtered water stays arsenic free is to frequently visit the filter installations and test the water. However, as just mentioned it is hard for government agencies to visit these projects regularly due to the state of the roads and the vastness of rural Bihar.

A few years ago, 50 solar panel based membrane filters have been installed by DNA infrastructures by order of the Public Health and Engineering Department (PHED) (Kumar P. , 2012). Out of these 50 many are currently broken due to improper or lack of maintenance. This is mostly due to the fact that, in the initial contract, the PHED did not take maintenance into account. After the filters were installed by DNA Infrastructure, they were mostly abandoned.

When this became clear, the PHED made a new public procurement for the maintenance of these plants which was eventually taken by WaterLife. WaterLife installed new absorption filters in these plants. This issue rose completely due to negligence in drawing the contract by the PHED.

All plants now have a local caretaker assigned who is responsible for daily maintenance and backwashing. A common heard issue in Bhagalpur of these caretakers is that their salary is not paid or is not paid in time. These caretakers in Bhagalpur are supposed to be paid by Mahesh, a contractor of the PHED (Ranidayara, 2012).

In newly constructed arsenic removal units by the PHED, the community itself is responsible for the payment of maintenance and the caretaker (Singh E. , 2012). The villagers are required to pay a monthly fee for their water to the Gram Panchayat who can save this money in a bank account and pay the caretaker and eventual maintenance costs. Hopefully, this solves some of the issues regarding maintenance and personnel costs.

Issues still remain regarding maintenance. Often times rural villagers cannot seem to reach the supervising agencies in case of failure of the arsenic mitigation unit. It is unknown where this communication fails. Several attempts to backtrace the steps taken and to figure out where the communication failed have not resulted in clear or unambiguous answers. Literature research in this field and more targeted research can help in finding the answers needed.

In order to counter this and to create more transparency regarding the state of arsenic mitigation units, the Department for International Development (DFID) has started a pilot project based on mobile text messages. It is difficult to find the reason that the supervisors are hard to reach. More research has to be done in this field.

In this system the cell phone numbers of select people living near an arsenic removal unit or a piped water supply are collected and the people are instructed to text a message to a certain number should there be something wrong with the water supply. These text messages go into a central database where all issues with all water supplies of Bihar can be checked. The hope is that this will improve information flow and transparency and will make it harder for field operators to neglect issues with water supplies in their area. Initial pilot studies have proven to be successful. It is not certain that this system will solve maintenance issues with arsenic mitigation units but it might be a step in the right direction. (Kumar P. , 2012)

8.2 Awareness building

During our field trips it became clear that a large portion of the rural population was not, or not completely aware about arsenic, its health effects and possibilities for mitigation. This is in contradiction with the information received from various actors that were interviewed (Singh E. , 2012) (Updhyay, 2012) (Basu, 2013).

Insufficient arsenic awareness can lead to numerous issues with arsenic mitigation projects such as:

- Incorrect use of the mitigation unit
- No willingness to pay
- No willingness to perform maintenance
- Vandalism

There are a number of possibilities to further enhance arsenic awareness in rural Bihar. These are:

- Awareness building in schools/health institutions
- Prolonged awareness building

These will be elaborated in the following paragraphs.

8.2.1 Awareness building in schools/health institution

During the field trips a number of schools in the Vaishali and Bhagalpur districts of Bihar were visited. None of the teachers were able to tell about arsenic, its effects or the possibilities for mitigation.

Although school attendance in rural Bihar is the lowest in the country, still more than 50% of the children attend school on a daily basis (ASER Centre, 2012), and a lot of progress regarding arsenic awareness and therefore mitigation can be made if this issue would be taught more in rural schools. Current tries to adopt sanitation and health in the school's curriculum have thus far not resulted in anything. More cooperation between government agencies is required to tackle this issue (Kumar P. , 2012). Since the Department for International Development (DFID) is already maintaining contact with many governmental agencies, they are in a perfect position to further work on this issue.

Although we have not spoken with any health institution or hospitals in India, it became clear that all doctors hardly have knowledge regarding arsenicosis. In the rural areas of Bihar, people with symptoms go to see a local general practitioner. The GP sees the symptoms, but they do not know that these symptoms are all due to arsenicosis. Actually, they have never heard about it.

The health sector is facing lots of problems. Especially in Bihar, lots of doctors are not well educated regarding arsenicosis. There is also not any co-operation between PHED and hospitals to tackle this huge problem. In the health sector, doctors should be more aware of problems regarding hygiene and drinking water. They should have more knowledge regarding arsenic, fluoride and iron, but it requires more collaboration between different parties

The only hospital that has specialized doctors in arsenicosis is in Kolkata (West-Bengal). Taking into account that people in rural Bihar has less money and knowledge regarding hygiene and drinking water problems, they cannot afford it to go to Kolkata to get a treatment.

8.2.2 Prolonged awareness building

Another often heard solution regarding awareness building is to spend more time in a village in the build-up of a mitigation project. Often a time, the mitigation supplying organization organizes a few meetings in a village and when they get the permission of the Gram Panchayat, they start building immediately. This does not provide the villagers with much trust in the organization, and the organization will not be able to truly get a grip on the issues and problems that will arise during the construction and usage of the mitigation project.

Therefore, in an ideal scenario, the mitigation supplying organization should spent a couple of weeks eating and sleeping in the targeted village so that mutual understanding and trust are built (Santdasani, 2012) (Kumar P. , 2012) (Choudhary, 2012) (Bose, 2012).

8.3 Negligence

There are many issues regarding arsenic mitigation that are due to governmental negligence. This comes forward mostly in the fact that a lot of mitigation structures are being constructed, without constructing them truly properly. Constructing all these mitigation structures does look god on paper for the Public Health and Engineering Department (PHED), however when you look at how many people are truly drinking arsenic free and safe water, the outcomes are a lot less hopeful.

Common issues regarding negligence are the following:

- Not enough attention to awareness building
- Improper transfer of the land
- Incorrect disposal of sludge and backwash
- Improper after-care service and maintenance

These issues will be elaborated in the following paragraphs.

8.3.1 Not enough attention to awareness building

In contradiction with most official statements (Singh E. , 2012) (Updhyay, 2012) (Dwivedi, 2012) (Basu, 2013), a lot of people in rural Bihar are still not aware of the effects of arsenic. Villagers that were interviewed regarding arsenic awareness while standing next to different mitigation structures were not always aware of arsenic or why the mitigation structure was placed.

Many mitigation projects are built in a sort of hit and run style, where the structure is deployed and the responsible company leaves directly after. The PHED should focus more on understanding the issues in the different villages and working on a solution together with the community, before installing mitigation projects. The PHED acknowledges this and will try to give more attention to the social aspects of the mitigation technologies in the upcoming years.

8.3.2 Improper transfer of the land

Most of the solar based arsenic removal units are built upon land that was previously owned by one of the village members. Many times, this land was not correctly transferred after the construction of the removal unit was completed. Therefore the villagers still consider this as their own land and choose themselves who they allow to take water from the filter unit and who they disallow.

We have seen this for example in Vaishali. A filter was installed here by DNA infrastructures and later maintenance was taken over by the WaterLife firm. Daily maintenance is done by the owner of the land. The Mukhiya of the village informed us that the inhabitants of his village were not allowed to take water from the filter (Ray, 2012). Our readings in the operation log book also showed that there was only around 50 litre of water used each day. This fits with the story of the Mukhiya.

The Mukhiya has tried to contact local authorities and the PHED about this issue, but due to the wealth and power of the land owner this has thus far had no results.

8.3.3 Incorrect disposal of sludge and backwash

Another issue that illustrates the negligence that is present in installing arsenic mitigation structures is the disposal of sludge and backwash. During maintenance of absorption filters, sludge and backwash with a high concentration of arsenic is produced. There are currently no ways to deal with this sludge and backwash other than to store it safely where none of it can again contaminate the ground water.

In many filter installations however, the sludge and backwash after maintenance are just stored in non-closed underground tanks or are just spread out over the area adjacent to the filter installation. This will cause very high arsenic concentration in the groundwater in the direct area of the filter installation, thereby poisoning the surrounding hand pumps.

8.3.4 Improper after-care service and maintenance

Another issue that comes forward because of negligence is that after-care service and maintenance is most of the time non-existent. Many absorption filters have already started showing arsenic levels over 10 ppb due to the filter media being saturated. Since there are not many checks on the water quality level these issues are found late and even when it is found the proper course of action is not always executed. This results in people that think they are drinking safe, filtered water while in reality the water is still contaminated. If they start showing symptoms after prolonged exposure to this water, they might lose faith in filter installations and go back to their hand pumps. Social damage like this is very hard to reverse.

Also if there are issues like those managed in the “improper transfer of land” paragraph, no action is taken most of the time.

More transparency and an active involvement from the PHED or other governmental organizations are needed in order to make arsenic mitigation projects successful in general.

8.4 Social conflicts

The last major issue regarding arsenic mitigation projects are social conflicts in the rural areas.

We have seen a lot of examples regarding social conflicts in arsenic mitigation projects. For example we have visited a village called Chanda, next to Sinha-Pandey Tola. Sinha-Pandey Tola was supplied with treated surface water from the Ganga River by the Mozempur plant. Chanda however, had been supplied but villagers of Sinha-Pandey Tola had destroyed the pipes to their village.

We have also seen many filters where the owners of the land the filter was placed on disallowed certain people or the entire village to use their water, for example in Vaishali and Maner. In Vaishali the land owner felt it was his right to do so, since the land on which the filter was placed was him and not properly transferred. The land owner in Maner disallowed people to use it since he was afraid the filter might break and he would be held responsible for paying the damages. However, even after offering payment, the villagers were still not allowed to use the filter.

In Bhagalpur we have seen filter installations that provided water through pipes and taps to the immediate area. Some of these taps, which were settled in concrete, were also broken and dysfunctional. This could also be due to social conflicts.

Since the caste system is still very common in rural Bihar, many of the social conflicts that are encountered could be due to caste differences. Solving these issues is hard and can only be done by educating the entire rural population, a process that will take many years.

9. Conclusions

This study has been performed in order to provide further insight in the current status of arsenic mitigation projects in rural Bihar, India. The main goal of this study was:

To provide further insight in the successes and failures of different arsenic mitigation techniques and provide a strategy for handling the arsenic issue in the upcoming years.

In this section the first part of this goal will be answered. The second part of this goal will be elaborated in the recommendations section.

There is a number of different arsenic mitigation technologies applied in the rural areas of Bihar. These are:

- Wellhead absorption filters
- Gravity driven absorption filters
- Solar panel based absorption filters
- Solar panel based membrane filters
- Treated surface water supply plants through piped water
- Open wells / sanitary wells

For further analysis, it is useful to split these mitigation technologies into 6 sectors. These sectors are based on whether the project uses some kind of filtration, or uses arsenic-free water to start with, and whether the project is household level, community level or multi-village level.

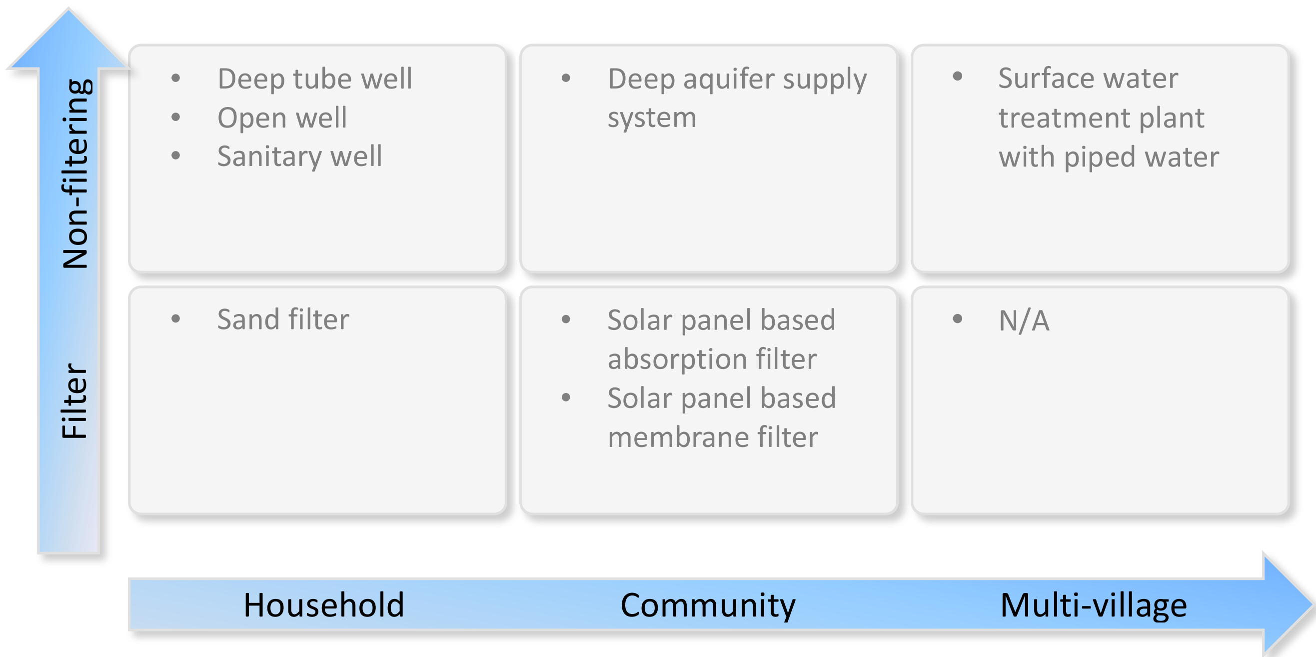

Figure 9-1: Classification of arsenic mitigation projects

For each of the six sectors of mitigation projects, the pros and cons will be discussed in the upcoming paragraphs.

Open wells are often mentioned as a solution for arsenic-free water. An issue with open wells is that it is easily contaminated by bacteria and other microbes. These can be treated using chlorine or by the use of sanitary wells. Constructing wells in Bihar is difficult due to the sandy surface. This makes constructing much more expensive than in other, rocky parts of India. Another issue is that during the drought, the wells will run dry and villagers will have to seek other water sources. Lastly, the wells that were tested during the field trips, all still contained arsenic levels of at least 15 ppb. While this is lower than the surrounding hand pumps, it is still above the level of 10 ppb set by the World Health Organization. Therefore, open wells cannot be considered as a long-term solution for dealing with arsenic.

Deep tube wells thus far seem as a safe and proper solution for getting arsenic-free water. However, the long term safety of deep aquifers is not guaranteed as improper installation of the tube wells and over consummation of water of these deep aquifers can lead to contamination of these deep aquifers. More research on the long term safety of these deep aquifers is therefore necessary in order to do further recommendations regarding the use of deep tube wells. Since villagers will have to install these wells themselves, it is critical that they are made fully aware of the effects of arsenic in order for deep tube wells to succeed as a solution for arsenic-free water.

Household sand filters have not been used much in Bihar. Experiences in other regions such as West Bengal and Bangladesh indicate that household level filters are often successful at the start of a project, but in the long term, people start losing their interest in the filter and maintenance of the filter is neglected. Complete arsenic awareness is necessary in order for household level filters to succeed.

Solar panel based filters have been deployed in Bihar with varying success. Many issues plague these community level filters. Firstly, there are a lot of social conflicts regarding the use of these filters. Certain households or even entire villages are excluded from the use of the filter by the maintainer. Reasons given for these exclusions are for example fear of the filter breaking. Also improper transfer of the land after construction of the filter is a reason that is often heard for exclusion.

Furthermore, there have been issues regarding maintenance after the construction. Recently, 50 of these filters have been installed by order of the Public Health and Engineering Department. However, maintenance was not a part of the construction contract and therefore most of these filters have become defunct. Maintenance is currently taken over by WaterLife and slowly these filters are being brought back in operation.

Another major issue regarding filters is the disposal of backwash and sludge. Since proper treatment of this highly concentrated material is expensive and difficult, most backwash and sludge is simply dumped in the area. This creates a high concentration of arsenic in the area and thereby poisons local villagers even more. The last issue regarding community based filters is the difficulty of maintenance. Since no guidelines exist on the replacement of the filter media, many filters have already started showing arsenic levels of over 10 ppb. Currently, the only way to keep this filters working properly, are regular check-ups by governmental agencies. However, due to the large number of filter units required and the vastness and inaccessibility of many rural areas, this is a very difficult task.

Deep aquifer supply systems suffer from the same issues as deep tube wells. As long as the long term safety of deep aquifers cannot be guaranteed, this is not a sustainable option for providing arsenic-free water. Furthermore, it is suspected that the same issues that have arisen with solar panel based community filters will raise with community level deep aquifer supply systems.

Surface water treatment plants with piped water are currently being constructed in Bihar. Issues that plague solar panel based filters are less prevalent with large surface water supply plants. Firstly the use of non-contaminated water removes issues regarding filter media, backwash disposal and sludge disposal; issues for which a proper solution is not yet available. Secondly, due to the large scale of these plants, it is easier for governments to maintain and check regularly. Lastly, since the water is provided through pipes, people are less aware of the water source and the fact that they are sharing it with other communities. This could mean that there are less social conflicts regarding drinking water.

In conclusion, most of the issues regarding arsenic mitigation can be put into four categories. These are:

- Insufficient maintenance
- Insufficient awareness of local population
- Negligence
- Social conflicts

All of these issues have to be managed in order for arsenic mitigation projects in the future to work.

10. Recommendations

In the conclusions section the first part of the main research goal is elaborated.

To provide further insight in the successes and failures of different arsenic mitigation techniques and provide a strategy for handling the arsenic issue in the upcoming years.

With the knowledge gained in this research it is possible to do recommendations regarding to dealing with arsenic in a future-proof and sustainable manner. These recommendations will be elaborated in this section. At the end of this section, knowledge gaps will be discussed and the need for future research elaborated.

In order for an arsenic mitigation project to be considered successful it has to meet a number of criteria. These are:

- Large total number of users
- Good availability to all villagers / low risk of social conflicts
- Low maintenance and initial cost
- Easy to maintain
- Good plans for future maintenance
- Good water quality (Arsenic, Iron, Microbes, Taste, Smell)

Dealing with arsenic in the future consists mainly of two parts. These are Social viability and technical viability. In the following paragraphs these aspects will be elaborated and recommendations for each type of viability will be made.

Social viability

In order to keep the mitigation project operational, it is of critical importance that all inhabitants are truly aware of the effects and presence of arsenic, and the need for mitigation. The first important step in achieving this overall awareness is to integrate basic knowledge about arsenic and drinking water and sanitation in general in the schools standard curriculum. Cooperation between government agencies is critical in order to achieve a decent programme for teaching these subjects. There are already development agencies, such as the Department for International Development, that maintain contact with different governmental agencies and they are in a perfect position to make this collaboration happen and get governmental agencies to include drinking water safety and sanitation in the schools program.

Due to the size and vastness of Bihar it is not feasible to have government maintained mitigation projects in every village. This means that the community has to step up and maintain these projects. In order for community maintenance to succeed, it is vital that the entire community knows the project and was involved in setting it up. Community participation and mobilization are necessary for community maintenance to succeed.

In order to build this community participation, prolonged awareness building is necessary. This means that the installing agency needs to spend time in a village to build trust and to get to know the villagers. Representatives from all groups in the village need to be assigned and meetings need to be held with these representatives in order to determine the placement of the mitigation structure, the placement of distribution points and other aspects.

In order for community maintenance to succeed, the community itself should also pay for the maintenance of the structure. Payments can be collected by the local government such as the Gram Panchayat or the Mukhiya. Paying for the water increases bonding with the project and improves self-controlling aspects of the community.

Technical viability

Because of the many issues that are prevalent with filtering arsenic contaminated water, such as sludge and backwash disposal and management of the filter media, this option is only viable as a last resort. It is better to use non arsenic contaminated water as a source. Since the long term safety of deep aquifers cannot be guaranteed if large quantities of water are being subtracted, the only arsenic-free water source that remains available is surface water.

Most of the arsenic affected areas in Bihar are relatively close to the Ganga River. Therefore, the Ganga is a suitable option for supplying safe drinking water. In order to supply a large portion of the Bihari inhabitants with drinking water, large scale surface water treatment plants have to be built which supply the treated water to the villages using pipes. In the long run these treatment plants can also provide household connections

One of these multi village surface water plants is constructed in Mozempur. This plant should be monitored carefully the upcoming years to see if this is truly a viable alternative. Possible issues with large scale treatment plants are that they require power to operate, and power is not always available in Bihar. The use of solar panels and storing treated water in water towers can minimize the downtime when a power failure occurs.

Another important aspect is surface water contamination by industries. This has to be monitored closely if so many people will become dependent on surface water as their drinking water source.

Treated surface water cannot be made available to all of Bihar on a short time scale. These plants require large investments in time and money.

In the meantime villagers that have access to an open well should be advised to use this instead of their regular tube well.

For villagers that cannot viably be supplied with surface water the only option at the moment seems to treat the ground water using filters, since the long term safety of deep aquifers cannot be guaranteed.

When using filters the following aspects need to be carefully dealt with:

- Social conflicts
- Exclusion
- Distribution of filtered water
- Sludge disposal
- Backwash disposal
- Maintenance
- Filter media replacement

Social conflicts and exclusion can be minimized by creating a finely-meshed grid for the distribution of the filtered water. Since people have many choices on where to get their water and do not have to share it with as many people, exclusion and vandalism have less effect than with a non-finely-meshed grid.

Sludge and backwash have to be stored in sealed tanks until a proper way of disposing of it is available. Future possibilities for disposing sludge and backwash are through bioremediation and making bricks out of the sludge.

For maintenance it is especially important for the entire community to be aware of the mitigation project so that there can be social control on the maintenance. For the replacement of the filter media it is necessary for governmental agencies to regularly check on the filter and whether the filter media is saturated.

Future research

Much research still has to be done in the field of arsenic in order to get a truly clear overview of the problem and possible solutions. The most pressing issues that need further research are:

- The reasons for failing communication between project users and supervisors
- The workload of the PHED and the time required for maintaining local arsenic removal projects
- The long term safety of deep aquifers
- The long term safety of surface water (especially the Ganga River)
- The correct disposal of sludge and backwash
- The health effects of long term use of activated alumina
- The effects and presence of arsenic in the food chain
- Better understanding of the source of arsenic and the way it is released into the groundwater
- Better comprehensive database of the concentrations to understand the possible effects on the distribution of the arsenic by subsurface flow
- Filter formations which should be easy to operate and maintain (adaption to local willingness)
- Knowledge on medical infrastructure relating to diagnosis and treatment of arsenicosis

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12. Appendix A: Interviews with rural population

In this appendix summaries can be found of the interviews that were conducted with the rural population in the areas where field trips were conducted. First, a blank version of the questionnaire is provided and elaborated. After that all interview summaries can be found grouped by region.

1

General

Ser. No	
District / Block	
Village	

Personal introduction

Name	
age	
sex	
marital status	
Family size	
profession	
Education rate/ Literacy rate	
Monthly family income	
religion/caste	

2

Water supply

	Which resource	Distance to resource?	How long have you been using this source	Do you have to share this resource	How much water	shortages?	Do you have to pay for this resource	Would you be willing to pay (how much)
Drinking;								
Washing								
Laundry								
Cooking								
Latrine								
Irrigation								
Cattle								

Health

Any illnesses	
Receiving treatment / medication	
Registered as arsenicosis	
Anyone in household has symptoms of arsenicosis	

3

Arsenic Awareness

What do you think Arsenic is:

....
....
....
....

presence of arsenic

....
....
....

health effects

....
....
....
....

remedial options

....
....
....
....

4

cause of contamination

....

....

....

....

involved organisations

....

....

....

....

testing TWs (red, green)

....

....

....

....

From whom is this information? (TV, radio, newspaper, magazine, folders, mouth-to-mouth,education)?

....

....

....

....

5

Extent of problem

....

....

....

....

Need for mitigation measures

....

....

....

....

Liabilityof involved organisations?

....

....

....

....

6

Arsenic awareness meetings

Has there ever been a meeting in order to build awareness? Organised by whom?

....

....

....

Who were invited to this meeting? (how many, on which base?)

....

....

....

Did you attend? Why? Why not?

....

....

....

....

How many did attend to the meeting?

....

....

7

Gender, age, status, religion Bias? Why?

....
....
....
....

What has been discussed? (presence, cause, effects, options, etc.)

....
....
....
....

What forms of information processing? (spoken lecture, images, music, etc.)

....
....
....
....

8

Who performed the information processing?

1.	One	/	Several
2.	Woman	/	Man
3.	Indian	/	Western
4.	Local	/	Not local
5.	Familiar	/	Unfamiliar

Did you like him/ her/them? Believe? Trust? Why?

....

....

....

....

What did you learn?

....

....

....

....

What were the results of the meeting?

....

....

....

....

9

Water source

Your water source tested?	
When has this test been conducted?	
Was this the first time it has been tested on arsenic? (frequency)	
How was your water source tested?	
Affected? Concentration?	
Who performed testing?	
Paint/seal?	

What did they tell you?

Reason of testing

....
....
....

meaning of contamination

....
....
....

10

meaning red/green

....

....

....

use of contaminated water

....

....

....

proposal of short term mitigation (sharing, chemicals, etc.)

....

....

....

Is your entire family aware this?

....

....

Do you, or anyone you know, drink arsenic contaminated water? Why?

....

....

....

11

If water source is arsenic-free

Do you care about how much water you use per day from TW?

....
....

Do you allow people with arsenic affected TWs to use yours?

....
....

How many people/families are using your TW?

....
....

Who are allowed and who aren't?

....
....

If distinction, on what ground (poverty, religion, family, age)?

....
....

How much water do you allow them to use?

....
....

12

If water source is contaminated

What water source do you use currently

1. affected shallow TW (page 13)
2. unaffected shallow TW (page 14)
3. deep TW (page 15)
4. pond (page 16)
5. dug well (page 16)
6. rainwater
7. other

13

Affected shallow TW

Do you treat the water by?

1. Filter

Do you know how the filter works	
Who provided the filter	
Did you pay for the filter (how much)	
Is the capacity sufficient	
Who does replace the filter?	
What if the filter breaks	

2. Chemicals

Which chemicals	
Who provided the chemicals	
Capacity sufficient	
What do you do with residue	
Do you like this filtration?	

3. Filter and Chemicals
4. passive sedimentation
5. Other
6. If no: why do you still drink this contaminated water?

....
....
....

14

Unaffected shallow TW

Whose TW?

....

....

Where is the TW?

....

How much water can you take? Sufficient?

....

....

Do you pay for the water?

....

....

How many families are using the TW?

....

....

Who can and can't use the TW?

....

....

15

Deep TW

Where is the deep TW situated? Does the location give problems?

Who is taking care of fetching water?

Problems with other users?

Who installed deep TW?

Who paid for it? Did you (have to) contribute? How much? Too much?

16

Surface water

Do you treat the water?

Is the surface water used also for:

- Fishing
- Laundry
- Latrine
- Washing

Who is in control of the source

Distance to the source

Who fetches the water

Problems with other users

12.1 Bhojpur

Date: December 1st 2012
Time: 11.00 AM

Supervisor of the Bakhorapur temple: Kanchan Kishore Singh
District: Bhojpur
Block: Barhara
Village: Bakhorapur

This Hindu temple is a place where Hindus come together to pray and marry. However, the influences of the temple in people's daily life are rather small.

This religious institution knows about the various problems in Bhojpur district: lack of electricity, supply of water and decent education. On the one hand, they feel no responsibility to provide solutions for the people and on the other hand, they have no fund to do something.

Kanchan knows about the extensive problem of arsenic in ground and groundwater. We have been told that there are no on-going projects in the village of Bakhorapur. We asked him what he knows about the water supply in his village. He told us that every household has its own hand pump. There are approximately 1000 pumps in Bakhorapur. Around 10% of the population in that village has ill symptoms due to arsenic.

In agricultural sector, many bigger farmers have Deep Tube Wells.

Most of the men work in the agricultural sector, while women stay at home to take care of the children and carry out household activities. We have been told that women face a higher risk to be contaminated by arsenic. The reason is that water from the Deep Tube Wells are not contaminated by arsenic, whereas Tube Wells at home have a higher risk to be contaminated.

Dr. Rajeev Kumar mentioned that in this village lot of researches has been carried out by the A.N. College and Delft University of Technology. But when we asked Dr. Rajeev Kumar and Kanchan why nobody has been able to provide a proper solution so far, no one could give us an answer.

Date: December 1st 2012
Time: 12:00

Dhrup Lal, 45 year old farmer. Rps. 6000/month.
District: Bhojpur
Block: Barhara
Village: Sinha

The first interview from the questionnaire we took was a farmer whose family live in a small house. In the backyard was a tube well. This would probably be contaminated with arsenic. During the interview with the owner, he told us he had never heard of arsenic. Because of this, we were able to conclude the meeting to build awareness was insufficient. The most important thing to tell the people is that they are consuming arsenic contaminated water, the health effects of this fact and the actions they should undertake. From earlier reports we noticed that responsibility should be minimalized, because of lack of money and interest. Besides we did not see the visible health effects of arsenicosis. Not with the owner, nor his children and wife.

Compared with other incomes farmers get in adjacent regions, he does not have a low monthly income for his 9 other family members. When he heard about the low quality of the surface water, he also decided to install a 70 ft. deep tube well 13 years ago. By circumstances we were not able to investigate how much he would be prepared to pay for arsenic free water. Given his relatively high income and small family size that could probably be significant higher than poorer families. Unfortunately this was hard to find out, because of his lack of knowledge and awareness about the arsenic problem.

This was also the first time a sample was taken from his tube well. Before that no educational or scientific institution, NGO or government tested his groundwater. Here we can conclude that there were insufficient awareness building and even if there were, it did not impress the villagers enough to talk about it.

Date: December 1st 2012
Time: 13:00

Sudersan Singh, 60 year old farmer. Rps 5000/month
District: Bhojpur
Block: Barhara
Village: Sinha

After the interview and a few samples were taken, we interviewed the next villager, from another block. He looked wealthier than the previous, but after asking his monthly income, that assumption was not true.

He actually knew what arsenic is. He was told by other villagers after they saw that some villagers showed some symptoms of arsenicosis. Despite of that, he used a tube well without filter. He did not know whether the tube well was contaminated. No organization or institution ever took a sample of the water.

Nor he, nor his child who was standing next, to him showed signs of arsenicosis. So probably, despite of the low depth of the hand pump (80 ft.), the pump does not contain arsenic.

The man was more educated than the previous. So he had some knowledge of what arsenic is and that it could be present in the groundwater. He also knew a little bit of the health effects and options to not drink contaminated water. He suggested surface water. Because he did not noticed any health effects of arsenicosis, there has never been an awareness meeting and other villagers also did not use any alternative option, he also still takes the water from his hand pump.

Another fact we were met for the first time is that he did not allow other people to use his pump. Before we came here we were told and we have read that the people would be aware of the problem en knew what arsenic is. That, in this case, is not true. People have little or no knowledge about the arsenic. So the question to use someone else his pump, which is not affected with arsenic, is not of interest in this case. People have their own pump, whether it is contaminated or not. So you do not have to go to the neighbours to use their pump, because they will probably have some kind of the same contaminated pump, if they even know about arsenic. Because there has no implementation of a mitigation technique been applied in that area, people do not have the reason to use somebody else his pump. That was the main reason we did not get an answer if the farmer distinct people from his pump on personal grounds.

Date: December 1st 2012
Time: 14:00

Brijbihan Pandey. A 55 year old farmer.
District: Bhojpur
Block: Barhara
Village: Sinha-Pandey Tola

The third location we visited was where the highest concentration of arsenic in Bihar was found, namely 1861 ppb. When we arrived we saw a blue pump, which run water constantly, a primitive rainwater harvesting unit and an open dug well with hand pump. The blue pump was the pump they were using at the moment, because of his abstraction location. This was namely the surface water of the Gang River. This water contains low to zero parts of arsenic. It was built by the PHED, the state government. We guess because this location is a special one, because of the highest concentration.

We also saw some UNICEF pictures, but we do not know what they have done exactly. Maybe the interview with UNICEF will bring outcome to this unanswered question.

Some young boys had the white spots on their skin, but that would probably be the reason of using the contaminated water before the PHED installed the surface water installation.

Brijbihan Pandey, the man we interviewed, was also a farmer in the little village. He said that before the PHED installed the surface water installation, they used a contaminated hand pump of 100 ft. depth for 20 years. The highest concentration which was found was 1861 ppb (A.N. College Patna). Because of this dreadful high concentration there was a meeting by UNICEF to create some awareness among the people. Brijbihan also attended, as well as a majority of the other villagers. The people who performed the information processing were partly Indian and partly Western and they were not local people. That may be the reason people were not really convinced by them.

It looked like the problem was solved here, but from other projects the main cause of the continued use of arsenic contaminated water was the bad maintenance. The Ganga piped water installation worked on electricity. If this falls away, the people will use a dug well, constructed by the owner (besides he did not see a problem in the fact other villagers used it also. But perhaps he said it, because of the dozens of villagers surrounding him). It is not likely they would use the dug well, because of the high concentration of iron, which oxidizes in the open air. This process gives a yellow colour to the water, which is not tasteful to drink anymore. On the other hand, it contains a hand pump, which reduces the process to obtain water from the well. It is important to keep in mind that the people are not aware enough of the problem of arsenic. If they think it is too expensive in the way of money or energy, they will reach out for the arsenic contaminated pump, because of his free use, easy way to handle and less difficult way to obtain water. They will use the high contaminated water pump again. When we asked who they think is responsible for the maintenance of the pump, they said with hesitating voice it should be the PHED.

Date: December 1st 2012
Time: 15:00

Siyaram Sing, Ombrakash Singh and Urmila Deri Singh (patient). Owner is a 55 year old farmer. Rps. 2100/month.
District: Bhojpur
Block: Barhara
Village: Chanda

After that, we walked 200 meter further away. There lived a farmer, who looked not very poor. He told that the village we just visited had cut of their supply of Ganga water. So that is also a possibility for the villagers not to get the arsenic free water. There lived a woman, who had clear spots on her chest. She was ashamed to show herself, because of her appearance. In that condition she would probably not functioning right in the social system, which can consequence in social disadvantage within the local community.

Because of the suppression of the other community the family was not able to obtain arsenic free water. That was the reason they still used a hand pump (110 ft. depth). They are using it now for 10 years and had access to the surface water of the Ganga for only a short period.

The family was very poor and uneducated. They do not earn very much and the family counts more than 30 members. But notwithstanding they actually knew about the arsenic problem. Probably because of the location, which was nearby the village were the highest concentration was found. They were also getting curious when the woman was showing the symptoms of arsenic. She was treated by the closest hospital. Despite of the ill member, the family was still using the water, because they do not have any better option. We guess they are aware enough (anyway more than average), also because they attended the meeting with UNICEF. They also said they met people of Central Groundwater Board. At the meeting were approximately 50 house owners present, which were around 250 people.

The Mozempur plant was build 1.5 to 2 years ago. Before that, in 2010, UNICEF visited the family and they tested the hand pump by spectrophotometry. The result was that indeed the pump was affected, just like the symptoms of the woman already hinted. UNICEF painted the pump red. Not much later the plant was build.

We asked them why they are still drinking the contaminated water and do not use a filter or chemicals, but as expected they have no money for that. Also stored water turns yellow in a few minutes, which indicated the level of iron and arsenic is very high. Also they thought this water is not drinkable.

Date: December 1st 2012
Time: 16.00 AM

Supervisor Mozempur water treatment plant
District: Bhojpur
Block: Barhara
Village: Mozempur

The last thing we visited this day was the water treatment plant. It was a great complex with installations that purify the water from bad bacteria. Firstly we looked around over the Ganga, the supply tank and inside the building where the water is treated (filtration and treatment with chloride). At the Ganga we were told that not only (low concentration of) natural arsenic is in the water, but also arsenic dumped by factories upstream.

When we spoke to the supervisor of the plant he told us the water plant offers clean water trough pipes for 39 villages of around 2000 people. The capacity of the plant is approximately 6.4 million litres a day. Out of this numbers when conclude that more households can be connected to the plant. He said that that was true and that 500 more households in Rajiapur will be connected.

For only the amount of Rps. 10 per month the people can obtain clean arsenic free water. That amount is payable for a family and that should not be a problem. This have to be conducted under the condition the people are aware of the problem and see the problem could have a fatal end.

The supervisor told the plant was built by the PHED for approximately Rps. 64 million and the operational costs are around Rps. 10 million per year. So also the maintenance is in hands of PHED Bihar. There were also plans to expand the reach to Buxar and Maner.

At last we asked the supervisor what he thinks about the best solution to this problem. He told us that everyone in the proximity of surface water, like rivers and ponds, should have their own water pipe.

12.2 Maner

Date: December 4th 2012
Time: 9.30 AM

District: Patna
Block: Maner
Village: Ramnagar

In the early morning, we arrived in Maner. These villagers are aware of the arsenic contamination problem in their village. Students from the Bethlehem University USA installed an iron adsorption filter in front of his house more than a year ago. Not much later, the village also received an aero-filter. Both filters are still functioning and the villager who lives the nearest to the filters has been designated to be responsible for the maintenance. This person is highly educated compared with the rest of the villagers.

Before his village received both filters, he made use of the affected hand pump inside his house. This hand pump has an arsenic concentration above 200 ppb.

One family member suffers from skin diseases due to arsenic. He or she has received natural treatment from the local GP. Since the new filtration has been installed, the health condition of this person has remained stable.

Since the adsorption filter is operational, the whole village makes use of this adsorption filter. There are approximately 1000 villagers who live in this village, but only around 400 are able to use this filter. The other 600 do not use this filter because of the distance between their houses and this unit (around 1-2 kilometres). There might be a probability that those people will suffer due to arsenic sooner or later.

Students from the Karlsruhe University of Applied Science installed the aero-filter a year ago. This filter was built to be tested, but it has never worked. The use and maintenance of this filter requires a skilled person. The villager told us that this is definitely not the solution.

Since the adsorption filter has been installed, he makes use of this source for drinking and cooking. For washing, laundry, latrine and cattle, he makes use of the affected hand pump inside his house. For irrigation he uses a bore well.

We also asked him if he is willing to pay for household connection tap water that is arsenic-free. He says that he is willing to pay an amount of 100 rupees per month.

In the case of building awareness, we have been told that only the Public Health Engineering Department and A.N. College came here to inform about the arsenic problem. After a while, the PHED did not come over anymore. Only the A.N. College came to visit the filters and check if everything is alright.

We later heard that most of the villagers however, are not allowed by the owner of this filter, to use it (Bose, 2012).

Date: December 4th 2012
Time: 1.00 PM

District: Patna
Block: Maner
Village: Haldi Chapsa

A few kilometres away from the Ramnagar village, we interviewed a random villager to check how big the awareness is. This villager and his family know hardly anything about arsenic. Then another villager, who also joined this interview, knows about the arsenic issue. He is a student from the Patna University, department of Geosciences.

His family and also the whole community in this village make use of the open well in front of his house. This well is used for cooking, washing, laundry, latrine and cattle. For irrigation they use a bore well, not far away from this open well.

Suddenly, a lady attended the interview and she showed us that she has a damaged skin. It can be caused by arsenic, but nobody knows. She receives natural treatment from the local GP.

It is possible that the water is contaminated with arsenic even in open well, but probably with lower concentration of arsenic. Due to lack of knowledge and awareness, it seems that no one really cares about this problem.

12.3 Vaishali

Date: December 10th 2012
Time: 9.00 AM

District: Vaishali
Block: Bidulpur
Village: Pakri

Interview with a local school named Gyan Deep Public school. This school provides for around 285 children courses from the first class to third class in maths, science and English. With this interview, we want to gather information of the awareness regarding arsenic of the children and teachers in this school.

This meeting was held at the schoolyard. The school has 3 classrooms and about 285 children get education. We spoke to the principal (Banban Kumar Chaudhry) of the school who is also a teacher-in-charge. We saw an open well, in front of this school, which was constructed 35 years ago. The whole school can make use of this water source and villagers who live near the school are allowed to make use of the open well as well. He said: 'it is a community water source, so if everyone wants to make use of it, they are all allowed to. It is probably arsenic free, and once a month the water will be treated with chlorine by me.'

We asked the principal what he knows about arsenic, and what he teaches the children about arsenic. He said: 'Arsenic can cause many illnesses like skin cancer. We cannot see the arsenic in drinking water, nor taste it. So the drinking water seems to be safe. We cannot tell the children about arsenic, because we lack knowledge about arsenic too!' He cannot tell us more than that. Then we asked: 'who provides the courses in this school, is that you (principal)?' He responds: 'the CBSE (Central Board of Secondary Education) compose the guideline what should be taught. The guideline does not say that we have to teach them about safe drinking water. If we have the knowledge, we would definitely inform those children about safe drinking water.'

From 2005 until now A.N. College has come to this village to test the hand pumps of the entire village. For us, it was surprisingly to see that no one has any illnesses or visible skin symptoms due to arsenic. Not much later, this area was designated as an affected area. We have been told that UNICEF came to this school to install a hand pump, without an arsenic filter in 2006. We are surprised again. Besides, there is no filter present. The hand pump has been destroyed by the school children. UNICEF never came back to check whether the hand pump is still functioning or not. The principal tried to contact UNICEF, but unfortunately they have never responded.

The school is not sure if it is willing to pay for pipe water. All children carry their own water bottle to school. School starts at 9.00AM and ends at 1.00PM. We do not think it is necessary to have pipe water in this school.'

The school cannot be blamed for the lack of knowledge about arsenic. We think it is mismanagement and bad communication of all organizations that are involved in the drinking water issue and in this particular case about arsenic.

We spoke to 2 school students regarding arsenic. Both of them have never heard about arsenic. It is alarmingly to hear that those children never have heard of it. If the children will not stop drinking arsenic water, all of them will suffer sooner or later.

Alas, we were not able to check the village how the people deal with arsenic due to time shortage.

Date: December 10th 2012
Time: 11.00 AM

District: Vaishali
Block: Bidulpur
Village: Chak Sikander

For this interview we accidentally met a villager, who is also an official-in-charge. With this interview, we want to gather information of his awareness regarding arsenic in drinking water. This interview was held in Vaishali district, Bidulpur block, Bihar.

A few kilometres away from the Deep Gyan Public School, we talked to Arjun Kumar, official-in-charge at the department of Development Authority at village level. He is graduated and earns around 5000 Rupees per month. With that money, he has to take care of his wife and 7 children.

This village is fairly educated. He knows a lot about arsenic, so he began to tell what he knows. An unknown NGO came by to tell the people how to deal with arsenic in drinking water. Almost everybody is aware of this problem, but there are not any arsenic removal units or household connection that provides arsenic free water to consume.

Some, who can afford it, bring bottled water from the town Hajipur to drink it. The distance from this village to the town is around 17 kilometres. Once in a while, someone provides bottled water from the town and delivers it to the villagers. Arjun Kumar said that he cannot afford to buy bottled water, because it is too expensive.

27 years ago he installed a hand pump in front of his house. He uses his hand pump for all purposes: drinking, washing, laundry, cooking etc. Only for irrigation, he uses a community bore well.

For what Arjun Kumar knows, there are no hand pumps in the village that has ever been tested. Most of the villagers are aware that arsenic could be a problem later, but it is not certain if the hand pumps are affected or not. Therefore we wanted to know if he is willing to pay for water through pipe and whether there is arsenic or not. He is willing to pay for a household connection that would provide arsenic free water, but he is not willing to pay more than 10 Rupees per month. Arjun Kumar does not want his money to be spent on filter in hand pumps, because it requires lot of maintenance and he thinks he is not able to maintain it.

‘A water treatment plant like in Mozempur is currently being built,’ he said. ‘In about a couple of years, we will get water through pipe. But we do not know when and how much it will cost.’

Date: December 10th 2012
Time: 12.30 AM

District: Vaishali
Block: Bidulpur
Village: Kolayanpur

When we arrived at the house of the Mukhiya, named Vijay Ray, he sent us immediately to the adsorption filter in his village. The adsorption filter is constructed in a shed by PHED and it requires electricity in order to function. A solar panel is installed next to the shed, which provides power for the adsorption filter. The son of the landowner checks how much water is used and he notes that down in a logbook every day.

Once a month, an engineer of an external company comes to check and maintain the filter. The engineer works for WaterLife. WaterLife is an external company that installs filter for drinking water.

The place where the filter was installed belongs to the community that is provided by the PHED. PHED built the filter on a place that belongs to a villager. That villager said: 'everyone can make use of this filter. It does not matter from which caste you are your profession etc.' we forgot to ask his name, so in this case we call him villager X.

When we went back to the Mukhiya, he explains what the real problem is in his village and probably also in whole India.

'Social conflicts in the Indian society are hard to solve. We also face that kind of conflicts. First of all, the filter that you have just visited is not for the community, but it belongs to him. The ground where the filter has been built on belongs to villager X. So when someone wants to get water from that filter, we all are not allowed to. The landowner will answer: 'it is broken, or there is no water anymore.'' The Mukhiya was very angry during the interview. What we can conclude during the interview is that PHED or other government organization that is responsible for land expropriation has never thought that this might be a problem in the future.

That is just one side of the story. We do not know if this story is true. Probably a government organization has already bought the land to build the installation, but the former landowner has never accepted the fact that the ground does not belong to him anymore, even he is compensated or not.

'No one can do something against it. We complained many times at the PHED, but we never get response. The law protects the landowner for excluding people to use the filter, because the filter was built on his land. So it is not useful to call the police, because he also has the money and power to fix everything.'

Later when he has calmed down, he provides us some general information about the village. He thinks that almost all of the hand pumps are affected by arsenic. So maybe the whole village, with a population of 2000, will suffer from the arsenic consequences sooner or later. He thinks that no one can buy bottled water like people from the Chak Sikander village, because the monthly income of these people is 300 Rupees per month, not minding the agricultural incomes.

Every household has its own hand pump with a depth of 120 feet. He assumes that the villagers can afford 100 Rupees per month for safe drinking water through pipe.

In the entire village there is about 18 dug well. The entire village can use that water source, but due to the long distance between their home and the open well, not everyone will get water from that source.

As mentioned earlier, there was a meeting to build awareness. 150 people of the whole village came, while all the villagers were invited. Not everyone attended the meeting due to lack of communication. But could it be also that there is a lack of community participation?

It is hard to say how many people are aware of this problem, and how many people make use of safe sources like open wells. Around 10 per cent of the entire village is suffering from the consequences of arsenic. Social segregation, caste system and ‘money is power’ are common problems in this village and perhaps across whole India.

12.4 Buxar

Date: December 14th 2012
Time: 12:00 AM

District: Buxar
Block: Brahmpur
Village: Jaunhi Jagdishpur

Buxar is a district on the west of Bhojpur. It is known for the many visual symptoms of arsenicosis. It is also a very poor district, which perhaps is related with the arsenicosis symptoms because of the malnutrition of the villagers.

The first village was near to an important road through Buxar. Here we met the local reference of the PHED in Buxar. He said the future solution for Buxar should be some mini water supply schemes with solar power. One scheme will provide clean water for approximately 1200 villagers. Already 5 villages in Brahmpur and Chakki have been adapted to these schemes. Also some primitive filters with active alumina and charcoal were established, around 50 for community use and 30 units in school compounds. He only argues the response from the villagers to maintain and operate is poor.

In Jaunhi Jagdishpur we saw the first tube well (174 ft., 2 years old) with filter. This one was demolished. The filter technique was active alumina and charcoal. If it is right the pump should be controlled by the PHED every 6 months. In the meantime community participation is required. However, after installation nobody was pointed out to maintain the filter. Also nobody was trained for this work. The media of the filters were overused, which was the reason the filtered water showed higher concentrations of arsenic and the filter was broken. The positive observation was that there were not any signs of iron (discoloration) or arsenicosis. However, the villagers told that there was somebody who showed skin disease. Though, he was not present so an analysis of his symptoms was not possible.

Date: December 14th 2012
Time: 13:00 AM

District: Buxar
Block: Brahmpur
Village: Ekdar

Here was an iron filter installed by IIT Mumbai and financed by DST, government of India. The filter procedure was based on iron nails. There was no maintainer nor operator assigned. The water supplied by the filter had a bad odour, so there is not a reason for the villagers to maintain it, because they do not even use it. Instead of that they used a hand pump 20 meter away. The area where the iron filter was located was divided by a wall with the hand pump. The people at the side of the hand pump also use that pump. They showed symptoms of arsenicosis.

A few meters further away there was a small village and the Mukhiya was present. Within a few minutes we were surrounded by people who showed serious symptoms of an arsenic contamination. Within a short period of time, the PHED will install such a mini scheme as described above. The PHED guy told that during the installation (approximately 3 months) a villager will be assigned to maintain the installation and receive training in that job. Also, the villagers will pay the costs. It is very likely they will pay for that, considering the fact they showed many symptoms of arsenicosis. Also a few people died, while they had the same scale skin diseases. Of the people interviewed, approximately 80% showed spots on their skin.

Date: December 14th 2012
Time: 14:00 AM

District: Buxar
Block: Brahmpur
Village: Harnatpur

In these villages we saw such an installation. There was somebody for responsible, that was a good thing. It only took a long time before we could take a look inside, it may be the consequence he did not open it very often. Here we saw 4 filters, financed by the PHED. The filter was from DNA and the contractor was WaterLife. One of the 4 filters was a sealed box, which was vibrating. Perhaps here was some corruption going on, because also the PHED was not aware of the situation.

Also the sludge was disposed in a concrete box outside the building. Unfortunately the box was leaking, so the sludge was disposed in the ground water.

12.5 Bhagalpur

Date: December 18th 2012
Time: 11:15 AM

District: Bhagalpur
Village: Subbanagar

The day after we started was an exhausting one, because of the long duration, poorly maintained roads and lack of sleep. In comparison: the distance was approximately 250 km and the time we have travelled was 10 hours. It indicates the roads are in bad shape and the area we would visit is not that developed.

Nothing was wrong about that assumption, concerning arsenic in the Bhagalpur area. Mainly because the local attendant, Radgir, told us about the situation in Bhagalpur. According to him a rising problem we did not see in Bhojpur, Vaishali and Patna, was the high concentration of arsenic in the surface water of the Ganga River near Bhagalpur due to arsenic contaminated dump water from small companies. Since the Ganga flows from west to east, it is plausible that these companies are located between Bhojpur and Bhagalpur. This fact seems to be contradictive with the sample work Radgir conduct in the region, because on the one hand companies are not punished to dump their arsenic in the Ganga River and on the other hand scientists constantly sample the water on arsenic and try to purify it. Compared with the natural occurrence of arsenic, this problem should be solved by just not contaminate the water.

The first village we visited was Subbanagar, where we visited a primary school. To our surprise there were standing 3 hand pumps in a row of 20 meters. These tube wells did not differ; they were all 110 ft. deep, had also an iron contamination and had no filter. The first was installed 10 years ago by a private contractor and financed by a local funding agency. The second pump was installed by the PHED. Radgir delivered in this case a report to the PHED, concerning the high concentration of arsenic. The result was an installation of a pump 5 meter away from the other pump. It is also notable to inform this pump did not even work anymore. So this was not a case of lack of maintenance, but a lack of commitment and responsibility (and probably corruption) by both PHED as Radgir. He gave the PHED a report, is aware of the current situation and does not feel the necessity to do something about the broken pump, which was the result of his 'report'. The third pump was financed by the MLA funding a month ago, during the Diwali festival. Hence nobody was present who could tell us something about what happened during the installation. You can call it coincidence or perhaps another case of corruption.

Date: December 18th 2012
Time: 12:15 AM

District: Bhagalpur
Village: Nayanagar Ranidiyara

Here we visited the first community based filter plant, which provides water (200 litres per day) for people who live in a range of approximately 250 meters, of the PHED. The filter method was activated alumina. The ground water contained a concentration of 250 ppb arsenic and after filtration a concentration of 100 ppb, which is still 90 ppb to high according to the standards.

This was also the case after completion of the treatment plant. Despite of that, nobody was worried or felt responsibility to improve the filter. It is possible that it contain too less activated alumina, which could be the consequence of corruption, or the activated alumina does not work effectively. Fact was that the problem has not been solved here yet.

The contractor is Mahesh hired by the PHED for the arsenic removal plant in Nayanagar Ranidayara. The system works as follows: the PHED decides to build an ARU (=arsenic removal unit) in area's which been determined by sampling. They care for the fund and hire a contractor, someone who will build, repair and indirectly pay the salary for the operator. That salary is derived from the PHED, but the PHED pays Mahesh to pay the operator, who is a local and lives (in this case) near the plant. It means Mahesh receives a lot of money and he will not be monitored. That means he can hold back money, which the local people notice at the bottom, but not the PHED from the top. That means that in this case the filter does not work properly and also the operator has not receive money for about 10 months. Mahesh claims the PHED has not paid him in a long period, which is also the reason for the insufficient maintenance.

About the maintainer, he is a local villager who lives near the plant. Inside he had a control book, where he writes the concentrations, date and backwash (yes or no). What was suspicious is the fact the last date he registered was two days after tomorrow and all the results were exactly the same. This indicates he does not do his work properly and only have the job to earn money easy. He earns Rps. 3000 per month. He does not have any supervisor who checks his work in a period of time. Besides that, he claims he backwashes the filter each day.

The following imperfections were found on the plant:

- The amount of filtered arsenic is insufficient (150 instead of 240 ppb)
- Inaccurate monitoring of the plant by and of the operator
- Filter contains a lot of iron, which affect the installation (it was almost completely brown)

Last but not least, the sludge is disposed through a pipe at the backside of the installation on the ground into the surface water. This may cause a high concentration of arsenic in the region, which affects (due to ground water flow) other hand pumps.

Date: December 18th 2012
Time: 13:00 AM

District: Bhagalpur
Village: Ranidiyara

Here was another filtration plant financed by the PHED and build by Mahesh. Its capacity is around 8 communities. Also this plant is the same case as the previous. It is not well maintained and the most people do not even use the plant. They think the other water, from the already present tube wells, is cleaner (both due to the smell as the appearance). There could be three reasons for that:

The water in the tube wells contains less iron than the water from the treatment plant. This is very unlikely, because the operator (who is somebody else than the previous) said the plant also have an iron filter. If both assumptions are true, there could be corruption present. Namely, Mahesh said there is an iron filter, but he kept the money and installed a sealed box.

The people are not aware enough about the problem. They think their old tube well provides clean water and did not give them symptoms of arsenicosis yet. So why should they use that other, which perhaps is also further away from their house?

Perhaps the plant has built on a locally high affected iron area and the filter works not properly. This could be the reason that the water turns brown in a shorter period of time compared with the water from the already existing tube wells. Thence people think the water from the plant is less drinkable than the water from the tube wells.

Also, our first notable observation was the tap, directly connected with the purification installation, was broken. Radgir said it was a plastic tap, which is easily to damage during the use of it. It sustained for only a few months. Also one community tap, which was of Ferro concrete, was demolished. It is unlikely that that had happened during the use of it. There could be two reasons for that, where neither Radgir nor the operator had a clear explanation:

Perhaps the oxidation of the rebar caused such an expansion the concrete broke.

Vandalism by the local people as the consequence of boredom, sturdiness or refusal of implemented techniques is another possibility.

Date: December 19th 2012
Time: 10:00 AM

District: Bhagalpur
Village: Singhnan

This day we would spend our time visiting fluoride affected areas and bioremediation plants. Due to lack of time, we would not visit many locations, because we also need to speak with the Professor of Botany of the Bhagalpur University.

The first location was a pump build by the PHED, next to a road. This area is not arsenic contaminated (yet) and there have only fluoride concentrations been found. The concentration at this pump was 20 ppm, which is equal to 20mg/l. The allowed concentration fluoride is around 1-1.5 ppm. Notable is that, just as in the arsenic cases, this pump was also not well maintained. Namely, the pump was not connected with the filter and the pump did not even supplied water. After this disappointing observation we continued our road.

During the trip to a school in Singhnan, Radgir told about the differences between fluoride and arsenic affected areas. He told fluoride flow in the subsurface because of the rocky underground. For arsenic is it hard to distribute in a rocky ground, but not for fluoride. Arsenic spread in clay layers (and basalt en granite), de fluoride trough 'red and yellow soil', according to Radgir.

He also enumerates the symptoms of fluoride diseases. These are: bone- and teeth problems and in the worst case cancer.

Next to the school in Singhnan was an open well located. Rajeev took a sample, because despite of the fact fluoride also oxidizes in open air, it is possible that the concentration of fluoride is recharged by the aquifer, where the open well is dug. The fluoride does not get the time to oxidize totally, due to the new fluoride affected water, which flows in the open well. At the school court there also was a tube well. The concrete surface was all brown and during the observation of the water, the iron particles were clearly visible. It is also plausible it is affected with fluoride, because many children showed symptoms of a fluoride tarnish on their teeth.

There emerged a strange situation, when Radgir wanted some names of the children (and their fathers) that showed symptoms of fluoride. It is namely not of necessity in this case. He gave the impression to look like an expert, notwithstanding he actually does not have that much knowledge about the fluoride. He said it was for an article, but are these names important in such a case? Almost all the children showed symptoms.

13. Appendix B: Interviews with other actors

This appendix contains all transcripts of the interviews conducted with the actors as defined in the "Actor Analysis" section.

13.1 PHED Laboratory

Date: December 5th 2012
Time: 11.30 AM

Public Health Engineering Department (PHED)
Name: Dr. A.K. Upadhyay
Position: Board member
Place: Head office PHED Bihar in Patna

We talked to Dr. Upadhyay, board member of the PHED. He told about the activities that take place in the rural area of Bihar. Their main focuses of PHED Bihar are to provide safe drinking water and safe sanitation.

In our interview we focused on safe drinking water and the arsenic issue in particular.

PHED provides two solutions. One solution is for the short-term. They place hand pumps and in the affected area they place arsenic removal filters in the hand pumps.

The second solution is proposal large projects. They try to provide safe drinking water with surface water from the ponds or the Ganga surface water. An example is the water treatment plant in Mozempur. This plant provides drinking water for 39 villages, with a total of around 80000 villagers. This drinking water is arsenic-free and safe to drink directly from the hand pump.

If we ask more about the funding and maintenance, he was not able to give us an answer.

Alas, not all of the affected areas can make use of this water treatment plant due to lack of funding. This should be the long-term solution for probably the entire country as there is a shortage of safe drinking water. Currently, the only alternative is to drink water from arsenic-free hand pumps.

Afterwards, we talked about awareness in the affected areas. On December 1st 2012 we visited Bhojpur district. It has come to our attention that not everyone has been aware of the arsenic problem; some people did not even know what arsenic is. It was for us interesting to know how they think about awareness. In this particular case, we asked them about the mind set and awareness in Bhojpur district and Maner block. He said that everyone knows about the high level concentration of arsenic in drinking water. He emphasized for the second time that everyone knows it. Contrary to what we have seen, not everyone has been aware of this issue.

Some hand pumps in the affected areas has been placed by PHED. They placed the pumps not far from a household that is able and allowed to take care of the hand pump. Most of the people who are allowed to take care of are the educated villagers. PHED provides courses on how to maintain the hand pumps and the villagers themselves are eventually responsible for the maintenance. The funds are provided by the State Government of Bihar. PHED is not willing to take care of other hand pumps. Those are installed by other organizations. They see it as the villagers' own fault if they use other hand pumps in a wrong way. We may conclude that there is no collaboration with other organizations that are involved with the arsenic issue.

In the future, more water treatment plants will be built in several areas in Bihar. In the meantime, people should use water from the hand pumps. Dr. Upadhyay expects that the arsenic problem will be solved within a period 10 years.

13.2 PHED Superintending Engineer

Date: December 13th 2012
Time: 10.30 AM

Public Health Engineering Department (PHED)
Name: Ir. D.P. Singh
Position: Superintending Engineer
Place: A.N. College, Patna – Bihar

In this meeting we focused on arsenic in drinking water. First of all, he said that installing more hand pumps is not the solution. It is hard to maintain, not cost effective and regarding arsenic, it is difficult to install filters in all hand pumps in the affected areas. The direction that the PHED wants to go, is to provide household connection in the long-run. It will take at least 10-20 years in order to implement this kind of solution. In the meantime, they will have to develop techniques that are sustainable, easy to maintain and also cost effective.

The PHED constructed a number of small water supply scheme in districts like Bhagalpur. Depending on the areas, it provides arsenic, iron or fluoride-free water. In those water supply schemes, 2 filters are present, vacuum pump and a tank for storage. Most of the tanks can store 1000 litre water. These kinds of supply schemes require electricity. Solar panels, which are present on the top of the roof, provide power for the vacuum pump. He emphasized that such water supply scheme is not left unsupported, like the hand pumps. In every unit, a caretaker is always present for maintenance.

D.P. Singh does not think this will be the solution in the future. Later, this water supply schemes will not be constructed anymore by the PHED, except in the remote areas of Bihar.

As earlier mentioned, the solution for the long-term would be the household connection. Big water treatment plants as in Vaishali and Mozempur are currently being built in Bhagalpur and Buxar.

After his short presentation regarding drinking water, he tried to leave as soon as he can. We tried to ask him questions.

We asked: 'we visited Vaishali on December 11th 2012. A small filter system was installed by the PHED. The ground, where the filter was installed, belongs or belonged to a villager named X. Villager X excludes other people in the village to make use of the water that comes from the filter. Mukhiya and any other people came to that place to try to solve this problem, but it has not had the desired effect. Villagers told us that they tried to complain at UNICEF and PHED, but they have never responded. How does the PHED deal with this problem?'

D.P. Singh answered: 'such a problem is easy to solve. I have to admit that the PHED has not enough skilled people for all these problems. Our main focus is to provide safe drinking water and sanitation. Problems that you mentioned are easy to solve. Villagers used to go to the police and then the police will solve this problem according to the Indian law.'

We tried to ask more questions, but he left as soon as he can.

13.3 Central Ground Water Board

Date: December 3th 2012
Time: 15:00

Central Groundwater Board Bihar (CGWB)
Name: Dr. S.N. Dwivedi
Position: Board member
Place: Head office Central Groundwater Board Bihar

The central Ground Water Board Bihar is part of the Ministry of Water Resource of the Government of India. This agency is responsible for providing scientific inputs for management, exploration, monitoring, assessment, augmentation and regulation of ground water resources in de state Bihar (cgwb.gov.in). So it is not the task of the CGWB to provide clean water, which is the task of the PHED. The CGWB is there for investigate the ground water which may be used for drinking purposes. It is a scientific branch of the government and is not responsible for the absent clean drinking water in some arsenic affected regions in Bihar. That is what Dr. Dwivedi, a manager of the CGWB, told us. They conduct research about subsurface flow and the chemical processes in the ground water.

About the arsenic issue he told us this can be solved by two kinds of managements: surface water (Ganga) and ground water. Dr. Dwivedi let us show he has got a lot of knowledge about ground water, but while being in the field also some social aspects attract his attention. He said that the main reason the arsenic problem has not solved yet is a pure management problem, namely lack of maintenance and vandalism. The people just prefer good looking, smelling and tasting fresh water and it should not be an awareness problem, which it is unfortunately. He means with that quote that it may not be the issue whether the people know the ins en outs of the hazardous effects of arsenic. The only thing the people want is an easy maintaining device which supply enough and fresh water.

Deep wells have possibilities for house taps, but again there is no enthusiasm because of the costs, which directly refers to the mind-set of the people. Paying too much money is not what people understand by ‘easy maintenance’. By asking what is affordable for the poor villagers, he told Rps. 100 per month must do the case. Subsidy has to keep the prices low and persuasion has to convince the people to afford at least something. When we told the plant in Mozempur provides water for only Rps. 10 per month, he told that that have to be reasonable.

The problem with the management (see above) is that there is too little awareness building en therefore the mind-set is not right. The other management problem is the bad maintenance by the ones who installed the concerning water supplier. A lot of wells are not useful anymore, because of lack of maintenance. People just ‘forget’ they installed a pump, according to Dr. Dwividi. He said the main solution of the problem is a more active government. He said that should be done with the following actions:

- Meeting/survey to make the people aware;
- Ask them what a good solution would be;
- Implementation;
- Active control, also with media.

That should be the order to install a water supply on community base. You can compare it with the famous bottom-up theory. Know what is desirable and possible, than the implementation and after that, strict control.

He also noticed that the fact few people show the symptoms of arsenicosis, the people are also less aware of the problem. They see the pure water and cannot realize there could be a chemical in it, which is dangerous for the health and if they also do not see people with the symptoms they confusion is bigger.

About awareness spoken, Dr. Dwivedi also suggests the government is not aware enough about the problem too. They could invest more money in the problem to solve it, but they do not. If they are more aware, there would be more money available and there will probably also be a better maintenance after installation.

13.4 Department for International Development

Date: December 15th 2012
Time: 11.00 AM

Department for International Development, U.K.
Name: Dr. Prakash Kumar.
Position: Team Leader- WATSAN
Place: Department of Environment and Water Management, A.N. College, Patna

We talked to Dr. Prakash Kumar, Team Leader –WATSAN group of the DFID. DFID is a United Kingdom government department. The goal of the department is 'to promote sustainable development and reduce the poverty in the world.' Along with several institutions throughout the world, DFID's main areas of work are education, health, social welfare, water supply & sanitation, infrastructure and environment protection.

First of all, he talked about the water supply scheme with solar panels in Bihar. Up until now, 50 water supply schemes have been built by DNA Infrastructure, commissioned by the PHED. It is not clear who is responsible for the maintenance, but Prakash Kumar thinks it is clear that DNA Infrastructure and PHED do not want to take the responsibility. Out of 50 water supply schemes, 11 are broken due to improper use or lack of maintenance. A reason that resulted in the problems is because caretakers of the schemes do not get their salary on time. Another reason is the conflict for land. Even if the people were compensated by the government for using the ground afterwards, they will not accept it.

Another problem with this water supply scheme is how to deal with the sludge disposal. The current problem is that the sludge disposal will go back in the ground. This will worsen the present situation and there is no solution for this kind of problem. That is the reason why Prakash Kumar thinks that small arsenic, iron or fluoride filtration is not the solution. He recommends surface water which is cheaper and easier to maintain.

Regarding community participation, PHED has no knowledge about this. PHED has not enough manpower to deal with all these problems and according to their tasks; they think they have nothing to do with social difficulties. So after 2010, PHED has not planned new water supply schemes. They will focus on large scale projects, such as water treatment plants which will use surface water from the Ganga.

DFID tries to narrow the gap between technical solution and community participation. Without community participation, a technical solution is doomed to fail. Where PHED is lacking behind regarding community awareness, DFID will try to narrow the gap.

Currently, DFID is writing a project proposal together with the PHED regarding piped surface water in combination with community awareness and participation.

Due to lack of manpower and other skilled people in PHED, they try to train engineering staff in many other things, like community participation.

Apart from working together with PHED, they also participate in projects of the Health Department, Department of Social Welfare, UNICEF, WHO and Education Department at state level.

Together with the Education Department, the DFID tries to build awareness through education. Prakash Kumar said that building awareness is also a case of school. They try to find a way how to implement this in the guideline that is used by the elementary school.

DFID also tries to start a pilot project in Gaya district. They have installed a small water supply scheme, which can only be used by the 'Dalit'. The Dalit is a group of people traditionally regarded as untouchable. In practice, those people are outside the caste and people who strongly believe in the caste system will never treat them as human-beings.

This water supply scheme was constructed by DFID and for the coming 5 years, they will be responsible for the maintenance. In the meantime, they try to find a solution. For example, they attempt to educate those people in how to maintain the scheme.

Another pilot project has also started in the same district. They gave every hand pumps an ID. With this ID, a hand pump can be traced everywhere. If a hand pump is broken or destroyed, anyone can contact the DFID by phoning them. DFID will take the necessary actions immediately and tries to repair the hand pump. All the people are satisfied with this kind of service. This project is going to expand in other districts in Bihar and if the PHED is willing to take over this method, the DFID will definitely provide assistance and support.

13.5 UNICEF

Date: December 11th 2012
Time: 16:00

United Nations Children's Fund (UNICEF)
Name: Dr. Nanak T. Santdasani
Position: Coordinator UNICEF arsenic problems Bihar
Place: UNICEF head office Patna

While we were on some fieldtrips, we also noted some UNICEF logo's and also some villagers told us about the work UNICEF performed is the regions of Bihar, especially awareness building. That was the reason to check the involvement of UNICEF.

We spoke to Dr. Nanak, who is the head of the arsenic issue on behalf of UNICEF in Bihar. Due to his little available time, we were not able to ask the precise actions and how everything works in the region, like the installing and the development of awareness among the people. What he said is that UNICEF does not install pumps in the region, since that is the job of the PHED. UNICEF is helping the PHED to develop a self-sustainable solution (technical support). Spoken about the PHED, he was very critical on this government agency. Mostly because of the fact the PHED does not care about the social aspect of the problem. From what we noticed in previous fieldtrips, that assumption may be right.

As stated above, the PHED were blamed for a lot of aspects. He said the mind-set is wrong, both PHED and the community. About the PHED he said that are too much focused on the engineering work, instead of community work. They do not provide capacity and willingness. Before implementation of another water supplier, they should check the awareness and willingness of the community to provide clean water along with the community. So also the community should be responsible after installation.

When we took comparison of the system in The Netherlands, so the water supply is in the hands of private companies, he said that such a system would not be possible in India because of the extent of the country. He also mentioned that if the community does not participate, the government will do that. This worsens the situation, because the government is not capable enough to provide clean water to whole India.

As a conclusion he said that firstly everybody should be willing to participate along with enough awareness and then hand over the installations. At all times the community should be involved.

13.6 NGO: Save the Environment

Date: January 5th 2013
Time: 3.00 PM

Save the Environment
Name: Dr. Proloy Basu
Position: Researcher
Place: Safe The Environment office, Kolkata- West-Bengal

Safe The Environment is an NGO for research, awareness and social development. This organization was established in 1989 and is active in the field of social and rural development, especially in the area of environment, health and drinking water. Accordingly, the organization has started to work on the arsenic mitigation in West-Bengal since 1992.

This NGO has done extensive research on arsenic mitigation in the rural areas of West-Bengal. With this interview, we want to gather information of their approach regarding arsenic in ground and groundwater.

Since 1992, this NGO has done many researches regarding arsenic. In the past they collaborated with different national and international organizations. On national level, they worked together with Ministry of Health and All India Institute of Hygiene and Public Health. Together with those 2 government institutions, they fought against the arsenic problem and built the first arsenic removal plant in West-Bengal in 1997.

Regarding health care, the first medical clinic was set up by this NGO. In North 24 Parganas, this medical clinic provides treatments for patients who are suffering from arsenicosis.

They have also done lot of social developments in rural West-Bengal. This NGO started to provide trainings for patients suffering from the consequences of arsenic and make them independent as these patients were not accepted by the society.

Apart from many social developments and health care facilities, they also develop small scale arsenic mitigation techniques. 2 different types of arsenic removal technology has been implemented by them: domestic type and community type.

This organization is expanding and will work in Uttar Pradesh and Bangladesh.

On our arrival, a salesman of the company 'Global Adsorbents PVT LTD' was present. He tried to sell activated alumina to Dr. Proloy Basu.

This NGO has worked with activated alumina from 2001 until 2004. In that period, it was discovered that activated alumina can cause kidney cancer, so they stopped using this material. But it is quite contradictive: on the one hand he told us that it can cause diseases, but on the other hand he tries to purchase it himself. Because of the low cost of activated alumina (around 150 Indian Rupees per kg), it is still used by many organizations. Other removal technology without activated alumina is more expensive and because they have to consider the cuts, they will use this alumina. We suspect corruption, but we cannot confirm it.

This organization works together with other government institution. The government provides funds and guideline. So in fact, this NGO is not a 'Non-Governmental Organization', but an extension of the government.

On the block level, they have to collaborate with the Panchayat. Without the permission of the Panchayat, they cannot do anything.

Instead of being independent from the government, an NGO is a part of the government. In our view, corruption will increase due to many government organizations.

13.7 Prof. Choudhary, Bhagalpur University

Date: December 19th 2012
Time: 12:00 AM

District: Bhagalpur

We would visit the professor of botany of Bhagalpur University as the final trip of Bhagalpur. We told him our observations of the day to Subbanagar and Nayanagar Ranidiyara, which did not gave us a good impression of the projects conducted in the district Bhagalpur. His opinion about the future solution was that there should a lot of small scaled mitigation technologies be installed. These technologies implementation need some time. In the meantime the PHED should tell the villagers after they pumped up their water to wait and let the arsenic oxidize and thereafter drink it. At the assumption the people do not drink the water due to the coloration by iron; he responded they would drink it because they are aware enough of the arsenic problem. In the field we found the opposite of that declaration.

Professor Choudhary pleaded that the small scale mitigation installations have to make use of new filters, developed by foreign institutes (in this case Layheigh, zirconium) which are better than the current filters (active alumina). So again, Bihar trusts on another foreign technology (RO-Karlsruhe, filter Maner-Layheigh), despite of the fact there are perhaps sufficient filter techniques. He also thinks big installations are not an option, because:

- The volume of the Ganga River around Bhagalpur is limited (!);
- Much manpower requisite.

His plan was: 'By targeting of highly affected areas by means of samples is it possible to choose tactical locations for small scale filter installations'. From this quote it is clear we were talking to somebody of an education or scientific institution:

- New filter techniques requisite, despite of the already existing techniques;
- More sampling. Hereby not realizing that when the last sample has been taken, the first does not agree with the actual concentration anymore, because of ground water flow;
- Universities and students should be responsible for (1) building awareness among the villagers, (2) installation and (3) maintaining.

The job of the PHED should be, according to Professor Choudhary, to finance such projects because of the extent of their budget. That money will go to make the people aware and building the installations. More functions of the PHED would be to attract interested agencies and coordinating education and scientific institutions. The maintenance is the responsibility of the community. They will be more aware of arsenic, because the students will live a few days or weeks with such a community, to really pursue the villagers they should drink the purified water and pay the operation costs. They will also train them to maintain the plants.

13.8 Prof. Arunabha Majumder, Jadavpur University

Date: January 7th 2013
Time: 2.00 PM

Name: Prof. Arunabha Majumder
Position: Professor-in-charge Jadavpur University
Place: A.J.C. Bose Road, Kolkata, West-Bengal

Prof. Arunabha Majumder is currently a professor-in-charge at Jadavpur University. Before he works at the university, he was the director-professor of All India Institute of Hygiene & Public Health which is a government institution. This institute is teaches and do researches regarding various disciplines of public health and allied science. Through several decades of its existence, this institute has contributed in the public health in India significantly. Regarding arsenic, they have done many researches and built awareness among people.

Currently, his work is focused on research and education.

Arsenic is a natural phenomenon and normally it can be found from 20 meters below ground level and deeper. Many tube wells are shallow tube wells, so most of the hand pump is affected by arsenic. Since arsenic became a serious problem, the state government of West-Bengal has tested more than 130000 tube wells. There are many initiatives to tackle this huge problem. One of the solutions is the solution of Project Well. They use rainwater and a dug well for drinking water. He criticized this project a little bit, because this water source needs to be treated with chlorine. He said: 'what is the long-term effect on your health?' This should be clear before you will use this as an alternative.

He suggests 4 solutions. The first one is a domestic filter, which is hard to maintain. The second is a water source that may be used by the entire community. The third one is use water from the deeper aquifers, but it requires more research what will happen with the different soil layers on the long-run. The last solution is to use surface water, a big water treatment plant.

Beside all these technical solutions, we talked about the management regarding drinking water. He suggests that a large central water supply plant is easier to manage than many small arsenic removal units. On the long-term, the government should implement and built this kind of plants.

Then we talked about the main issue within the government: corruption. He said: 'corruption is definition you create by yourself. If a teacher did not teach the pupils good enough while he or she receives wages, do you consider this as corruption or negligence of your duty? If a private company installs not the right filter, do you consider that as ignorance, negligence of duty or corruption? Corruption is a definition you create by yourself.'

But he did not deny corruption. There is corruption, but it is hard when and what you can consider as corruption.

14. Appendix C: Field trip arsenic tests

This appendix contains the arsenic concentrations of different water sources that were encountered in the field trips. The samples are tested with a photospectrometer at A.N. College in Patna

Village	Water source	GPS Data	Arsenic (ppb)
Bhojpur			
Bakhaurapur temple	Hand pump	N25 37.165 E85 06.545	49
Sinha	Hand pump	N25 41.075 E84 37.851	47
	Hand pump	N25 41.072 E84 37.860	54
	Ganga water supply	N25 41.075 E84 37.851	5
	Hand pump	N25 41.601 E84 37.764	317
	Hand pump	N25 41.175 E84 36.954	42
Pandeytola	Hand pump	N25 41.172 E84 36.951	485
Chanda	Hand pump	N25 40.973 E84 37.047	77
	Irrigation tube well	N25 41.013 E84 37.024	112
Mozempur	Ganga water supply	N25 41.093 E84 35.418	8
Mahuli/Sahjahapur	Hand pump	N25 41.026 E84 35.419	91
Bhagalpur			
Amsichak	DNA filter water	N25 21.707 E87 19.042	29
Barohia	Raw water	N25 21.317 E87 19.480	201
	Filter water supply		69
	Back wash water		179
Singhanan	Primary school Hand pump	N25 21.707 E87 19.042	17
	Open well water		17
Ranidiara	Hand pump	N25 21.316 E87 19.482	100
	Hand pump		113
Subbatola	Primary school Hand pump	N25 37.061 E84 18.835	93
	Primary school Hand pump OLD		79
Buxar			
Akdar	Hand pump	N25 37.858 E84 19.286	29
	Hand pump	N25 38.447 E84 19.337	41
Dhanchapara	Raw water	N25 37.056 E84 18.821	41
	WaterLife Filter water		15
Johi Jagdispur	Raw water	N25 37.152 E85 21.841	34
	PHED Filter water		20

Village	Water source	GPS Data	Arsenic (ppb)
Vaishali			
Pakri school	Open well	N25 39.843 E85 17.534	14
Bidupur	Hand pump	N25 39.062 E85 19.480	32
Chaksikander	Hand pump	N25 40.909 E85 21.452	37
Chechar	Hand pump	N25 37.152 E85 21.841	39
Kalayanpur	Raw water	N25 40.892 E85 22.543	79
	WaterLife Filtered water		22
	Hand pump		61
Maner			
Haldi Chhapra open well	Open well	N25 40.981 E84 52.430	44
Hathi Tola HP	Hand pump	N25 39.879 E84 52.720	54
Maner HP	Hand pump	N25 38.893 E84 54.125	61
Naya tola HP	Hand pump	N25 40.927 E84 52.763	57
Ramnagar HP	Hand pump	N25 38.009 E85 05.081	91
	Leihigh filter		91
	Backwash upper tank		54
	Backwash lower tank		52
	Sludge		275
	Filtered water		14
	170ft deep bore well		29