ACIAR SDIP Foresight Program: Status Report

Groundwater quality in the Eastern Gangetic Plains: How important is it, and what needs to be the response?

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Executive Summary

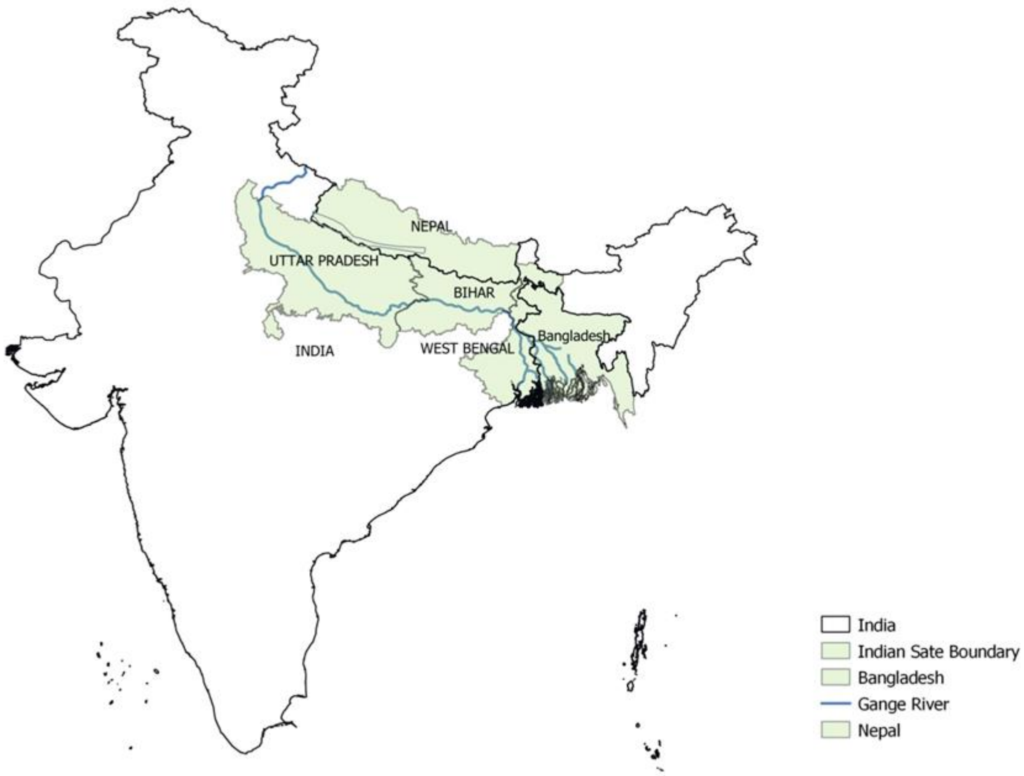

FIGURE 1 EASTERN GANGETIC PLAINS (EGP) REGION

The Eastern Gangetic Plains (EGP) is home to a highly dense population in South Asia, and hosts some of the region's poorest communities. This almost entirely agrarian dependent population has the following features that influence water use:

a) Alluvial deep plains which have rich reserves of groundwater fed by ephemeral to seasonal, and sometimes perennial streams and rivers of the river Ganga.
b) Near to absent systems of surface water irrigation systems that can be relied upon.
c) High dependence on irrigation through groundwater for basic livelihoods.

The combination of the above factors means that the region's several hundred million rural residents depend highly on tubewell based irrigation, mostly powered through diesel pumps and now increasingly by electric pumps. While this by itself is inaccessible to many of the poor farmers, the added problem which has now burdened the region is that of groundwater contamination. The widespread presence of arsenic, and now other emerging contaminants are threatening the status quo of groundwater based irrigation and livelihoods, generating important questions about the balance between livelihood and public health. Recent studies such as by Singh et al. (2019) and Macdonald et al. (2016) present a vivid regional picture of deteriorating groundwater quality at a widespread scale, with tens of millions of people affected (Table 1).

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The larger numbers that current studies report are in the range of 20 million affected with Arsenic problems in Bangladesh (Human Rights Watch 2016), 10.4 million in West Bengal (Lok Sabha 2017), 5 million in Bihar (Delft 2013, Kumar et al, 2014 2017), 23.4 million in UP with more than half of this in the Eastern parts (Bindal and Singh 2019), 0.5 million in Nepal Terai (Shreshta 2012, Yadav et al 2011). See **Figure 2** for a mapping of publicly available Arsenic data from EGP and **Appendix** for an explanation of the methodology used here. Note that this is a first such analysis and mapping of Arsenic at a district level for this region, and this will be updated with more availability of such public data sets.

TABLE 1 SCALE OF ARSENIC AND DIARRHEAL PROBLEMS IN THE EGP REGION

Location	Arsenic: no. of people affected	Under 5 diarrheal mortality and Infant Mortality Rate (IMR)
Bangladesh	20 million (Human Rights Watch 2016)	6% of IMR (Alam et al, 2017) of IMR 32
West Bengal (India)	10.4 million (Lok Sabha 2017)	13% (Lahariya and Paul 2010) 290 of IMR 32
Bihar(India)	5 million (Delft 2013, Kumar et al. 2014)	13% of IMR 38
UP-EGP (India)	12 million (Bindal and Singh, 2019)	13% of IMR 43
Nepal Terai	0. 5 million (Shreshtha 2012)	42% of IMR 46 (Pinto 2008)
	Total: 47.9 million	

Secondly, another large problem which is perhaps even more important is that of diarrhea and viral contamination problems of water, due to the combination of poor sanitation, and poor hygiene practices combined with high dependence on groundwater for drinking from relatively shallow water table conditions. Around 22% of all mortality in Uttar Pradesh (UP) and 14% of all mortality in West Bengal is attributed to diarrheal and related diseases (IS, 2017). Bangladesh on the other hand has been able to reduce diarrheal deaths from 560 per million in 2003, to 145 in 2013 to just 3 per million in 2017. This has apparently been achieved through a strong public health system with effective communication networks through health care workers, along with simple and effective approaches such as oral rehydration salts (ORS).

One important element linking arsenic and diarrhea has been brought out in recent studies for example by Buchmann et al. (2019), who describe the unintended consequences of increasing diarrheal morbidity due to have a single-minded focus towards arsenic mitigation and prevention. The scale of the problem itself is large enough to be considered with seriousness as shown in **Table 1**.

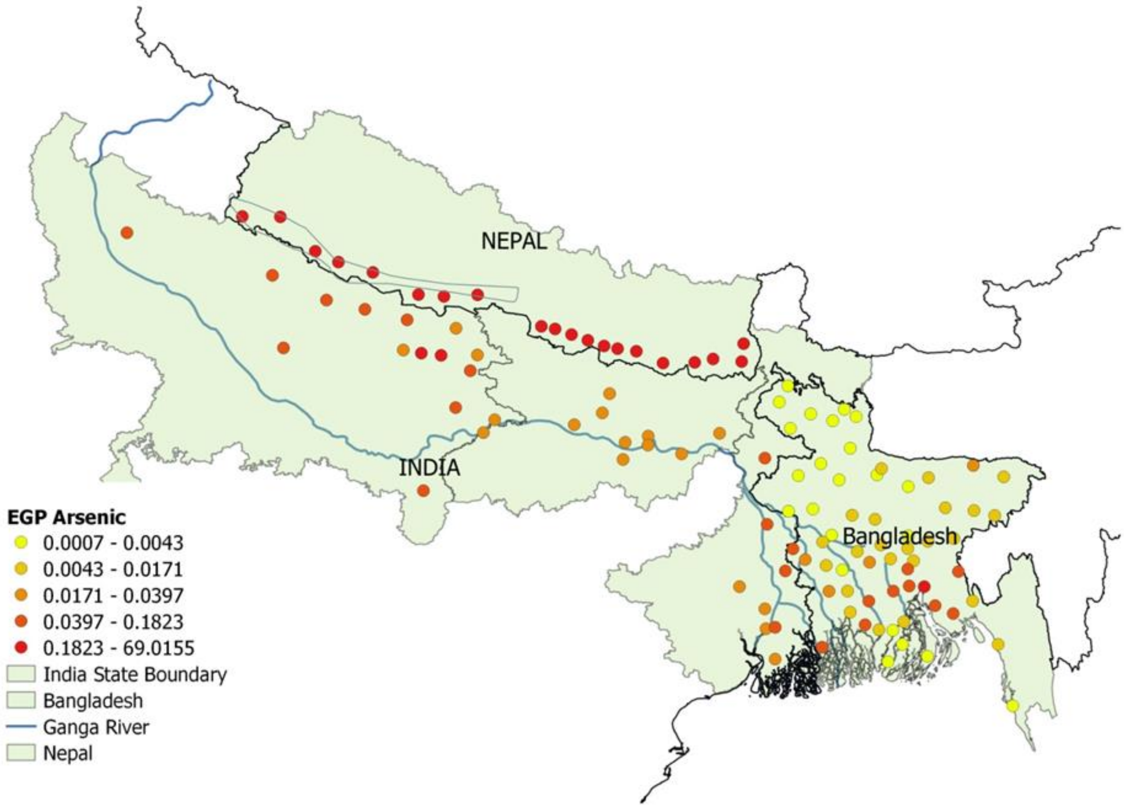

FIGURE 2 MAPPING OF PUBLIC DATA OF ARSENIC IN EGP AT A DISTRICT LEVEL

(ORIGINAL MAP AND ANALYSIS PREPARED FOR THIS STUDY BASED ON DISTRICT LOG AVERAGES OF 34,000 WELL DATA ACCESSED FROM BRITISH GEOLOGICAL SURVEY (BGS), GOVT OF INDIA AND SHRESHTA (2012) RESPECTIVELY FOR BANGLADESH, INDIA AND NEPAL, SEE APPENDIX 1 FOR METHODOLOGY

This study presents a multi-faceted analysis considering the scale of the water quality problem, its public health consequences, the options for water treatment and water supply; the connection with irrigation and livelihoods; the experience with behaviour change communication; and other aspects such as emerging contaminants. Following is a summary of each of these aspects:

- A central question is the **data conundrum**. While each of the three countries have varied availability and openness of water quality data, the larger question is about how much data is sufficient and enough. The current data systems need to be overhauled and rethought about how such information is collected, analyzed and shared.
- The most common response amongst well-meaning researchers, scientists, NGOs and government agencies is to install community-based **water treatment plants**. While numerous technologies and modes of engagement are prevalent, sustainability is a critical question for most of the plants. Commercial operators are increasingly able to penetrate into the rural affected regions, but it raises questions of equity and accountability as a consequence of such practices, with a large population of have-nots amongst the safe water users.
- **Domestic water filters** have been developed for all the known contaminants and piloted by many agencies across the region. These projects typically involve building of local capacity for maintaining the filters. However, none of these projects have scaled and there is doubt over such approaches at present.
- A major risk perception of water contamination and specifically the arsenic problem in the region is that of **cancer hotspots**. It is well established that some of these contaminants increase

cancer risks. However, what remains to be seen is whether the hotspots are indeed due to water quality related problems, or if are there other factors which we might be missing. More research is needed to answer these questions.

- Rice being a major crop of the EGP, the alarm over contaminants such as arsenic in rice or **contaminants in the food chain** is something which can affect the region's agricultural economy if not addressed properly. Here, what emerges is that standards in terms of concentration (parts per billion (ppb)) and amount of daily consumption together decide the potential risk. This varies highly across the region, therefore any blanket statement about contamination potential is unjustified. What is called for is data dependent regional mapping at district or provincial level to give indicative risk index. This could cause a crisis locally but also act as a call for action, based on such indexing.
- Information based on local data, and **behaviour change** aided by well-designed communication is cited as one highly effective process to guide communities towards solutions. Indeed, ground based evidence shows that sustainability of practices such as switching towards colour marked safe water sources needs reinforcement through data based communication. Yet this entire process needs backing from programmatic action, and a combination of both wider media and local community-based support for a sustained period, otherwise as reports show, there is very high slippage back to unsafe practices
- Increasingly, **surface water based pipeline systems** are touted as a solution for safe drinking water problems in rural areas. The plan is for regional pipe water schemes as for some schemes in Bangladesh and West Bengal, and small and local schemes such as in Bihar, India. Current experience across the region however paints a dismal picture of the sustainability of water supply and especially the quality of water from these systems. Major concerns include financing of operation and maintenance, participation and ownership after handover to the community.
- **Groundwater based irrigation** being a primary cause of the geogenic water contaminants crises, it is an open question as to whether better control over irrigation can result in reducing the problem of contaminants within the aquifer itself. Testing this needs a strong convergence across sectors, and support from policy. This could be a subject for intensive local action-research to try and see if it is possible for the problem to be mitigated at the source itself.
- The highly sensitive linkage between groundwater-based **livelihoods and groundwater contamination** also means that policies need a balance between looking at minimizing impacts to livelihoods while reducing the risk to public health. For example, in the past, widespread ban of groundwater irrigation in summer has caused a negative impact on livelihoods and hence nutritional intake. This puts a major constraint on how the issue can be tackled in this region.
- **Nutritional enhancement for reducing impact of toxicity** is an approach that is gaining momentum for ameliorating various water contaminant related diseases. While research is ongoing, there is much evidence pointing to resistance developing with better nutrition. Apart from safe drinking water, this gives an alternative approach for mitigating the problem at a regional scale.
- Some approaches such as using **pond water with basic treatment** are now being tested. Initial success shows that this could be both a sustainable and equitable route to have a region wide approach for safe water supply.
- Options such as going back to **open and dug wells** are one possibility for reducing contaminants in water, and this is highly effective for problems such as fluoride and arsenic. However, such water sources also suffer from the fact that they dry up easily and are impacted by poor sanitation. Therefore, making it work needs a lot of community participation and policies that also help it to work.

- **Emerging contaminants** are present widely in the region and could be a cause for major concern. Recent research shows manganese, uranium and chromium emerging and these by themselves and in combination with existing contaminants could pose serious public health risks. It is time to take them seriously and map throughout the region to be ready for future problems.

The data conundrum: how much data is sufficient to understand water quality?

The distribution of groundwater contaminants shows tremendous diversity at all scales. Not just spatially but also vertically downwards, where each geological layer has a different signature of the quality of water.

Different studies have documented these variations across the three countries of the EGP for various contaminants. The respective governments also have a system of data recording which has different variations. A recent international study by the Open Knowledge Foundation of 100+ countries shows varied levels of transparency and availability of such water quality data (OKFN, 2016).

India scored 65% on this open knowledge index and ranked 10th; Bangladesh ranked at the bottom ranking of 24th with 0% on the open knowledge index, and the same was true with Nepal. It calls for much improvement in the openness indicators of these countries measured by type of license, machine readability, public availability, availability free of cost, easily downloadable, and being up-to-date.

Some universities and other institutions are also playing this monitoring role, for example for the case of arsenic in Bangladesh the British Geological Survey (BGS) plays the role of data dissemination at a countrywide scale. A similar role albeit on a relatively smaller scale is played by the SN College in Patna, Bihar, and the School of Environmental Studies, Jadavpur University for West Bengal in India.

But by and large a central data question remains. Even within a village the distribution of water contaminants is very high as shown by several studies (van Geen et al., 2003).

Whereas some such villages are branded as high arsenic contamination and large investment arrives in the form of treatment plants, many such villages also find a lot of pockets of safer water free from these same contaminants. In such cases, the availability of water data is at a very local scale and also its accessibility needs to be very localised for decisions to be taken.

How much data is enough, and how accessible it needs to be, is a question we need to think more about. Whereas the social costs of such data is very high, even very localised information seems justified given the level of variability we know exists. But the current status of publicly available laboratories and their data recording and dissemination systems seem quite incapable of such deep data at frequent intervals.

It calls for a very different paradigm of water quality data collection and dissemination, which is now being discussed in the region: the collection of data in a distributed manner, but one that is trusted thorough processes of data collection. This might help the deepening of water quality data and its availability for very local decision making. But this 'trusted thorough processes' has some associated inbuilt trust and procedures which need to be followed for authenticity and validity of data.

Water Treatment Plants: are we climbing the wrong tree?

Removal of water contaminants by community-based water treatment plants has been a mode of intervention for the past three decades in the region. Plants for removal of iron from water have been implemented widely and then for arsenic and fluoride in recent decades. There are a wide range of technologies for such solutions, but of late some particular technologies such as Reverse Osmosis (RO) are being promoted, although they are quite often incompatible with the actual need on ground. This has also attracted the attention of regulatory authorities such as the recent stricture on RO from the National Green Tribunal (NGT) of India. Similar efforts are ongoing in each of the countries in the region for appropriateness of technologies.

These technologies have been implemented on the ground by various means, initially as research projects by academic institutions, and later by civil society organizations (CSO) who have enabled community-based mobilisations around such plants. The respective government agencies have installed these plants in various modes ranging from fully investing in the entire capital costs (Capex) along with Operating costs (Opex) for a certain period ranging from three to ten years. There are now an increasing number of water enterprises which are active in this domain with varying models of operation such as franchising, community partnerships and other modes. Independently operating water entrepreneurs have also entered into this domain by setting up water treatment plants and selling water in cans across the region.

Apart from the questions over technology suitability and appropriateness, there are larger questions of sustainability for each of these models. Studies reveal that most of the plants, which are installed with very low community involvement and no user fee cost, have a limited expiry date of operation ranging from a few months to a couple of years (Hossain et al., 2005; Hossain et al., 2015).

Some of the plants which are installed directly on water sources also have the problem of theft of machinery and lay in disuse even after a few days of installation. The water enterprises have varying modes of reach and sustainability. In case of community-based installations, a reach of 30% of population is considered as an industry gold standard. Most often for large villages greater than 2,000 in population, such reach is sufficient to recover the Opex. Such plants therefore continue for longer duration with a part of a community getting safe drinking water and the other having to resort to the water sources that they might have access to.

In the case of the independent water entrepreneurs, the development of water supply is opportunistic. The order of pecking is traders and small institutions of small towns and villages, affluent families of densely populated villages and then those having small vans to reach out to other such community of potential users. Quite naturally the users who can avail of such facilities are those who are willing to pay the price of such water and these are either those having no other water source such as traders, and others whose perception of safe water is strong enough to warrant their affordability of this water. Studies however also indicate that there is a latent willingness to pay for arsenic free water amongst a large section of the rural population (World Bank, 2002).

The spectrum of water treatment plants across the EGP region does serve a large population given the high population density, and typically allows for enterprises to function in amenable pockets. However, looking at the region's vast population of poor households, this option either leaves a big hole in their pocket or leaves them out of these options, unless there are financially unsustainable plants installed with free water.

The goodwill is clear in domestic filters, but will they ever scale?

Iron, arsenic, fluoride and other contaminants have together a variety of domestic water filter options developed by academic and research institutes, NGOs, government agencies and others. The benefits of these domestic water purifiers to the user families have been shown by numerous studies to be extremely high and worth the investment on such unitary filters.

However, the history of sustainability of these programmes, and any possibility of scaling, are very poor. The reasons are several:

- Maintenance of such domestic after filters is much more difficult than that of community ones. Dispersed and widely spread domestic assets are hard to maintain in this region.
- Continuous usage of these filters by families would need constant adherence to behaviour change habits. However, there are high chances of relapsed behaviour and many of these filter lie in disuse after some time, as people do not see immediate benefit and change in risk perception. Factors that people pay attention to such as colour, odour and taste are more critical.
- Robustness of these technologies is very poor. As compared to urban areas there are many chances of failure of technologies in remote rural locations and very few solutions have been tested prior at such places.

Some of the filters such as for iron (Terafil) have shown a lot of potential based on the above factors. despite support from government programmes they have failed to reach any scale. Simple arsenic removal filters using iron nails and biosand (called the Kanchan filter) have been promoted in Nepal at a small scale.

One criticism of the manner of promotion of domestic purifiers has been that any such household asset needs sustained marketing, and especially social marketing in this case. The supply chain of the product needs to be in place, and one needs to have sufficient density of customers to justify service centres. The business model of such domestic filters is fine in urban centres, but when it comes to rural areas, the burden of marketing costs is something that nobody is willing to take on.

This is probably when public policy comes in wherein mass communication to promote a range of private products that benefit socially, could be something to ponder upon. The entire sector could be promoted through support with know-how, subsidies and promotion, over a fixed time period, and then it is quite possible it grows on its own.

The above thinking however, has the possibility of public authorities getting away from their basic duty of supplying safe drinking water, and promote private interests, hence quite difficult to get going.

Can we really connect higher cancer rates to water contamination?

A visit to the Mahavir Cancer Centre in Patna, Bihar, reveals the seriousness of the cancer crisis in rural parts of Bihar in eastern India. Most of the patients are from poor areas of north Bihar, and studies show that arsenic in water seems to have a close connection.

The health impacts of arsenic can range from skin lesions, keratosis to problems in kidneys and lungs. The carcinogenic aspect of arsenic in water has been a matter of long debate because cancer can appear even after the exposure ends. From the data we have from Integrated Management Information System (IMIS) of the drinking water ministry, the states of Bihar, Assam and West Bengal have many pockets of high arsenic in groundwater.

In Bihar, 18 districts have high arsenic in groundwater and there is a continuous rise in the cases of cancer. Research and data analysis from the Mahavir Cancer Sansthan and Research Centre (MCCRC) suggest that prolonged ingestion of arsenic containing drinking water is associated with increased risk of bladder cancer in addition to cancer of the skin, lungs, digestive tract and kidney. Dr. Ashok Ghosh from MCCRC analysed the trends in cancer cases and arsenic affected districts i.e. Bhojpur, Bhagalpur, Buxar, Vaishali, Patna and others in Bihar (Abhinav et al, 2016). He concluded that there are various cases of arsenic poisoning and cancer cases are detected in these arsenic hotspots of Bihar. High concentration of arsenic was found in patient's drinking water source, their blood, hair and nails. This suggests that arsenic is getting into their human system and may trigger processes for getting cancer.

Liver, lung and bladder cancers in Bangladesh have been linked to arsenic in water. Studies indicate a doubling of mortality risk due to cancer in Bangladesh (229.6 vs 103.5 per 100,000 population after the onset of Arsenic in groundwater in the past 3 decades) (Chen et al., 2004; Mostafa et al., 2008).

Because cancer can be triggered by mutation through genetic, behavioural and environmental factors, it is important to understand that causal factors for cancer may be due to multiple factors and not necessarily water alone.

The term cancer catches people's imagination and politics is played by not focusing on the root issues. Putting all the blame of cancer on water shifts the debate from other factors which may be causing cancer. A sense of danger prevails with a basic need of life i.e. drinking water. Adding poor communication about the causes of cancer has people thinking that "certain" drinking water sources cause cancer, affecting the poor the most when they cannot find safer alternatives.

Toxins in the food chain: how serious is the issue?

Arsenic in rice, heavy metals in rivers getting into river bed grown vegetables such as water melons, fluoride in dry land crops such as millets and others, are growing concerns which reflect a bulging rural agriculture economy heavily dependent on groundwater, yet not being able to acknowledge the fact of toxins moving through food. The Daily Tolerable Intake (DTI) of any toxin through water, food or any other source is something that determines the serious of risk of that contaminant. Another factor is the bioavailability of the contaminant through that route, but for safety purposes it is better to assume full bioavailability.

For arsenic DTI is 2.1 micro grammes per kg of body weight according to the WHO (WHO, 2010). For example, for the 50 kg adult, the DTI would be around 110 micro grammes per day. This could be intake through both water and food. If rice has 1,000 ppb of arsenic, one kilogram of rice would contain 1,000 micro grammes of arsenic. If the consumption of rice in Bangladesh is around 350 g per day, then around 350 micro grammes of arsenic would be consumed only from rice itself. This makes it highly harmful. Another rice sample with 100 ppb arsenic, would result in 35 micro grammes per day of arsenic consumption, which is lesser than DTI. Then one needs to look at water as a source of arsenic too. A simple tool has been created for this risk assessment at bit.ly/arsenicrice.

Briefly put, a Quantitative Chemical Risk Assessment (QCRA) is needed to look at how dangerous a particular contaminant can be from food. Just the presence need not be always risky. It depends of the daily consumption quantity, and also on bioavailability, something which we did not consider above.

Regionally, rice samples show a wide range of arsenic content from endemic areas. The EU has brought out standards for arsenic in rice ranging from 100 ppb to 300 ppb with more stringent standards for infant cereal food (UK Nutrition, year?).

Cooking methods also make an impact of how much arsenic gets absorbed within the body. Rinse washing can remove around 10% of arsenic, whereas using a high volume of water to rice in cooking of up to 6:1 can remove up to 45% of arsenic from rice. This is assuming that the water does not contain arsenic which unfortunately is not true for many (Senanayake and Mukherji, 2014).

According to Meharg (2004), at arsenic levels of both safe levels below the WHO limit and at high levels of around 300 ppb, arsenic from rice contributes between 30 – 60% of total dietary intake. This is therefore a highly ignored subject in the region and just the provision of safe drinking water might not be sufficient in these areas to counteract arsenic poisoning.

To sum it up, the larger concern about all rice from the EGP region having contamination with arsenic is highly flawed. In fact, a district/province level indicative risk assessment should clear this up. Secondly, cooking methods have a big impact on consumption of arsenic. The larger issue of livelihoods being dependent on irrigation needs to be kept in mind so that policies can be made balancing risk to public health and livelihoods.

When do behaviours change: is it just a matter of economics or is there space for priorities to change?

Many of the questions around poverty and priorities for preventative health aspects such as water quality issues, centre on a change in behaviours. Adoption of solutions and change in behaviour over the long term, especially for the poor, brings in aspects of affordability and perception of the water quality problem.

A study by Das et al. (2016) in West Bengal looked at the acceptance of community and changes in behaviour around arsenic free water by paying a user fee charge. In this case, it was found that most of the users who were paying a fee felt the maximum change was in terms of the colour of water, which was related to high iron levels not arsenic. Very few people actually valued the real problem, which is arsenic. It shows that the aspects which people value more would not be the same as those which are important scientifically.

The question of whether colour coding of tubewells makes a difference to user behaviour shows interesting results. Haque and ShyamSunder (2014) analyzed the behaviour of communities towards wells marked green (safe) and red (unsafe), and concluded that as compared with mass communication based messages, localized colour coding of wells leads to a 60% decline in unsafe water usage. However, more than 50% of the community continued to drink water from the red marked wells. This is in spite of a majority of them knowing the risk of contamination.

Some factors such as education levels, presence of arsenicosis affected patients and other aspects emerge as possible explanations to this continuing misuse.

Persistent information also has an impact on people's behaviour. A study by Balasubramanya et al. (2014), looked at switching behaviour by people from safe to unsafe water and vice-versa, and their relationship with testing of water and the communication of results. Over time from 2005 to 2008, the proportion of people switching to safer water sources has increased, and this was related to their recall of the arsenic testing of water. The study advocates the frequent testing of water to maintain behavioural change.

The perverse consequence of reliance on information to switch behaviours has been recently recorded by Buchmann et al. (2019). There is now evidence of unintended consequences of communities switching their water source due to the arsenic threat, but now suffering from increased infant mortality and diarrheal diseases. In this case, behaviours are modified by information which represent only part of the reality.

Largely, since testing of arsenic water is not that easy and no early visual symptoms are seen, the detection is quite difficult. This, adding to the recent cancer scare, is causing extreme reactions and responses related to people's perception vs reality, as shown in **Table 2**. Given the high poverty of the EGP and dependence of people on irrigation for livelihood, it is important to consider how to communicate and manage all four spaces.

TABLE 2 BEHAVIOUR AND PERCEPTIONS AROUND WATER QUALITY IN THE EGP

	Perception - high arsenic	Perception - no arsenic
Reality - high arsenic	This is the space for action and desirable	This is the space of denial due to many reasons either lack of information or lack of priority
Reality - no arsenic	This is the 'scare phenomenon' and over reactions like say to cancer, or the WB Boro paddy case	This is also desirable, as to the space of preventing problem in the longer run, if there is a risk

The story of these three contaminants arsenic, iron and Bacterial/Viral contamination underlie a common thread. Priorities of the community can vary from one place to another and colour/taste and related aspects still play a crucial role. However, even very well intended interventions have resulted in adverse outcomes. Therefore, promotion of just one aspect of safe water needs to be sensitive to other priorities of the community, and that could be helpful in developing much more effective and sustaining habit changing practices amongst the affected communities.

Surface water to every house with pipes: Will it be a reality soon?

Surface water supply through pipelines for the EGP region is a much promised dream. Each of the three countries have schemes with differing levels of promise.

Bangladesh has the Rural Water Supply and Sanitation Project (BRWSSP) (Ibrahim, 2004) that has shown a steady progress since the past decade with increasing coverage. However, looking at the entire scale of arsenic affected areas, the reach of surface based pipe water is still very low.

The Indian national rural drinking water program is achieving its targets of providing access to water in remote habitations through groundwater based village supply schemes. However, with falling groundwater tables and issues of water quality like fluoride, arsenic and other emerging contaminants having clear public health impacts, this requires reimagining the idea of safe drinking water sources once again. Because surface water is relatively free of these chemical contaminants and the idea that water quality and quantity can be controlled in a centralised supply system, it is making way back strongly within the policies and programs of many drinking water initiatives. Commitments are being made by the central and state governments alike to achieve "Har Ghal Jal" based on SDG 6 to achieve universal and equitable access to safe and affordable drinking water for all.

In the eastern Indian Gangetic regions, the states of Bihar and UP have lagged in parameters based on household connections and piped water supply as identified by the Ministry of Drinking Water. The population in these states are heavily dependent upon Chapakals (handpumps which tap groundwater). Right from 2013, there was a push through various schemes towards Piped Water Supply Schemes (PWSS). A world bank project named Neer Nimal Pariyojana to provide piped water supply to households in rural areas is being implemented in phases. To deal with groundwater quality issues, PWSS is envisaged as a solution in the centre-backed national water quality sub-mission targeting 28,000 habitations affected with arsenic and fluoride with clean water in the states of Bihar, Assam and West Bengal. Riding on the PWSS narrative, the central government plans to launch 'Nal se Jal' (Water from Tap) in a mission mode to provide piped water to all by 2024.

PWSS come with heavy capital costs, simply because of the extent of infrastructure required to execute and maintain them. In 2016, two big states in India (Telangana and Bihar) declared PWSS as state flagship program to provide safe and sustainable piped drinking water supply from surface water sources. Both the schemes have massive figures in terms of the scale and the expenses. Bihar's Har Ghar Nal ka Jal scheme will need investment of about INR 47,000 crores coordinated between different departments.

Numbers will catch people's imagination as a response to their water woes. But other questions arise which need equal attention: Where is the money coming from? Who is going to pay? Will the government pass the expenses incurred through various other taxes?

In practise, the concerned departments are not able to recover enough money to maintain these systems and many are not operational. As a result, today there is defunct infrastructure (broken pipes, tanks, overhead structures and so on) seen in many villages. Many piped water schemes periodically slip back to 'partially covered' or 'not covered' status. Build and rebuild has been a syndrome when it comes to rural water supply schemes. Whether "Nal se Jal" will be simply another case of rebuilding is an important question. What it takes to sustain such initiatives through innovative community monitoring exercises will be key to the vision for safe drinking for all.

Irrigation and the drinking water question: can we manage with improved irrigation management?

The majority of usage of groundwater in rural areas of the EGP region is for irrigation. The mechanisms by which geogenic contaminants are released into aquifers are quite closely related to the manner in which groundwater is used through tubewells.

Water table fluctuations from summer to monsoon is regarded as one dominant theory for arsenic release.

Groundwater pumping can increase arsenic levels in irrigation and drinking water. A recent study also proposes that land subsidence due to over pumping over clay layers could be causing arsenic to be released from deeper aquifers (Smith et al, 2018). This is a new mechanism and the proposal is that it could be a widespread one.

In this sense, groundwater-based irrigation has a strong linkage to the presence of arsenic and fluoride in drinking water. The question therefore is that whether tighter management of groundwater-based irrigation can bring in better management of such contaminants in the aquifer. Practically speaking, the possibility of such management is not very strong due to the livelihood linked policies and strong dependence of the rural poor with ground water based irrigation. However, it remains to be seen if there can be better control over these contaminants through irrigation control.

Walking the tightrope between livelihoods and health risk

Eco-anxiety is a growing concern worldwide. Even in the South Asia region, there is a divide between those who are aware of issues, concerned and connected with power centres to take action, on one hand; and on the other hand, those who are at the margins of society, affected by water contamination, but at the same time highly dependent on scarce resources such as land, water and soil for their basic livelihood.

One such example of this divide was the ban on Boro paddy in West Bengal in 2007 as quoted by Mukherji (2007). It was argued that the excessive zeal shown by eco-anxiety resulting in banning of Boro paddy by the West Bengal government would actually result in severe loss to farmers resulting in high malnutrition. This would further aggravate any existing situation of arsenicosis since poor nutrition makes arsenic toxicity worse. This ban was subsequently revoked, and it paved the way for farmer livelihoods dependent on the summer Boro paddy to be regained.

Concerns about arsenic and rice today in the EGP region is widespread. Especially the risk of cancer is something which troubles many people. However, it also needs to be kept in mind that a lot of people living in poverty in this region are very closely dependent on groundwater based irrigation. By generalising the extant of arsenic regionally and by linking summer groundwater based irrigation to high arsenic, a highly over cautious route was adopted.

Another issue that connects contamination with public health risk is that of Encephalitis across the region. There are several causal mechanisms for Japanese Encephalitis (JE) and Viral Encephalitis (VE) such as the recent malnourishment related incidents of north Bihar. The JE situation is eastern UP of India is connected with rice fields and piggeries in close proximity with a dense population and children having low hygiene. VE is exaggerated by the lack of sanitation - water connection through toilets and shallow water table. However, responses to JE and VE do not consider the huge impacts on livelihood patterns which depend significantly on rice and livestock for the poorest. This is another area where a balance is needed between livelihood and public health.

The tightrope between balancing environmental concerns and farmer livelihoods is critical to this region since it is the same people who bear the brunt on both ends. The huge social and economic health burden of water contamination is equally important.

Is nutrition improvement the answer to water contamination diseases?

The widespread prevalence of water related toxic contaminants along with regional and local disparity in the extant of the associated diseases has led to research looking at reasons as to why certain people and communities are less or greater prone to these symptoms.

One answer has come from the nutrition side. The region as a whole is highly affected by malnutrition of different sorts, having a close association with poverty levels. Now it has been shown that malnutrition also has a close link with diseases such as arsenicosis and Fluorosis, apart from relatively better established links with diarrheal and related problems (Mitra et al., 2004). Anemia and chronic diarrhea with linkages to environmental enteropathy are a vicious loop within which poor nutrition, Anemia and unsafe water are closely interlinked.

Some studies surmise that low consumption of animal protein, calcium and some other nutrients might increase the chances of skin lesions due to arsenicosis. Similar linkages have established for fluoride intake (Reddy, 2009; Susheela, 2001). The Jury however is open as to which nutrients and to what amount affect beneficially or adversely impact these diseases. Nutritional enhancement is now increasingly being touted as a possible response to these diseases. In some cases it opens up another route for action, especially in situations where the level of exposure is not that significant and the stage of disease is still early.

Are we missing some obviously simple responses?

In the larger atmosphere lying between options such as regional pipewater schemes, or water treatment plants, and other solutions, some responses are looking at the obvious. Small ponds and availability of surface water is plenty across the region of the EGP. However, this water is unfit to drink mostly due to infectious contaminants and suspended matter. This is difficult to treat.

The Sulabh organization in India has been looking at this option and promoting local pond water as a solution to the arsenic problem after appropriate treatment. Availability of pond water is surely a much easier option, especially in the eastern parts of EGP such as West Bengal, Bangladesh and parts of Bihar. If this sort of local treatment and safe water supply scales up in the near future, then it might show a very good alternative to currently available options.

The past is attractive, but can we really go back to shallow open wells?

The relative toxicity difference between arsenic (III) and arsenic (V) is one angle which has been suggested as a possible intervention angle. In the process of oxidation of arsenic (III), and exposure especially in open dug Wells, the hypothesis is that arsenic (V) is formed, and that too after sufficient exposure to the atmosphere dissipates as Arsenite gas. Therefore, dug wells could be a much safer option to use in the entire region.

This option explored by organizations such as the Megh Pyne Abhiyan (MPA) in Bihar is yet to receive scientific support and endorsement from government agencies in the mainstream (MPA, 2012).

However, such options pose a challenge nevertheless. Having withdrawn people away from dug wells for a generation, and people getting used to community and private handpumps, it is quite a difficult challenge to get them to accept dug wells as drinking water options.

Added to that fact is that poor sanitation and waste directly being dumped into such open wells make them much less attractive as sources of drinking water. Programmes such as India's Swachh Bharat Abhiyaan have promoted safe sanitation practices, mainly the use of on-site sanitation toilet pits. However, there are concerns that these poorly constructed pits are further contaminating the shallow groundwater, resulting in further spread of diarrheal and related disease burden due to the fecal-oral transmission (Krishnan, 2011).

An online assessment tool called SanitContam (bit.ly/sanitcontam) helps in providing a risk estimate of the possibility of groundwater contamination from on-site sanitation practices. Understanding such risk can help in solutions such as using open wells for safe drinking water by planning along with the community and spacing of wells from on-site sanitation contamination sources.

For such solutions to go ahead, and even possibilities such as rooftop rainwater harvesting, there needs to be a larger scale support from different government policy and initiatives together so that behaviour change at that scale could be supported. Otherwise they have the danger of ending up a small and very interesting initiatives that do not have the necessary supporting ecosystem to thrive and scale.

Other and emerging contaminants

As we move from west to east in the EGP, arsenic contamination is prominent starting from east Uttar Pradesh, Bihar, West Bengal, Assam and Bangladesh. High iron levels are also seen among these places but people have found a way to deal with it using sand filters. As if arsenic was not enough, fluoride contamination is also seen with increased groundwater exploitation through tubewells and depending upon the type of geology in the region. Severe symptoms of fluorosis are seen across different parts of Bihar and West Bengal in India.

An interesting perspective on iron coming from Bangladesh is that of dietary contribution of iron from drinking water (Merrill et al., 2011). This study indicates around 41 mg daily iron consumption from water. However, how much of this is bioavailable and leads to reduction in Anemia is still unknown. Iron from water in higher amounts also has other health implications, with linkages to iron related diarrheal problems and in very rare cases liver cirrhosis.

We must also note some interlinked problems such as Cholera being linked to saline water, and therefore issues such as coastal salinity ingress, climate change and changing regional weather patterns potentially contributing to a rise and return of Cholera (Magny and Colwell, 2009).

A staggering 42% of more than 3,500 water samples across Bangladesh showed high manganese concentrations (, 2010). This now needs to be strongly considered because of the potential health implications. Along with manganese, some emerging contaminants are uranium and chromium and manganese. The Indian government has launched a nationwide uranium detection initiative in which traces have been detected from this region too. Chromium is now widely prevalent due to industrial sources. Kumar et al. (2018) identified uranium hotspots in south Bihar, and from this first study, there is indication of much widespread contamination in the region, especially in rocky areas.

According to the WHO standards on manganese and health implications, (WHO, 2011), there is a possibility of adverse neurological effects in affected people is a possibility from inhaling high amounts of manganese. Several studies across the world indicate this as a possibility and hence Bangladesh would at some point of time need to take this seriously.

Pesticides, herbicides and use of agricultural chemicals lead to some contamination of groundwater, which can reflect in drinking water supplies. The detection of pesticides is tough in the EGP region given the priorities of existing research, availability of resources and capabilities of laboratories. However some early research point to initial concerns. Especially, the proxy of Nitrate could be applied to having an understanding of agrochemicals as a whole. The problem with Nitrates through is that they could come from a variety of sources, especially animal faeces and human faeces. Studies in Bangladesh show rural areas with Nitrate concentrations much higher than the WHO safety limit (Majumder et al 2008). Similar such studies in Nepal show elevated Nitrate concentrations in rural areas (Chettri and Smith 1995). In India, the government records Nitrate as part of public government data sets. Routinely, Nitrate concentration show higher ranges and studies have pointed out local high values (Kumari et al, 2019).

In addition to the water quality issues, this region is also a hotspot of the Acute Encephalitis Syndrome (AES) which is a broad term referring to the brain disorders or infection caused by bacterial and viral attacks. The Japanese Encephalitis (JE) virus is the most common cause of encephalitis syndrome. AES has multiple transmission routes including the risk of entero-viral and to some extent of bacterial contamination. It also has strong linkages with unsafe drinking water and poor sanitation, which increases the risk of transmission of AES. Hence providing safe drinking water to many districts in this eastern belt has become a top priority for the drinking water department.

The linkages between many of the existing and emerging contaminants to public health is a topic of new research and much work needs to be done in this region for this direction.

Key recommendations

- Data collection and a sharing paradigm on water quality in the EGP needs a major shift if we plan to make a difference to the 50+ million people affected by arsenic pollution and other issues.
- While community based water treatment plants and domestic purifiers serve well at small scales and pilots, they are quite doubtful as options to reach scale in this region.
- Surface water through pipelines have some pockets of good reach, but as a whole, it might be better to consider treated local surface water from ponds as a safe water option.
- In order to better grasp the rice and food contamination of toxins such as arsenic, it might be good to come up with a data based index at a district level which is indicative of risk to health.
- Since livelihoods closely depend on tubewell irrigation, any policy regulation for water quality needs high sensitivity in the region for protecting people's livelihoods.
- Better nutrition as an option for preventing water contamination based diseases needs attention.
- Cancer and other disease hotpots are emerging in the region, but one needs caution before declaring them as solely linked with water. More research is recommended to define these links.
- Change of behaviour around water contamination needs sustained data and information over longer time frames. It is therefore suggested to have a mass media and localized sustained campaign with a long term vision of behaviour change, rather than one time activities.
- While options such as open wells look interesting to improve access to safe water, the associated poor sanitation problems and high risk of diarrheal mortality means that we must be cautious in recommending this option.
- Lastly, emerging contaminants pose a serious risk to the region. Uranium and manganese are just two of several such toxins entering the food chain through water. Managing them needs data first on a regional scale.

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Appendix: Methodology for Arsenic Map of EGP

The analysis and mapping presented in **Figure 2** of this study is presented here.

Three datasets have been accessed:

1. Dataset of the British Geological Survey (BGS) of Arsenic in Bangladesh. This dataset has a total of 4157 data points across the country
2. Dataset of www.nrdwp.gov.in of the Government of India of Arsenic data in three Indian states Uttar Pradesh, Bihar and West Bengal from 2018-19. This dataset has 10,691 well points
3. Paper published by Shreshtha (2012) on Nepal Terai giving summary of 20,154 well data

Since the distribution of Arsenic data varies logarithmically from 1-0 ppb to 2000-3000 ppb, taking linear averages gives a very skewed picture biased towards the higher values. In case of India and Bangladesh, since there was access to the raw well data, we have taken log averages over each of the districts.

In case of Nepal, Shreshtha (2012) reports the number of samples in each range i.e. 10 ppb – 20 ppb, 20 ppb to 50 ppb and greater than 50 ppb, giving also the maximum value found in the district. We have followed this process here:
Step 1: take a linear average of the first two ranges, weighted by the number of samples, and at midpoint of the range representing the range data ie 15 ppb and 35 ppb respectively.
Step 2: tale a log average of the third range between 50 ppb and maximum value
Step 3: take a linear average of the above two averages weighted by the number of samples

This dataset will be further refined by accessing datasets of a recent study from India and of previous years of Govt of India data. Also other such datasets are being explored. The permalink of the map and data will be available so that any update is reflected there.

Foresight for Food Systems Status Reports

The Foresight for Food Systems in the Eastern Gangetic Plains (EGP) is a project led by IFPRI that seeks to lay down the groundwork for an open, scientifically informed and participatory foresight for food exercise in the EGP region led by regional scientists and engaging with other stakeholders like policy-makers, private investors, and farmers. A set of status reports on different components of the food system for better understanding of the current status, future challenges, research and knowledge gaps has been prepared for informed policy making for a sustainable future. The status reports will provide inputs into foresight and scenario building exercises in the region.

This work is funded by the Sustainable Development Investment Portfolio (SDIP), an Australian Government development strategy to increase water, food and energy security in South Asia to facilitate economic growth and improve livelihoods, targeting the poorest and most vulnerable, particularly women and girls.

SDIP initiatives aim to build technical capacity, share and generate knowledge, facilitate transboundary dialogue and mobilise the private sector and civil society in support of this objective. The focus area for SDIP initiatives is the three Himalayan river basins – the Indus, Ganges and Brahmaputra – which cover parts of India, Pakistan, Bhutan, Nepal and Bangladesh.

SDIP is a 12-year strategy (2012-2024), recognising that many of the critical interventions required for improving the integrated management of water, food and energy at the river basin level require sustained engagement to build regional cooperation and capacity over time. The Australian Centre for International Agricultural Research (ACIAR) is one of seven partners in SDIP. ACIAR SDIP funds research and development activities that improve agriculture's contribution to sustainable food systems. For further information on the project please visit https://aciarsdip.com/component-2