Evaluating Strategies to Reduce Arsenic Poisoning in South Asia: A View from the Social Sciences

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Abstract:
The World Health Organization has labeled the problem of arsenic contamination of groundwater in South Asia as “the largest mass poisoning in human history.” Various technical solutions to the problem fall into one of two broad categories: Cleaning contaminated water before human consumption, or encouraging people to switch to less contaminated water sources. In this paper we review research on the behavioral, social, political and economic factors that determine the field-level effectiveness of the suite of technical solutions, and the complexities that arise when scaling such solutions to reach large numbers of people. We highlight the conceptual links between arsenic-mitigation policy interventions and other development projects in Bangladesh and elsewhere analyzed by development economists, that can shed light on the key social and behavioral mechanisms at play. We conclude by identifying the most promising policy interventions to counter the arsenic crisis in Bangladesh. We support a national well testing program combined with interventions that address the key market failures (affordability, coordination failures, and elite and political capture of public funds) that currently prevent more deep well construction in Bangladesh.

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1. Introduction

Much of the world’s disease burden is due to poor environmental quality (Pruss-Ustun and Corvalan, 2006). In many cases, environmental health challenges permit choices that can reduce the risks that people face (Pattanayak and Pfaff, 2009). For instance, people can invest in preventive health products such as bed nets to reduce their risk of malaria, or chlorine tablets to reduce the risk of acute gastrointestinal diseases like diarrhea. Policies designed with methods to overcome behavioral barriers can be the solution to these public health challenges.

An estimated 45 million Bangladeshis consumed drinking water with arsenic concentration exceeding levels deemed dangerous to the human body according to a report published in 2009 (BBS/UNICEF, 2011). The World Health Organization (WHO) referred to chronic exposure to arsenic from drinking well water in Bangladesh as “the largest mass poisoning of a population in history” (Smith et al., 2000; WHO, 2012). As a response, the government and various non-governmental organizations (NGOs) implemented strategies to mitigate exposure to arsenic. Initial attempts at studying arsenic mitigation focused on technological aspects of arsenic removal, and geochemical processes. These efforts will only be successful to the extent that the technology will be widely implemented by policymakers, and/or adopted and used by households drinking contaminated water. Complexities in implementation, the political calculus of policymakers, coordination failures in the community, or simply, household aversion to behavior change may undermine the promise of technically effective solutions.

This paper analyzes promising interventions with the potential to address the arsenic crisis through a social scientific lens. Social scientists are well equipped to design mechanisms that can address the behavioral complexities that may arise when attempting to implement technical
solutions. For example, economic analysis can help identify why demand for point-of-use filters is so low despite their apparent large benefits. Mechanism design can be used to overcome collective action failures. And randomized controlled trials (RCTs) and other techniques can be used to rigorously evaluate the effects of policy interventions, to advise policymakers on the strategies that work best.

Promising arsenic mitigation interventions can be divided into two broad categories: Either removing arsenic from contaminated groundwater before it enters the human body, or encouraging users to switch to a different water source that has lower arsenic concentration. Interventions to remove arsenic before it enters the body include filtering water. There are small water filters that individual households can invest in, or larger filtration systems that are shared by the community. Interventions such as subsidies, information campaigns, or marketing, can be designed to target the underlying reasons for the low adoption of filtration systems. Those reasons may include cash liquidity constraints, lack of information, credit market imperfections or coordination failures. Similarly, social science research can also inform interventions that encourage the second category of solutions: Switch to cleaner sources of water. This could involve either providing information about contaminated wells through test kits, or building deep tube wells to collect water with lower concentration of arsenic. Such interventions produce their own set of implementation challenges, such as the politics of deep well placement. This review paper will discuss research on that issue.

The paper will conclude by examining the complexities of scaling up arsenic-mitigating interventions to address the problem at large scale. Issues of political economy, network and spillover effects, macroeconomic impacts, and external validity will be discussed in detail.
2. Background

Arsenic contamination is not unique to Bangladesh, but it is the most affected country by far. Arsenic is naturally released into groundwater by Himalayan sediments. As a result, the groundwater in many countries in South and Southeast Asia (including India, Myanmar, Nepal, Pakistan, Cambodia, Laos, and Vietnam) is contaminated to some degree (Ravenscroft et al., 2009). Bangladesh is especially affected, with an estimated 45 million Bangladeshis consuming drinking water with arsenic concentration exceeding the WHO guideline of 10 microgram per liter (Kinniburgh and Smedley 2001; Fendorf et al. 2010).

There was a massive shift towards groundwater in Bangladesh in the 1970’s and 1980’s due to public health concerns about bacterial contamination of surface water sources. Excess infant mortality from diarrheal diseases, cholera and other water-borne illnesses led governments, international donors and and NGOs to undertake massive programs promoting shallow tube-well installation across the country, to reach aquifers free of pathogens.

The presence of arsenic in ground water was first noted in the early 1980s in Western Bangladesh, when visible manifestations of the disease were first identified and attributed to water from shallow tube wells (Chakraborty and Saha, 1987). It was not until the late 1990’s when the scale of the problem was fully understood, and prompted massive public health action to test all tube-wells in the country (Dhar et al., 1997). By 2005, 1.4 million shallow wells that drew groundwater above Bangladesh’s drinking water standard of 50 micrograms/L in arsenic were painted red, and another 3.5 million wells that were below the standard were painted green. Since then, most tube wells installed after the national testing campaign remain untested today (Ahmed et al., 2006).

Early efforts to mitigate the arsenic crisis focused on switching from groundwater to surface water from hand-dug wells, rain water storage devices, and (filtered) pond and river water (GOB,
However, although switching to surface water sources may have reduced arsenic consumption, it had the unintended consequence of increasing the risk of disease through fecal contamination (Howard et al., 2006; Johnston et al., 2014; Lokuge et al., 2004).

The health impacts of chronic arsenic exposure are severe. It is estimated that 6 percent of total mortality in Bangladesh is due to chronic exposure to arsenic (Flanagan et al., 2012). The main cause of the excess mortality is cardiovascular disease, and not cancers that researchers have linked to arsenic elsewhere (Chen et al., 2011; Smith et al. 2000). Chronic exposure has also been linked to increases in stillbirths, infant mortality, and motor and intellectual impairment of children (Parvez et al., 2011; Quansah et al., 2015; Rahman et al., 2007; Wasserman et al., 2004).

Arsenic exposure negatively effects productivity. Pitt et. al (2012) estimates that reducing Bangladeshi Arsenic retention to US levels would, on average, increase household income by 9% per male worker. At the national level, arsenic related mortality is expected to cost Bangladesh US $12.5 billion over the course of 20 years (Flanagan et al. 2012).

3. Strategies to Reduce Arsenic Consumption

Solutions that mitigate consumption of arsenic in the water supply involve different categories of interventions, as well as coordination between policy makers, implementers, communities, and the end users. There are two broad strategies to address arsenic poisoning. The first is to clean the contaminated water before it enters the body by means of technological solutions like filtration systems. The second category of solutions is to have people switch to clean sources of water by means of well testing and building low-arsenic deep tube wells. These interventions involve overcoming information frictions and expanding access to alternative sources of water. This section discusses these two sets of strategies, and the interventions motivated by these strategies, along with the design and implementation challenges policymakers must consider (see Table 1 for a summary).
3.1 Cleaning up before it enters the body

Filtering methods to clean contaminated water was promoted by the National Arsenic Mitigation Policy in response to the discovery of arsenic in well water. Pond sand filters, small community slow sand filters, were promoted because it could purify readily available surface water such as ponds and rivers. However, support for sand filtration diminished because of the susceptibility of fecal contamination (Howard et al., 2006). Efforts to remove the arsenic from the groundwater by large arsenic removal plants has not seen much success, and ensuring proper maintenance proved to be a challenge (Hossain et al., 2005). Interventions that demonstrate arsenic removal through effective filtration at the household level can be promising, provided demand for such products is sufficient. Community filtration systems that serve a large amount of people may be sustainable if maintenance efforts are properly coordinated. This section will go over these options, their challenges, and recommendations.

3.1.1 Point-of-Use Treatment

Point-of-use arsenic purification filters such as the SONO water filters, three-pitcher filters, and READ-F filter, have been shown to effectively reduce arsenic levels (Hussam and Munir, 2007; Sutherland et al., 2002). However, field tests have found disappointing results on their adoption and usage (Johnston et al., 2010). Sanchez et al (2016) provided households READ-F filters, an easy-to-use device that filters shallow well water and encouraged them to use them over the six month duration of the intervention. Initially, participants experienced lower urinary arsenic levels. However, benefits eroded over time and arsenic returned to pre-intervention levels by the end of the study period. After one year, 95 percent of filters were abandoned. Households cited “inconvenience” as the primary reason for abandonment (Johnston et al., 2010).
More research is needed promoting the use of point-of-use filters. It is unclear, for example, how much households would be willing to pay for filters and how to get households to actually use them. Although limited research has been done on the demand for arsenic-removal filtration products, research on other water purification products have shown that demand has been low among poor households (Ahuja et al., 2010). In Ghana, for example, demand for Kosim water filters that is micro-biologically effective at removing more than 99 percent of E. coli in field trials, is low relative to the costs (Berry et al., 2019; Johnson et al., 2007). Kremer et al., (2009) find low willingness to pay for point-of-use chlorine treatment in Kenya when households were given coupons to redeem at local stores.

The puzzling evidence showing low demand in water filters is not unique. It has been the focus of a large body of literature in economics as to why products with high benefits- whether they be bed nets, latrines, or fertilizer - have such low demand (Duflo et al. 2011; Foster and Rosenzweig, 2010; Guiteras et al., 2015; Meredith et al., 2013). Demand for preventive health products in particular tends to rapidly fall at even small positive prices (Ashraf et al., 2010; Cohen and Dupas, 2010). The reasons behind why demand is so low has been the focus of a large body of research. Factors such as cash-liquidity constraints, or a lack of information can be the key barrier to adoption, and insights into research on these topics can shed light on promising policies promoting arsenic mitigation technologies.

Many preventive health products require large lump-sum costs. For example, Sono Filters which remove arsenic through chemical reactions with iron, costs about USD 40 (Hussam and Munir, 2007). If affordability is the concern, then a credit program or payment plan can enable households to invest in the health product and reap the long-run benefit may be sensible policy. In
another setting, providing access to micro-consumer loans for insecticide-treated bed nets led to large uptake, as high as 52 percent, among the sample population (Tarozzi et al., 2014).

Subsidies can also help alleviate financial constraints, but concerns about how lower prices affect peoples’ valuation of products, and consequently their actual usage, have sometimes reduced support from policymakers. Higher prices may cause greater product usage, known as the sunk-cost effect; or higher prices can lead to selection by buyers towards households that have a greater propensity to pay, otherwise known as the screening effect. Ashraf et al (2008) experimentally document the screening effect for home water purification systems, but do not find any evidence in favor of the psychological sunk cost effect.

Households may also under-invest in preventive technologies because they lack information about health risks. In Kenya, although 70-90% were aware of the availability of point-of-use chlorine in their local stores, 30% of households were not aware that drinking "dirty" water was a cause of diarrhea (Kremer et al., 2009). Simply providing information on the relative benefits can be an effective way to increase preventive health investments. Such interventions have been effective in other sectors such as education, where studies show that simply providing information on the returns to education can increase school completion rates (Jensen, 2010). Information programs have also been designed for arsenic mitigation efforts in Bangladesh, and we will discuss this in the next section.

3.1.2 Community Filtration Systems

Centralized community-based water treatment systems are an alternative to household point-of-use filters that can supply arsenic-free water to around 100-200 families (German et al. 2019, Sarkar et al., 2010). Current units can produce up to one million liters of clean water before needing replacement (Sarkar et al., 2010). Community filtration systems have certain advantages over
household filters. For example, arsenic levels are easier to monitor with centralized filtration systems because the tests only need to be administered at one community unit, instead of household filter units that are spread out. Household filters also produce waste that is more difficult to collect which could lead to improper disposal. Centralized systems make it easier to coordinate proper waste disposal compared to household filters which would be logistically more difficult (Johnston et al., 2010). However, the high cost and regular maintenance needs lead to concerns about long-run sustainability of community-based systems. Maintenance of rural water infrastructure has been found to be a challenge in many settings. For example, over a third of rural water infrastructure in South Asia is estimated to be not functional (World Bank, 2003).

Institutional arrangements such as community-based maintenance arrangements where community members organize funds and provide maintenance, may be an effective way to ensure that point-of-source filtration units are operable. In such arrangements village water committees collects small fees from villagers that contribute to the cost of maintenance. Maintenance itself is conducted by caretakers who are appointed by the villagers' committee. In some models, committees are operated on a voluntary basis with little explicit public authority for revenue collection (Miguel and Gugerty, 2005).

Collective action barriers may undermine community-based arrangements. Lack of coordination between community members and free riding are challenges faced by many community-level interventions such as community toilets- where one study in Bhubaneswar, India showed that one in six toilet seats were found to be entirely non-usable (J-PAL, 2012). In Kenya, Miguel and Gugerty (2005) report that 50 percent of borehole wells that were maintained using a community-based maintenance model were inoperable by 2000. In rural Tanzania, free riding and lack of coordinated maintenance decisions decreased the functionality rate of NGO-installed clean
water pumps and consequently lowered rates of child survival and school attendance (O'Keeffe-O'Donovan, 2019).

Communal arrangements must be structured to ensure that incentives are correctly aligned and that the community can monitor its members (Duflo et al., 2012). Some evidence suggests that systems of private contracting of maintenance is an efficient way of maintaining water sources (Kremer et al., 2008; Galiani et al., 2005). Water collection fees can be used and can discourage free riding, leading to an increase in functionality (O'Keeffe-O'Donovan, 2019). Current community-based filtration systems that charge user fees, as low as $0.15-$0.30 a month, and compensate unit caretakers have been found to be financially sustainable and lead to local job growth (German et al., 2019). Complementing a system with delivery services can increase demand and revenue generation (German et al. 2019, Johnston et al., 2010; Sarkar et al., 2010).

### 3.2 Switch to water that is already low in arsenic

The second strategy to mitigate arsenic poisoning is to encourage people to switch from a high-arsenic water source to a clean water source. Individuals choose their water source to maximize their welfare subject to the constraints they face and their information set. Consuming arsenic contaminated water may be indicative of information failures, or a lack of alternative clean water sources. For instance, since arsenic levels in groundwater vary greatly over small distances, informing people of the status of their wells can induce them to switch to neighboring clean wells. Fortunately, concentrations of arsenic usually do not change over time, although some aquifers and wells need to be monitored more frequently than others (Fendorf et al., 2010). Increasing access to clean water, such as through low-arsenic deep tube wells, can also be effective in getting people to switch from their arsenic-contaminated wells.
3.2.1 Information and testing

People may drink from contaminated wells if they lack information about the arsenic concentration in their shallow well relative to other nearby wells. The distribution of arsenic incidence in groundwater is difficult to predict, and varies greatly, even over small distances. Most owners of contaminated wells live within walking distance of a well that is low in arsenic (van Geen et al., 2002). If the arsenic levels of wells were known, people may switch to cleaner sources. Testing the groundwater concentration is therefore essential to provide the necessary information for people to switch (van Geen et al., 2002).

Arsenic tests are attractive because of the low cost to administer them. In previous interventions, the cost of a simple test was as low as USD 2.26, with the cost of supplies only amounting to USD 0.30 per test. Because of the large health consequences of chronic exposure to arsenic, simply providing information through arsenic tests can therefore a highly cost-effective intervention, as long as people respond to the new information. Evaluations show that providing test data to households, in some cases along with various forms of reinforcement, has induced a quarter to a half of exposed households to switch away from contaminated wells (Ahmed et al., 2007; Madajewicz et al, 2007; Bennear et al., 2012; Balasubramanya et al. 2013, Pfaff et al., 2017).

One issue of arsenic tests is how, and who, should provide the tests. Public provision has not been able to fully meet the needs for testing. Recent estimates show that despite the national well testing campaign between 2000-2005, more than half of the currently used tube wells in Bangladesh have never been tested for arsenic (van Geen et al., 2014; Jamil et al. 2019). National testing campaigns have not been repeated and most wells have by now been replaced, and therefore never been tested.

Private testing may be a useful complement to public provision. The prospect of a private market for arsenic testing can induce local entrepreneurs to identify untested wells and market their
services (Barnwal et al, 2017). Despite the low cost, poor households may not be able to afford arsenic test kits. An evaluation in neighboring Bihar shows that while demand for test kits is substantial, it is also highly price-sensitive: Take-up falls from 69% to 22% when cost increases from Rs. 10 (US$0.16) to Rs. 50 (US$0.80). This steeply downward-sloping demand curve is reminiscent of demand for other effective preventive health care products such as insecticide-treated bednets and deworming pills (Cohen and Dupas, 2010; Kremer and Miguel, 2007). Subsidizing testing kits may be efficient policy if encouraging initial usage helps neighbors learn about the value of testing, and increases the demand for future testing. Barnwal et al (2017) finds that demand for test kits rose from 27% to 45% two years after the initial subsidy campaign without any change in the nominal sales price.

Households would switch away from contaminated to cleaner wells after testing only if they know about the health consequences of arsenic in the first place. Interventions that combine tests with education about arsenic poisoning have been shown to increase switching (Chen et al., 2007; Pfaff et al., 2017). For example, Khan et al. (2015) found higher switching rates amongst children after an arsenic education curriculum designed to raise awareness of arsenic poisoning was administered in elementary schools in Araihazar, Bangladesh.

Tests are commonly provided by representatives from organizations outside of the village who leave once tests are administered - leaving little opportunity to provide, and reinforce, educational material. Training community members to deliver arsenic education in concurrence with testing may be a less costly way to monitor arsenic levels, and reinforce information about health consequences. Such community health promoter programs are a widely used intervention to improve the quality of healthcare services, from health education to family planning and distribution of preventive care products, around the world. However, community members have not been found to decrease arsenic exposure any more than outside testers (George et al., 2012). Poor monitoring and a lack of
incentives - common problems with other CHP programs—may have been a reason why no
difference was found. Providing monetary incentives to health workers, or better monitoring, may
help improve performance and lead to better outcomes (Bjorkman et al., 2017, BenYishay and
Mobarak 2019).

3.2.2 Well-sharing Arrangements

Many shallow wells are privately-owned and arsenic concentration levels vary from
household to household. Sharing arrangements between owners of clean shallow wells and owners
of dirty wells can increase the proportion of the population consuming clean water. Such
arrangements are possible in areas where houses are geographically close to one another, and people
interact on a regular basis—which is often the case in small village economies (Barnwal,
2017). However, households may not be willing to share with people outside their social network.
Low-income households also may be less able to barter for access to a neighbor’s clean well than
households which are better off (Madajewicz et al. 2007).

Social factors have been found to be important determinants of water source usage (Mosler
et al., 2010; Inauen et al., 2013). Social norms may be such that well-sharing is not socially
acceptable, and social stigma associated with well contamination may prevent households from
revealing the status of their well and lower the willingness to form sharing arrangements with
households with clean wells. Households with unsafe wells have been found to purposefully conceal
the results of the test - suggesting that social stigma could partially be to blame (although this could
also be explained by concerns that the reveal would lower property value) (Barnwal, 2017).

Interventions that address social norms and risk can also lead more people to share clean
water. For example, combining testing with a group-commitment component where groups of
households make a public commitment to their group before seeing test results - that if their well is
tested as clean, then they would promise to share with those with unclean wells - can address free riding and aversions to water sharing. If poor, rural households are risk averse, then such a ‘risk sharing contract’ with ex-ante commitments can improve joint welfare for the group of households, and help to develop positive social norms about water sharing.

Public commitments have been shown to be effective in changing behavior and has been tested for other public health goals, such as latrine adoption. For instance, Community-led Total Sanitation (CLTS) programs is an intervention aimed at changing social norms about open defecation (OD) by having communities pledge to become OD-free. Bakhtiar et al. (2019) show that combining a form of CLTS program where community-members made public pledges in front of their neighbors was effective in increasing adoption of latrines, as opposed to private pledges and financial incentives. In the context of arsenic, Inauen et al. (2013) show that public commitments enhance the effects of information on well testing.

Guiteras et al. (2015) show that combining a form of CLTS with subsidies that reduce the cost of hygienic latrines not only increased latrine adoption, but they also found that the increases in adoption spilled over to households who did not get subsidies. Additionally, they find that neighborhoods that received more subsidies saw greater adoption compared to neighborhoods receiving less subsidies- strongly suggesting that social norms influenced people's decisions to invest in latrines. That is, if more of my neighbors invest in latrines, then it is more desirable for me to invest in latrines as well. More research is needed to see whether such demand complementarities exist for arsenic mitigation. If such influences change well switching behavior, policies can be adjusted to target only a few people with information campaigns and have them spread the information throughout the community (Madajewicz, et al. 2007)
3.2.3 Installing Deeper Wells

In addition to well testing and well sharing another provision to address the arsenic issue is to install wells that reach deeper aquifers where arsenic is not as prevalent. In some areas, such aquifers are accessible at depth <90 m and therefore reachable by local drillers using a manual method and affordable for individual households (Gelman et al. 2004). In Araihazar, Bangladesh, this has been a particularly popular and cost-effective form of arsenic mitigation (Jamil et al., 2019). Many households switched to private intermediate depth wells in response to early well testing in 2003. The cost of installation was around USD 200 per well but estimates in the area show that exposure to around 60,800 inhabitants were reduced by this form of mitigation, at an average cost of USD 28 per person.

Wells of intermediate depth are costly, and interventions to address affordability become even more important. Some form of subsidy or credit may become necessary to help households afford the installation costs. If there are learning externalities, then subsidies can induce others to subsequently adopt. Understanding the social dynamics of demand is useful to target subsidies efficiently. For instance, targeting well subsidies to certain groups, such as highly influential people in a social network, or people of lower socioeconomic status, can lead to greater subsequent adoption if neighbors learn more about the benefits and costs of the new technology, or by changing social norms. Social learning appears important for nontraditional cookstoves adoption in Bangladesh, where households make inferences about the new stoves based on information from people in their social network (Miller and Mobarak, 2014). It was also relevant for hygienic latrines in Bangladesh (Guiteras et al., 2019).

Although 90 percent of intermediate depth tube wells in the Araihazar well survey were found to have low arsenic levels, there is still a risk that such a large investment will not give you arsenic free water. Implementing an insurance scheme that compensates private individuals if it
turns out that their intermediate-depth well is contaminated with arsenic may also help increase demand. Insurance products have been shown to increase the adoption of new technologies in other sectors, such as agriculture (Cole et al. 2013; Karlan et al., 2013).

Tube wells that are deeper than 150 meters are more consistently low in arsenic, but beyond the financial reach of most households. A deep tube-well, when properly located, can meet the needs of several hundred villagers for years while requiring little maintenance (van Geen et al., 2003). Over two hundred thousand deep wells were installed as of 2007 by both NGOs and the Bangladesh government (DPHE/JICA 2009). Despite their engineering promise, installation costs remain a large barrier, and choices of where to place deep wells creates important complexities. The cost of drilling a well is linear in depth and installing a deep well can often cost around US $850 inclusive of labor and materials (Ravenscroft et al., 2014). This cost is well beyond what most rural households could afford, so private deep wells do not seem to be a feasible solution.

Most of the deep tube wells that are currently in operation were financed by governments and NGOs. However, such arrangements have probably not led to large improvements in health outcomes. This is because over half the deep wells that have been installed were sited in areas where the prevalence of contaminated shallow wells is modest (DPHE/JICA, 2009; van Geen, 2016). Households in heavily affected areas live too far from installed deep wells- beyond the 100-150m walking distance that previous studies have found to be the maximum that rural Bangladeshi households are willing to walk to fetch water (van Geen et al., 2003; Opar et al., 2007). From a blanket survey of all wells across Araihazar upazila in Bangladesh, van Geen et al. (2016) find that only 29 percent of As-contaminated shallow wells are located within walking distance (100 m) of at least one of the 915 intermediate or deep wells in the study area. If deep wells were more evenly distributed, the percentage of shallow wells covered would have increased to 74 percent. Even when
the engineering and financing constraints are addressed, there still appears to be some issue with the spatial distribution of deep well placement (see Figure 1).

One possible explanation for this inefficient deep well placement is elite capture of this valuable public resource. Local government officials in Bangladesh have large discretionary authority over the siting of deep wells. In Araihazar, a district where a lot of the arsenic poisoning research has been conducted, the central government allocates funds to local government officials to install 50-100 deep wells each year. The location is determined on the basis of input from the bureaucrat in charge of the sub-district (the Upazila Nirbahi Officer or UNO), the senior local government official called the Upazila Parishad chairman who is directly elected, and the 12 Union Parishad chairmen who are also elected (van Geen et al., 2016). This decentralization of service delivery to local governments has been embraced by developing countries since it is believed that local governments have more accurate local information to target services better (World Bank, 2004). However, taking a decentralized approach in rural communities with poverty, socio-economic inequality, and a lack of political awareness, may lead to distortions in targeting towards elites (Bardhan and Mookherjee, 2000).

Evidence of elite capture of deep well placement has mounted. In 2017, Human Rights Watch accumulated anecdotal evidence based on village interviews that politicians were preferentially placing wells near political supporters (Human Rights Watch, 2016). Van Geen et al. (2015) report that about a third of deep wells were placed in inaccessible locations, such as inside the compounds of private households. Madajewicz et al. (2017) find that a community participation intervention that was designed to limit influence of elites, led to an increase in clean water access. Finally, Mobarak et al. (2019) investigate the extent of elite capture by combining geospatial data on well placement and newly-collected geo-coded data on the location of political and economic elites. The authors find strong evidence that local politicians are more likely to have deep wells built near
them during periods when their political party is in power. This form of elite capture accounts for
about a fifth (18%) of the inefficient spatial allocation of deep wells.

Since deep tube wells have high installation costs relative to local incomes, one solution is to
have communities pool funds together to invest in communal deep wells. Khan et al. (2012) find
that households are willing to pay on average about 5 percent of their disposable average annual
household income for a communal deep well fund. However, this requires community members to
coordinate with one another on the amount they are each willing to contribute, which could vary
from person to person. They have to agree on the location of the new water sources; and collectively
maintain the infrastructure after installation (Cocciolo et al., 2019).

There are non-trivial challenges to successfully coordinating investments across households.
Cocciolo et al. (2019) finds that larger groups led to fewer households, and fewer female household
members participating in community meetings, less time spent deliberating over source location, and
fewer households contributing to the cost of installation. As a result, larger groups saw smaller
increases in the use of deep wells compared to smaller groups. More empirical evidence is needed
about the drivers of collective action failure and on how community networks change as
interventions scale.

4. Complexities of Scaling Policy Interventions

Large-scale public health problems such as arsenic poisoning across Bangladesh require
large-scale solutions. Implementing the strategies discussed in this article - treating contaminated
groundwater or switching to low arsenic groundwater - is challenging, and complexities may arise
when going from a project in one district to a nation-wide policy. As a program scales, for instance,
there may be spillover effects on non-beneficiaries, on friends and neighbors, and on markets;
political reactions from voters and governments; macroeconomic, growth, and welfare impacts; as well as concerns about the external validity of small-scale pilot results.

Interventions may have spillover effects onto neighboring households or communities, interact with social networks, and affect market prices, and wages. For example, the more people use filters, purchase well test kits, or engage in well sharing arrangements, the more attractive these behaviors could become to other members in a social network. Installation of more deep wells or community filtration systems in a given area could crowd in markets for spare parts, tools and skilled labor, leading to positive spillovers in maintenance costs and better functionality. If people are less exposed to arsenic they may become more productive employees, leading to more employment opportunities and higher wages in the community. More research on spillover effects can inform policymakers on unintended costs and benefits that can remain hidden in small-scale programs. This can motivate cost-effective intervention designs. For example, subsidies for test kits or filters may only need to be provided to a subset of households if demand for such products is interlinked between households, thus lowering the cost of the program substantially.

People may also adapt and react to policies in ways that can produce unintended effects. Some of those consequences might be negative. For example, Field et al. (2011) hypothesize that the wide-scale switch to surface water after the discovery of arsenic in 1994 might have led to higher exposure to fecal-oral pathogens, which in turn increased infant and child mortality. On the other hand, people may also adapt in ways that produce unintended benefits. Keskin et al (2017) show that mothers react to arsenic exposure risk by increasing the propensity and the duration of breastfeeding (which provides infants some measure of protection against arsenic contamination), and this in turn reduced infant mortality. The effects of any arsenic mitigation policies at scale will be inclusive of such adaptation and behavioral responses. For comprehensive policy evaluation, it is important for social scientists provide rigorous analysis on these types of questions.
As arsenic mitigation programs scale up it may change the behaviors of politicians and policymakers in response to the program. For example, if politicians have control of discretionary funding of deep wells, they may choose to install more in their home areas to gain votes, or target placement near other politicians to gain political supporters. If funding for wells is externally funded by international NGOs, programs may erode political accountability if leaders claim credit for successful programs (Deaton, 2013). Or, externally funded programs may crowd in effort or financial resources by politicians, as been found in the case of externally funded sanitation programs in Bangladesh (Guiteras and Mobarak, 2016). Research has already shown that political factors have led to inefficient deep well placement in Bangladesh through elite capture. More research is needed on how best to address these political influences. For instance, research on community participation in deep well placement that imposed rules designed to limit appropriation of projects by elites effectively expanded access to clean water sources (Madajewicz et al., 2015).

Changes in individual behavior induced by a program can, at scale, have macro-level impacts. Large-scale interventions that reduce arsenic consumption could boost human capital and labor productivity which can lead to long-run growth. However, macroeconomic models often require parameters to properly predict macro-level impacts. Rigorous evidence from RCTs can help calibrate these models to more accurately determine these impacts in the medium to long run, and even simulate alternative policy scenarios. Net welfare impacts are also important when evaluating a program but are difficult to measure without modelling. For example, people may experience non-monetary disutility by walking a longer distance to a communal deep well and may be more vulnerable to crime if they have to walk far and at night. Modeling can be used to answer normative questions about welfare tradeoffs that are important for policy decisions.
Social science research aspires to generate evidence that policymakers can use to scale promising programs. Even if the research discussed above produced internally valid estimates of the policies studied at pilot scale, there are open questions about how programs would work outside the context of those evaluations. Replication studies and subsequent meta-analyses will be useful to aggregate results from different contexts.

5. Policy Recommendations

There are tradeoffs in expanding access to clean water through well testing, versus installing deeper, more expensive low-arsenic wells. Jamil et al. (2019) conduct a cost-effectiveness analysis of alternative strategies, and find that free nation-wide well testing is the most cost-effective way of reducing exposure (see Figure 2). Well-testing alone reduced the exposed population of Araihazar in the short term by about 130,000 people. The next most effective way was installing private intermediate-depth wells, which lowered exposure for 60,000 at a cost of US$30 per person. In contrast, installation of deep tube wells and piped-water supply systems by the government reduced exposure of little more than 7000 inhabitants at a cost of US$150 per person (see Table 2 for more details). These numbers are a strong argument in favor of free well-testing.

Simply providing test results addresses an information failure, which has been found to be a major impediment to the adoption of preventive health technologies in a variety of contexts. Informing people about the level of arsenic they are exposed to bolsters their demand for alternative sources of water. Therefore, well tests must precede investments in alternative sources in order to maximize the effectiveness of testing.

If well-testing were complemented with interventions that make private intermediate-depth wells more affordable (such as with subsidies or microcredit), that combination can induce adoption and reduce exposure. A national database of well locations with test results can help policymakers target
subsidies to areas with a high density of contaminated shallow wells. Designing subsidies that encourage sharing private intermediate wells with neighbors can also increase the coverage.

Although Jamil et al. (2019) find that deep well construction is much less cost-effective, the Mobarak et al (2019) analysis suggests that much of that is due to inefficient placement and elite capture. Deep wells are often forcibly “privatized” by politicians, and this causes fewer households to get access to clean water, even after expensive deep well construction. Institutional reform that limits the discretion of public officials to site deep wells as they please would increase the efficiency of public funds that are deployed for well construction. Increasing either voter awareness, or national government supervision of local politicians, might put pressure on politicians to distribute deep wells in a fairer and more efficient way. We think that combining a national well testing program with policy interventions that address these market failures currently preventing deeper well construction is required to properly address this massive health crisis in Bangladesh.
References


Barnwal, P., Geen, A. Van, & Goltz, J. Von Der. (n.d.). Cost-sharing in environmental health products: evidence from arsenic testing of drinking-water wells in Bihar, India * 1 Introduction.


Filters, S., & Response, R. R. (n.d.). What has worked – as measured by declines in urinary arsenic? How representative is Araihazar of the country as a whole? What forms of arsenic mitigation should therefore be promoted?


### Table 1: Strategies to Reducing Arsenic Poisoning, Challenges, and Recommendations.

<table>
<thead>
<tr>
<th>Strategies</th>
<th>Interventions</th>
<th>Challenges</th>
<th>Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cleaning up before it enters the body</td>
<td>Point-of-use Household Filters</td>
<td>Cash liquidity constraints, information failures</td>
<td>Credit, Subsidies, Information Provision</td>
</tr>
<tr>
<td></td>
<td>Community Arsenic-Removal Technology</td>
<td>Coordination of Maintenance</td>
<td>Private Contracting, Collection Fees</td>
</tr>
<tr>
<td>Switching to cleaner sources of water</td>
<td>Well Testing Kits</td>
<td>Private vs. Public Provision</td>
<td>Community Health Promoters, Subsidies, Awareness Campaigns</td>
</tr>
<tr>
<td></td>
<td>Well Sharing Arrangements</td>
<td>Social Stigma</td>
<td>Public Commitments, Risk Sharing Contracts</td>
</tr>
</tbody>
</table>
|                                   | Deeper Wells                         | Cash liquidity constraints, 
information failures, elite capture.             | Credit, Subsidies, Well Testing, Community-Pooling Arrangements, Efficient Placement |
Table 2: Comparison of Interventions (Jamil et al., 2019)

<table>
<thead>
<tr>
<th>mitigation method</th>
<th>Araihazar activity</th>
<th>exposed population reached</th>
<th>exposure proportion reduced</th>
<th>exposed population reduced</th>
<th>cost ea. govt/NGO (US$)</th>
<th>total cost govt/NGO (US$)</th>
<th>cost ea. household (US$)</th>
<th>total cost household (US$)</th>
<th>total cost per exposure reduced (US$) actual</th>
</tr>
</thead>
<tbody>
<tr>
<td>testing and switching</td>
<td>48,800 wells tested (21,380 safe)</td>
<td>220,000</td>
<td>60%</td>
<td>132,000</td>
<td>2.5</td>
<td>122,000</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>private intermediate wells</td>
<td>845 private intermediate wells installed (7610 safe)</td>
<td>67,600</td>
<td>90%</td>
<td>60,800</td>
<td>200</td>
<td>1,690,000</td>
<td></td>
<td></td>
<td>28</td>
</tr>
<tr>
<td>deep tubewells</td>
<td>916 deep wells installed (907 safe)</td>
<td>51,200</td>
<td>10%</td>
<td>5120</td>
<td>800</td>
<td>733,000</td>
<td></td>
<td></td>
<td>143</td>
</tr>
<tr>
<td>piped water supply</td>
<td>312 connections installed (all safe)</td>
<td>2180</td>
<td>100%</td>
<td>2180</td>
<td>250,000</td>
<td>250,000</td>
<td>300**</td>
<td>93,600</td>
<td>158</td>
</tr>
</tbody>
</table>

Note: This table from Jamil et al. (2019) presents comparisons of the effectiveness of various forms of arsenic mitigation conducted in Araihazar, Bangladesh with their costs.

**10 years @ US$2.50/month.
Figures

Figure 1: Clustering of Deep Wells (van Geen et al., 2015)

Note: From van Geen et al. (2015) showing the clustering of deep wells. Overlapping circles of radii 100m around installed deep wells shows that 29% of people with a contaminated well (red) were within 100 meters of a deep well.
Figure 2: Cost Effectiveness of Different Interventions (Jamil et al., 2019)

Note: From Jamil et al., 2019 which shows the number of people whose exposure was reduced in Arai hazar, Bangladesh compared to the cost per person of the different interventions.