ECONOMIC RESEARCH CENTER
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E-Series

No.E16-6

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August 2016

ECONOMIC RESEARCH CENTER
GRADUATE SCHOOL OF ECONOMICS
NAGOYA UNIVERSITY

Arsenic Contaminated Groundwater and the Socioeconomic-Gradient in Child Health: Evidence from the Arsenic Mitigation Campaign in Bangladesh

Ava Cas* and Eiji Mangyo+

Abstract

We examine the impact of arsenic exposure on child health in Bangladesh. The geographic variation in groundwater arsenic level as well as the massive well-testing and awareness campaign in the late 1990s offer a natural experiment inducing variation in child's exposure to arsenic. Given the government's efforts to encourage households to switch away from "unsafe" wells, areas with "unsafe" groundwater arsenic levels prior to the campaign had greater improvement in child height-for-age relative to areas with "safe" arsenic levels. Results are statistically significant for children from educated households but not for children from uneducated households.

JEL classification: I14, O15

Keywords: child health; socioeconomic status; arsenic; Bangladesh; early life

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1 Introduction

Little is known about whether environmental and natural toxic releases at the level that generally occurs in the population have effects on human health. An obvious challenge for empirical studies is the difficulty in identifying the population's exposure to toxicities as toxic matters are mostly unobservable or unknown. In cases where it is known or observable, there is a concern that individuals exposed to such matters are likely to differ from the unexposed individuals in unobservable ways. A few studies that have carefully explored this question examined the effect of air pollution on infant health (Chay and Greenstone, 2003; Currie and Neidell, 2005; Neidell, 2004). But majority of studies that attempted to examine the health impact of other globally occurring toxic substances such as lead and arsenic are either based on small sample epidemiological studies or are subject to methodological weaknesses.

Moreover, the question of whether parental socioeconomic status plays a role in cushioning children from the deleterious impact of health shocks is of interest to many economists. Studies show that there is a strong and consistent relationship between parental socioeconomic status (SES) and child health (Case et. al., 2002; Currie and Hyson, 1999; Currie et. el., 2004, Currie and Lin, 2007). In particular, this relationship tends to be more pronounced as child gets older (Case et. al., 2002; Currie and Stabile, 2003) due to accumulated exposure to health shocks. However, the existing evidence is mainly based on correlations and it is difficult to ascertain that this relationship is causal.

In this paper, we examine the impact of arsenic exposure on child health in Bangladesh. With over 90 percent of the Bangladeshi population (and 95 percent in rural areas) relying on groundwater as their main source of drinking water, the discovery of the arsenic contamination of groundwater prompted the government to conduct massive well-testing and awareness campaign in the late 1990s to encourage households to switch to arsenic-free drinking water sources. The paper uses the geographic variation of naturally occurring arsenic in groundwater as well as the massive well-testing and awareness campaign upon its discovery as a natural experiment inducing variation in child's exposure to arsenic.

Our paper offers several contributions to the existing literature. *First,* we provide new evidence on the economic status-gradient in child health. In their paper, Case et. al. (2002) suggest that the well-known association between income and health in adulthood may start from childhood, and they show consistent association between household income and child's subjective health status. Using a natural experiment that leads to variation in child's exposure to arsenic, we examine the impact on child height-for-age depending on parental socioeconomic status. *Second,* to our knowledge, our study is the first to examine the impact of arsenic exposure at the population level on child's long-run measure of nutritional status (height-for-age). Asadullah and Chaudury (2011) examines the correlation between arsenic exposure and test scores while Field et. al. (2011) investigates the unintended consequences of the arsenic mitigation efforts on infant and child (up to age 2) mortality. *Third,* we use a rich dataset to investigate the effects on other child and maternal health measures as well as on child health parental investments. Although our main outcome of interest is height-for-age, as height reflects environmental influences particularly during the first few years of life, we also look at the occurrence of diarrheal disease. The latter allows us to also corroborate the results of studies suggesting that switching to fecal contaminated surface waters or remote tube wells which requires water storage led to incidence of diarrhea (Field et. al., 2011; Escamilla et. al., 2011; Wu et. al., 2011). In addition, we examine the pathways to child health by investigating the impact of the health shock and the subsequent public health efforts on maternal health and labor supply as well as prenatal and postnatal parental investments related to child health.

Given the government's efforts to encourage households to switch away from "unsafe" wells, our results show that districts with average groundwater arsenic level of 51-100 μg/L prior to the massive public health effort had greater improvement in child height-for-age after it had begun relative to those districts considered to have "safe" level of average groundwater arsenic (0-50 μg/L). In particular, among children from households whose heads have no education, we find no significant differences in improvement in height-for-age among children from various areas with varying arsenic level after the massive public health effort had begun. On the other hand, among children from households whose heads have any formal schooling, we find positive and statistically significant difference in height-for-age among children in areas with average arsenic level of 51-100 μg/L relative to those areas with average arsenic level of 0-50 μg/L. Furthermore, we find that such pattern persists once we stratify the sample by younger (0-24 months) and older (25-48 months) age groups, although the estimates are larger and statistically significant for the older age group. These results are similar to the patterns observed by earlier studies that look at the correlation between household income and child health (Case et. al., 2002; Currie and Stabile, 2003).

Consistent with the patterns we observe among children, we find that mothers in districts with average groundwater arsenic level of 51-100 μg/L have better nutritional status (as measured by body mass index) relative to mothers living in districts that have, on average, "safe" level of groundwater arsenic. This is particularly the case for mothers from educated households. Since women are the ones who draw water from the wells in Bangladesh, we also examined their awareness of the government's well-safety campaign and whether they adhere to it. Our results suggest that educated women were more aware of the well-safety campaign and were more likely to adhere to it. These results thus also add to the growing body of literature that highlight the importance of mother's education on child's health.

The remainder of the paper is laid out as follows. Section 2 provides the essential background. Section 3 lays out the theoretical and empirical framework. Section 4 provides the data and descriptive statistics. Section 5 presents the estimates and robustness checks. Section 6 concludes.

2 Arsenic Contamination of Groundwater and the Subsequent Mitigation Efforts

2.1 Groundwater Arsenic Contamination: A Major Public Health Issue

Prior to the early 1970s, people from Bangladesh have been drinking mainly from bacterial contaminated surface water which has led to high incidence of water-borne diseases and parasitic infections. In order to address this public health issue, the government of Bangladesh and the international organizations (United Nations and World Bank) started promoting shallow tube wells as a safe alternative source of drinking water. This led to massive construction of tube wells in the 1980s (around 11 million), the vast majority of which were privately owned (van Green et. al., 2005). At the time of this mass installation, the aquifers were not tested for arsenic as the tests for metal impurities were not mandatory until years later.

By 1990s, groundwater was the main drinking water source for over 90 percent of the population, and for 95 percent of the population in the rural areas (World Bank, 2007). Unfortunately, this initiative driven by the government's good intention to help control water borne diseases had the unintended consequence of exposing the population to another staggering health problem caused by toxic arsenic in groundwater. Several natural geological and anthropogenic processes are deemed responsible for the arsenic contamination. One explanation is that the arsenic's source in sediments is mainly the parent rock or minerals from which it was deposited. The arsenic is absorbed onto particles of iron oxyhydroxides and sulphides, which are easily oxidized and become water-soluble, releasing arsenic that is transported along during erosion and precipitation (Shanker et. al., 2014; Nickson et. al., 2000; McArthur et. al., 2001).

It was in 1994 when arsenic contamination of water in tube wells were confirmed and documented. But by the time it was discovered, it was found that approximately 28 to 35 million Bangladeshis have been drinking arsenic contaminated groundwater for over 2 decades (BGS/DPHE, 2001). After several testing and ruling out of other sources, in 1997, the World Health Organization (WHO) publicly declared arsenic contamination of groundwater as a major public health issue and in a later report considered it as "the largest mass poisoning of a population in a history" (Smith, 2000).

2.2 Testimonials on the impact of arsenic poisoning

Anecdotal evidence suggests that the arsenic contamination of groundwater had debilitating impact on its victims, not only in terms of physical health but in their ability to carry out day-to-day activities. In *New York Times* article, Rohde and Manik (2005) describes Salma Begum, aged 30 and the mother of three, who lives in the village of Abirpara in central Bangladesh and is one of the victims of arsenic poisoning.

> *All over Ms. Begum's tiny, slowly withering body, signs of arsenic poisoning have emerged. Ugly and painful boils cover her hands and feet. Her veins protrude from her skin. Dark spots cover her arms, legs and parts of her body she declines to show. Her skin itches endlessly when exposed to sunlight.*
>
> *She said her largest problem was a creeping weakness and constant ache in her arms and wrists. Her arms have grown so feeble that she struggles to hold her 2-year-old son and care for her husband and two daughters. As she speaks, she constantly kneads the muscles in her forearms and wrists, as if trying to wring the pain from her flesh. Ms. Begum said she could not afford to buy medicine to counter some of the symptoms. [She] grows weaker and more frustrated by the day.*

Even years later, Kirby (2013) describes the atrocious condition of a person who suffered from arsenic poisoning during his visit in Alumpur, a tiny village in Western Bangladesh.

> *__ is one of many villagers in Alumpur suffering from Arsenicosis, as particularly evident from his cancerous hand. He is the only remaining survivor of his siblings, all of whom died from arsenic poisoning. __ lives alone with his wife and two daughters, all of whom are unemployed and financially dependent on __ for their survival. Since being forced out of work 3 years ago, he has been unable to provide for his family, who are now struggling to survive on basic subsistence agriculture. A few local villagers put their savings together and brought __ some painkillers in a desperate attempt to ease his suffering, however he is still unable to afford a biopsy and amputation.*

2.3 *Bangladesh's Arsenic Mitigation Efforts*

The crisis led the government to create the Bangladesh Arsenic Mitigation and Water Supply Project (BAMWSP) in 1998. With a US$30 million loan from the World Bank and Swedish government, the Bangladesh government implemented a large-scale well-testing campaign analyzing over 5 million tube wells across the country and found that roughly 30 percent of the population (approximately 35 million people) have been drinking water from tube wells that have arsenic level above the national standard of 50 micrograms/liter (µg/L) while roughly 45 percent of the population (57 million people) were drinking water above the WHO recommended limit of 10 µg/L (Bennear et. al., 2012).

The massive well testing followed by the comprehensive awareness and education campaign took place during 1999-2003. Tube wells with arsenic levels above the Bangladesh standard of 50 µg/L were painted red and labeled "unsafe" while those below 50 µg/L were painted green and labeled "safe" (Balasubramanya et. al., 2013). Households were strongly encouraged to stop drinking from wells that were painted red and urged to find alternative drinking water source such as deep tube wells, dug wells, surface water, piped water, treatment of arsenic contaminated water, sharing of safe shallow tube wells and rainwater harvesting. Around the same time, the government also constructed over 9,000 deep tube wells across the country in order to tap into deep aquifers that were less likely to be contaminated with arsenic (Field et. al., 2011).

Previous research show that the well-testing and labeling campaign encourages significant switching of households to alternative water sources especially among those with "unsafe" wells. In the 25 km^2 area of Araihazar region, Madajewicz et. al. (2007) find that over 50 percent of the households with unsafe wells have switched, despite the distance of alternative wells. One year later, Opar et. al. (2007) finds that over two-thirds of the households with unsafe wells have switched to alternative water sources.[1] In contrast, only 15 percent of the households with wells labeled as "safe" have switched. They also find that in general, higher education increases the probability of switching away from unsafe wells, and that more educated households tend to switch to private wells compared to community wells. According to the authors, it may be that better educated households are more likely to be aware of the arsenic status of their neighbors' private wells and have better negotiating power when convincing their neighbors to share their private wells with them (Opar et. al. (2007)).

3 Theoretical and Empirical Framework

To motivate the empirical analysis, in equation (1) we model health H_{ijt} of child i in each district j and time period t as a function of the quality of drinking water W_{ijt} consumed as well as all nutrition inputs which are unobservable to the econometrician, η_{ijt}. The quality of drinking water depends on whether there are "unsafe" level of toxic contaminants such as arsenic, A_{ijt} and whether there are diarrheal pathogens, D_{ijt} present. For simplicity, it is assumed that exposure to

[1] The alternative water sources include a different existing private well (55%), new constructed well (21%), community well (16%) and undetermined source (8%).

certain level of arsenic has a larger negative impact on health than exposure to diarrheal pathogens.

(1) $H_{ijt} = W(A_{ijt},D_{ijt}) + \eta_{ijt}$

Obtaining drinking water from tube wells exposes the child to arsenic but not to diarrheal pathogens while sourcing water from alternative drinking water sources such as surface water or marked "safe" tube wells that are farther away protects the child from arsenic but increases the likelihood that the child gets exposed to diarrhea-causing pathogens. Thus the child's exposure to arsenic, A_{ijt}, (or diarrheal pathogens, D_{ijt}) in drinking water, depends on the household's probability of switching, S_{ijt}, from arsenic-contaminated groundwater to arsenic-safe drinking water sources upon the government's massive testing of tube wells. In practice, effect of S_{ijt} would vary by the safety of groundwater arsenic level, L_j, which is determined by the government's arsenic test results. The government labeled wells as either "safe" to drink (less than 50 μg/L) or "unsafe" to drink (more than 50 μg/L) upon testing and prioritized its mitigation efforts on households with "unsafe" wells to encourage them to switch to alternative sources of drinking water.

(2) $A_{ijt} = g(L_j) * S_{ijt} + \upsilon_{ijt}$

Note S_{ijt} is unobserved to the econometrician. We assume based on empirical and anecdotal evidence, that two important factors have led parents to switch to alternative sources of drinking water. The most important one is the government's massive well testing and aggressive labeling and awareness campaign that started in the late 1990s. As mentioned earlier, the aggressive well testing and labeling campaign encouraged households to switch to alternative drinking water sources, particularly those with unsafe wells.

Thus from (2), the first factor for identifying the effect of arsenic exposure on child health is the geographic variation in the pre-existing levels of naturally occurring arsenic while the second factor is the exposure to the massive well testing and awareness campaign of the government. Combining these two factors forms the main variable of interest in a difference-in-difference framework. In particular, we compare cohorts born between 2000 and 2004 (aged 0-48 months in 2004) after the massive testing and awareness campaign already began vis-à-vis cohorts born between 1992 and 1996 (aged 0-48 months in 1996) in locations with varying average district arsenic levels: 0-50 μg/L, 51-100 μg/L, above 100 μg/L.

Estimating equation (3) yields the reduced form differences by pre-existing arsenic level for some outcome Y_{ijt} for person *i* in district *j* at time *t*.

$$(3)\ Y_{ijt} = \alpha + \beta_1\ As\_51\text{-}100_{ij}*Yr2004_t + \beta_2\ As\_100up_{ij}*Yr2004_t + \delta_j + \gamma_t + \beta_3\ X_{ijt} + \beta_4\ Z_{jt} + \varepsilon_{ijt}$$

in which Y_{ijt} refers to the outcome of interest, $As\_51\text{-}100_{ij}$ is a dummy variable equal to 1 if the mean district arsenic level is 51-100 μg/L and 0 otherwise, As_100up_{ij} is a dummy variable equal to 1 if the mean district arsenic level is greater than 100 μg/L and 0 otherwise, $Yr2004_t$ is a dummy variable equal to 1 if the cohorts aged 0-48 months were born after the massive well testing and awareness campaign began and 0 otherwise, δ_j are geographic fixed effects, γ_t are year of birth (time) fixed effects and X_{ijt} is some vector of individual level control variables such as gender and age (in months), indicator for mother's education, mother's height and indicator of household head's education. Z_{jt} refers to time-varying percentages of communities with secondary schools and health facilities in the district.

If the government's mitigation efforts have successfully led households to switch from arsenic-contaminated wells to arsenic-safe drinking water sources in districts with average arsenic levels of more than 50 μg/L, our framework suggests that β_1 and β_2 would be positive for the outcome height-for-age. At the same time, our framework also suggests that β_1 and β_2 would be positive (although probably small) for the likelihood of incurring recent diarrhea.

Now, another factor that can lead parents to switch to alternative drinking water sources is their education level. In Grossman's (1972) concept of health capital, the stock of human capital, as measured by education, is known to lead to shifts in productivity. In particular, the effect of education on child health may be considered via health knowledge and the parent's ability to make use of information (McCrary and Royer, 2011). It is assumed that schooling increases the ability of an individual to process information and thus enable one to efficiently improve health capital. By estimating (3) separately for educated households and non-educated households, we can examine whether β_1 and β_2 are larger and significant for educated households compared to non-educated households. Likewise, following Case et. al. (2002), we assume that the protective role of education becomes more pronounced with the length of time the child has been exposed to the health shock. Thus, we further estimate the model separately for younger and older age groups so we can examine whether β_1 and β_2 are larger for older children.

The estimates are unbiased under the identifying assumption that outcomes in each district would have changed to the same extent, apart from any change due to the massive efforts of the government to encourage households to switch away from "unsafe" groundwater. It is impossible to test this assumption directly but the availability of data for the time period prior to 1996 helps to form indirect tests to examine whether different categories of average district arsenic levels had been trending differently. In addition, the model also assumes no spillover effects or change in composition of households across the districts with varying average arsenic levels. To investigate this assumption, we account for possible migration and restrict the analysis to those households who have continuously resided in the same location since the time of massive testing and awareness campaign have begun.

4 Data and Descriptive Statistics

This study uses the children, household, and community level data of the 1996 and 2004 Demographic Health Surveys, which we merge with the National Hydrochemical Survey (NHS) of wells conducted in 1998 and 1999 by the Department of Public Health Engineering of Bangladesh (DPHE) in collaboration with the British Geological Survey (BGS). We calculate the average arsenic level at the district level using the NHS data. Figure 1 shows the union-level variation in arsenic level across the country. The red dots show the areas that have average arsenic level of greater than 100 μg/L, blue dots show the areas that have an average arsenic level of 51-100 μg/L and the green dots show the areas with 0-50 μg/L.

The BGS/DPHE carried out the survey in two phases: the first phase (1998) covered what were thought to be the most affected southern and eastern districts of Bangladesh, while the second phase (1999) completed the rest of the districts of Bangladesh except for the three districts of the Chittagong Hill Tracts (for a total of 61 out of 64 districts surveyed).[2] Thus for the main analyses in this paper, we will focus on children in the 61 districts where the data on arsenic tests of wells are available, but as a robustness check we replicate the main analysis on all 64 districts by calculating and imputing the average arsenic level for the other three districts based on the average arsenic levels of wells in the areas surrounding these districts.

Our main outcome of interest in this paper is child height-for-age. Height reflects the influences of both genetics and environmental influences with the latter being particularly important from prenatal to first few years of life (Martorell and Habicht, 1986). Using the WHO growth reference (WHO

[2] The NHS provides chemical test results for the 3534 boreholes from 61 out of 64 districts of Bangladesh.

Multicentre Growth Reference Study Group 2006; de Onis et al. 2007), height-for-age is calculated for children from ages 0 to 48 months. To support our main findings, we also check whether the switching away from unsafe wells to alternative sources of drinking water such as surface water or safe wells that are farther away have led to diarrheal diseases as suggested in some studies (Field et. al., 2011; Escamilla et. al., 2011; Wu et. al., 2011). The advantage of using DHS is that it allows us to also examine the mothers' body mass index, employment status as well as mothers' prenatal and postnatal health behavior. In addition, we take advantage of additional information (although available in 2004 DHS only) on the mother's and household head's knowledge of arsenic, their understanding of the labeling of wells and information on which well they obtain their water from. These variables help us to further pin down the possible pathways by which the comprehensive mitigation efforts across the different areas with varying pre-existing arsenic levels have affected child health.

Table 1 shows the means and standard deviations of the background characteristics of children in 1996 prior to the massive well testing and information campaign, by average district arsenic level. In general, the average age of children, percentage of male children and mothers' average years of education are not statistically different across the areas with varying intensity of average district arsenic level. On the other hand, mothers in the districts with highest average arsenic level tend to be slightly older than those in other areas. The household head's education is higher in districts with average arsenic level of 0-50 µg\L relative to districts with average arsenic level of 51 µg\L and above. This may be partly reflecting the effects of the arsenic crisis on the socioeconomic outcomes of the previous generation. In addition, there are also statistically significant differences in the share of communities in the district with access to secondary schools and health services.

Table 2 shows the simple difference-in-differences for the child outcomes: height-for-age and diarrheal disease indicator. Examining the mean height-for-age of cohorts aged 0-48 months in 1996 (Panel A), the statistics suggest that although children living in the districts with “safe” average arsenic levels are slightly taller relative to those in districts with “unsafe” average arsenic levels, pairwise comparisons yield statistically insignificant results. Meanwhile, across the three different districts with varying average arsenic levels, mean height-for-age increased for the cohorts aged 0-48 months in 2004. However, it increased more for those children living in the districts with “unsafe” average arsenic levels, particularly for those in districts with average arsenic level ranging 51-100 μg/L. This reflects the government’s efforts to inform and convince households with “unsafe” tube wells to switch away to safer alternative drinking water sources. Comparing the height-for-age of children over time and between “unsafe” and “safe” districts, the coefficient for the difference-in-difference is positive and statistically significant for districts with average arsenic level of 51-100 μg/L. On the other hand, the coefficient for difference-in-difference is positive but small and not statistically significant for districts with average arsenic level of greater than 100 μg/L.

In Panel B we observe an increase in the probability of incurring recent diarrhea among young children in these districts as well, over time and relative to districts with arsenic level below 50 μg/L, reflecting the switching of households to arsenic-safe drinking water sources in the districts with average arsenic level of 51-100 μg/L,. However, the mean changes are quite small and not statistically significant.

5 Estimation Results

5.A Child Health

We begin our analysis of the impact of arsenic exposure on child health by showing the results of a locally weighted regression of height-for-age on household head's education by categories of district-level average groundwater arsenic level. The graphs in Panel A of Figure 2 show the results for children aged 0 to 48 months in 1996 and in 2004 or before and after the massive well-testing and mitigation campaign have started. The figure shows that, prior to the start of the arsenic mitigation strategy (1996, left graph), there were no significant differences in child height-for-age across the districts with varying average arsenic level at any level of household head education. The districts with average arsenic level of more than 100 μg/L has a slightly different trajectory which may reflect the dangers of having been exposed to very high level of arsenic for a long time, but as shown earlier in the Table 1, on average there are no statistically significant differences in the height-for-age of children across the three categories of district-average arsenic level. On the other hand, performing the same analysis for children aged 0 to 48 months in 2004 (right graph) shows that although there are no significant differences in child height-for-age across districts with varying arsenic level when household head has no formal education (or zero years of education), the gap in height-for-age between children in districts with average arsenic level of 51-100 μg/L and in districts with average arsenic level of 0-50 μg/L is increasing with higher household head's education. Meanwhile, the districts with average arsenic level of more than 100 μg/L follows a similar pattern observed in 1996.

Turning to more formal analysis, Table 3 shows the regression analyses of changes in height-for-age and in recent diarrhea incidence between 1996 and 2004 across different categories of district-average arsenic level. Columns (1) to (3) presents the results for the full sample. The coefficient in column (1) suggests that children's height-for-age improved from 1996 to 2004, on average about 0.21 standard deviations higher in districts with average arsenic level of 51-100 μg/L relative to districts with average arsenic level of 0-50 μg/L. This estimate is reduced (0.13 to 0.14 standard deviations) when individual and parental controls (column 2) as well as community-level services (column 3) are added to the model, although still statistically significant. Columns (4) to (9) estimate equation (3) for the sample whose household head is educated and for those whose household head is not educated. In this paper, we use household head's education as our measure of socioeconomic status. The advantage of using education instead of current income is that the former allows us to capture the effect of permanent or long-run average income, where investment in children decisions are likely to be based on. As presented in columns (4) to (6), when the sample is restricted to those children whose household head is educated, the estimates become larger (about 0.22 to 0.28 standard deviations) and also statistically significant. On the other hand, when the sample is restricted to those children whose household head has no formal education (columns (7) to (9)), the estimates become very close to 0 and not statistically significant.

In panel B of Table 3, I examine the same regressions for recent diarrhea indicator. If the hypothesis that families in districts with arsenic level of above 50 μg/L are more likely to be encouraged to switch over to safe alternative water sources, then it is likely that some of these families are also likely to return to using surface water as an alternative water source. Therefore, children in these districts have higher probability of incurring diarrhea relative to children in the districts with average arsenic level that are considered to be safe by the government (0-50 μg/L). Columns (1) to (3) support such hypothesis, showing a marginally significant probability (0.03 to 0.04) that children would incur diarrhea. This likelihood increases slightly to 0.05 and becomes even more significant when the sample is restricted to those children with educated household heads. On the other hand, consistent with the pattern of findings for height-for-age, the coefficients become very small and insignificant when the sample is restricted to children whose household head is not educated.

Table 4 presents the robustness checks and alternative specifications of the baseline results for those with educated and non-educated household heads. Panel *A* shows the results for children with educated household heads. Column (1) of Table 4 addresses the concern on migration and restricts the analysis to those households who have continuously resided in the same residence in the past six years or since the time of the massive well-testing and awareness campaign have started.[3] Compared to the baseline results with full specification in column (6) of Table 3, accounting for migration makes the estimates larger and statistically significant for the outcomes height-for-age and diarrhea incidence.

The baseline results may also be confounded by mean reversion across the different districts. That is, if some districts have high arsenic level and poor health outcomes due to some temporary shock, then we might expect that the health of the children will get better in the next period independent of the average district arsenic level. In column (2), we add the interaction of 1996 height-for-age with the birth year dummies. This effectively accounts for the initial levels of children's health in the districts with different average arsenic level. The resulting estimate for height-for-age is slightly smaller than the baseline estimate but it is still statistically significant while the resulting estimate for diarrhea occurrence is basically unchanged from the baseline estimate.

One particular source of confounding might be certain shocks and policy changes that may have affected children's health. While we do not know of any particular shock or policy change that have coincided with the average level of arsenic at the district level, to the extent that these shifts were at the level of division by year, we implement a way to purge our estimates of this confounding.

[3] The Demographic Health Survey asks women about the number of years they have been residing in their place of residence.

In column (3), we add a (division X after) fixed effects. Although this makes the standard errors bigger and thus make estimates less precisely estimated, the results are essentially similar to the baseline estimates.

In column (4), we replicate the analysis using data on all 64 districts by calculating and imputing the average arsenic level for the other three districts based on the average arsenic levels of wells in the areas surrounding these districts (within 10 kilometers). Our resulting estimates for height-for-age is relatively close to the baseline estimates and marginally significant but the estimate for recent diarrhea experience is zero and not statistically significant. This may have partly to do with the size of the area considered for interpolation.[4]

Since the World Health Organization's standard for safe arsenic level is less than 10 μg/L, which is way below the standard set by the Bangladesh government, in column (5) we change our specification slightly to examine how children living in districts with average arsenic level of 0-10 μg/L, between 51 to 100 μg/L and greater than 100 μg/L fared compared to children in districts with average arsenic level of 11-50 μg/L before and after the arsenic mitigation campaign has begun. With this new comparison group, we find the same pattern of results as the original estimates. Basically, children's height-for-age in areas with average arsenic level of 51-100 μg/L have improved over time by 0.21 standard deviations more compared to children in areas with average arsenic level of 11-50 μg/L. Meanwhile, we do not find any statistically significant difference in child health when comparing children in areas with average arsenic level of greater than 100 μg/L and less than 10 μg/L, respectively, relative to areas with

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[4] The interpolation is similar to a weighted average where weight is inverse distance between the geographic point of interpolation and the location of the measured tube well. We have tried imputing the average arsenic level based on average arsenic level within 5 km and 2 km radius but by doing so, there are many geographical areas which do not have any measured tube well, making interpolation impossible.

average arsenic level of 11-50 µg/L. The pattern of results for diarrhea indicator is essentially the same.

Our results would be biased if the districts with varying arsenic level would have evolved differently over time, even in the absence of the massive arsenic mitigation efforts of the government. It is very hard to test this assumption due to lack of past data especially for height-for-age. We attempt to take advantage of the 1993 Demographic Health Survey which has available data on recent diarrhea indicator and use it to test for parallel trends, although this may not be as reliable as using height-for-age. We re-run the above model comparing children aged 0-24 months in 1996 vis-à-vis children aged 0-24 months in 1993. We restrict our analysis to those ages 0-2 years old (0-24 months) to ensure that there are no overlap in birth cohorts in 1993 and 1996. The result of this analysis is somewhat surprising as we find negative and statistically significant change in diarrhea experience over time in districts with average arsenic level of 51-100 µg/L relative to districts with average arsenic level of less than 50 µg/L. The negative sign suggests that the families in the districts with arsenic level 51-100 µg/L are possibly consuming water from contaminated wells which would make them less likely to incur diarrhea. Given that this is opposite of what we observe in the main results, we interpret this result as lack of evidence for pre-existing positive trends in diarrhea incidence even before the arsenic mitigation campaign was launched. However, this result may suggest that families in areas with average arsenic level of 51-100 µg/L may have better health behavior than families in other areas, which may partly explain the significant results observed earlier. We will return to this discussion later once we examine the maternal health investments towards their children.

Panel B of Table 4 shows the results for children with household heads who are not educated. Consistent with the patterns observed in Panel A of Figure 2 and the results in Table 3, we find that the estimates are close to zero and not statistically significant. One exception is the sizable estimate observed in column (3) when we add the *division X after* fixed effects although this estimate is not statistically significant.

Next, we estimate Equation (3) for those with educated and non-educated household head, stratified by child's age. Before turning to the results of the formal analysis, Panel B of Figure 2 presents the locally weighted regression of height-for-age on child age in months by categories of district-average groundwater arsenic level. The left-hand side of Panel A show the results among children aged 0 to 48 months in 1996 (prior to the arsenic mitigation campaign) while the right-hand side show the results for 2004 or after the massive well-testing and mitigation campaign have started. As shown in the graphs, prior to the start of the arsenic mitigation strategy (in 1996), there are no significant differences in child height-for-age across districts with varying average arsenic level over age in months. On the other hand, when we examine the same analysis for same aged children in 2004, we find that although there are no apparent differences in child height-for-age across districts with varying arsenic level when children are very young (age 0 to 12 months), the differences across the districts with varying average arsenic level tend to get larger as the child gets older.

Table 5 presents the formal analysis for the estimates of Equation (3) by household head education indicator and by child's age in months. The first two columns present the results for the case of educated household head. Panel A shows the results for height-for-age. Column (1) examines the case of children aged 0-24 months. The results show that from 1996 to 2004, average height-for-age of children in districts with average arsenic level of 51-100 µg/L improved by 0.13 standard deviations more than in districts with average arsenic level of 0-50 µg/L but it is not statistically significant. However, when we examine the case of older children (aged 25-48 months) in column (2), the estimate is larger (0.48 standard deviations) and also statistically significant. On the other hand, when we examine the same estimates for the children in non-educated household head in columns (3) and (4), we find that estimates are small (close to zero) and not statistically significant regardless of the age of the child. Meanwhile, the estimates for changes in height-for-age over time among children in districts with average arsenic level of greater than 100 μg/L are unusually large and have opposite signs, although not precisely estimated.

Panel B of Table 5 presents the results for the recent diarrhea indicator. As shown in column (1), for very young children (those in the first two years of life), the probability of recent diarrhea occurrence increased more, over time, in districts with average arsenic level of 51-100 μg/L relative to districts with average arsenic level of 0-50 μg/L. We do not observe similar pattern in the older children (aged 25 to 48 months) which suggest that younger children are likely to be affected more by the switching of households to alternative water sources that are likely to be bacterial-contaminated. This is consistent with the findings of Field et. al. (2011) which suggest that the switching away of households from tubewells to alternative water sources like surface water may have had unintended consequences on infant health.

5.B Maternal Health and Labor Force Participation

Since child health is likely to be affected by the health status of the mother, we examine the changes in mothers' health over the period 1996 to 2004 in districts with varying levels of arsenic contamination.[5] Panel A of Table 6 estimates Equation (3) using mother's body mass index as the outcome, excluding the controls for child's birth year dummies and household head's education and including a time dummy instead (Yr2004). Body mass index (BMI) is commonly used as measure for adult health and nutritional status. The Demographics Health

[5] Case et. al. (2002) finds that the health of the mother is more strongly correlated with the child's health than the health of the father. Thus, this is consistent with the notion that women with poorer health may bear less healthy children.

Survey obtains the body mass index of women respondents and is defined as weight (in kilograms) divided by the square of height (in meters). Column (1) shows the results for all mothers of children in our sample. Consistent with the patterns observed for children, the mother's body mass index increased over time from 1996 to 2004 in districts with average arsenic level of 51-100 μg/L relative to districts with average arsenic level of 0-50 μg/L. In contrast, in districts with average arsenic level of greater than 100 μg/L, there were essentially no change observed. In columns (2) and (3), we stratify the sample by household head education indicator. Focusing on the sample of mothers with educated household head, we find that estimate become larger (0.69) and statistically significant for the observed changes in districts with average arsenic level of 51-100 μg/L relative to districts with average arsenic level of 0-50 μg/L. While the estimate for the change in mother's BMI also becomes larger in the districts with average arsenic level of greater than 100 μg/L, it is not statistically significant. On the other hand, when we examine the sample of mothers who have non-educated household head, the estimates are much smaller (0.26) and even negative (-0.34) and not statistically significant.

Another possible explanation for the observed changes in child health over time could be the changes in maternal labor supply. If healthier mothers in districts with average arsenic level of 51-100 μg/L increase their labor supply over time, this may affect child's health through increase in household's average income. In Panel B of Table 6, we examine the effect on mother's employment status. The results for the overall sample in column (1) and the stratified samples in columns (2) and (3) suggest that there is essentially no change in the labor supply of mothers in districts with average arsenic level of 51-100 μg/L relative to those in districts with average arsenic level of 0-50 μg/L.

The above results suggest that the observed changes in child health before and after the massive arsenic mitigation campaign in districts with average arsenic level of 51-100 μg/L may be partly attributed to changes in the health of the mother in these areas. In particular, mothers in educated households seem to have benefited from the government's mitigation campaign more than the mothers in non-educated households although the difference in the estimates is not statistically significant (not shown). In the next section, we therefore examine what possibly explains the differences we observe in the outcomes for mothers and children in households with educated household head and non-educated household head.

5.C Knowledge/Awareness of the Government's Well-Safety Campaign

In this section, we investigate whether there are any gaps in the knowledge or awareness of the government's well-safety campaign between the educated and non-educated households in the areas with varying average arsenic levels. The Demographic Health Survey added some questions in their 2004 survey to examine the women's (or mother's) knowledge of tube wells' safety based on the information provided by the Bangladesh government.[6] Table 7 examines the binary outcomes that indicate whether the respondent knows what a red-painted well means, what green-painted well means, whether the respondent obtains water from green well vis-à-vis red or unmarked well and whether the respondent obtains water from unmark well vis-à-vis green or red painted well.

Panel A examines whether household head's level of education, our proxy for household's socioeconomic status, affect the mother's knowledge of wells' safety and whether they are more likely to obtain water from safe wells. We also include an interaction of household head having any formal education with the varying levels of arsenic in our specification: 51-100 μg/L and >100 μg/L, to

[6] These are the same mothers whose health and labor supply were examined in Table 5. Although the survey is conducted among all women aged 15-49, our sample for this analysis focuses on the mothers of children in the sample for our main results.

examine whether the effect of household head's education on the outcomes would depend on the average level of arsenic level in the area. As shown in the results, the more educated the household head is, the more likely is the child's mother knowledgeable of what green-painted well means and the more likely is she able to obtain water from the appropriate well (for instance, choosing a green-painted over red painted or unmarked well). This last column (column 4) serves as a validation to check whether the respondent (mother) avoids obtaining water from unmark well as well. The results of the interaction terms suggest that the effect of household head's education (socioeconomic status) on the mothers' well-safety knowledge and behavior do not seem to vary by the average arsenic level.

In Bangladesh's culture, women are the ones who draw water from the wells. Thus in Panel B we examine how women's education affect their knowledge of the government's well-safety campaign and their probability to obtain water from the safer wells. Based on the results given in columns (1) to (4), mothers who have any formal education have higher probability of knowing what a red-painted and green-painted well means compared to mothers with no educated. They are also less likely to draw water from the wells and more likely to draw water from the green wells although the latter is not statistically significant.

We also examine interaction of the indicator of mothers having any formal education with the varying categories of arsenic levels in our specification: 51-100 μg/L and >100 μg/L, to examine whether the effect of mother's education on the outcomes would depend on the average level of arsenic level in the area. In contrast to the results in Panel A, we find that the effect of mother's education on her knowledge of what green-well means and on her ability to obtain water from green wells seem to matter more in districts with average arsenic level of 51-100 μg/L relative to districts with average arsenic level of 0-50 μg/L. If the government's mitigation campaign focused on encouraging households to switch away from “unsafe” wells or those wells with arsenic level of more than 50 μg/L, then it is possible that women who were more educated in areas with average arsenic level of 51-100 μg/L would have been more likely internalize this new information and had more ability to act upon it.

5.D Mother's Prenatal and Postnatal Health Behavior

The robust estimates on child health (height-for-age) in the main results may be due to differences in the parents' prenatal and postnatal health behavior in districts with varying average arsenic level. Choices made regarding how often the child's mother goes for antenatal visits and whether the mother gets tetanus injection during pregnancy as well as whether the child gets the appropriate vaccination (BCG, DPT, polio and measles) may have short-term and long-term consequences on child health. In addition, these behaviors may be correlated with socioeconomic status and so may potentially explain the differences in child health we observe in educated and non-educated households.

In Table 8, we estimate Equation (3) on various measures of prenatal and postnatal investments in children. Panel A shows the results for the whole sample while Panel B and C show the results for those with educated and non-educated household heads. The first two columns examine the prenatal behavior of the child's mother examining the number of antenatal visits (column 1) and whether she gets tetanus vaccination (column 2). Interestingly, we find that mothers of children in districts with average arsenic level of 51-100 μg/L have increased their antenatal visits over time relative to mothers of children in districts with average arsenic level of 0-50 μg/L. This pattern persists even when we restrict the sample to educated (panel B) and non-educated households (panel C). In contrast, mothers in districts with average arsenic level of greater than 100 μg/L have decreased their antenatal visits over time relative to mothers of children in districts with arsenic level of 0-50 μg/L. If the health of the mothers in areas with dangerously high arsenic levels (greater than 100 µg/L) have been affected negatively by arsenic poisoning, then that may explain the decline in the number of antenatal visits among mothers in these areas. We find that this pattern persists when we examine the sample for children with educated household heads but not when we examine the sample of children with non-educated household heads.

While these results provide an interesting picture of the resulting prenatal behavior of the mothers in areas with varying arsenic level, they do not sufficiently explain the main results presented earlier especially given the positive antenatal behavior observed even among mothers from non-educated households in the areas with average arsenic level of 51-100 µg/L. Meanwhile, we find no differential effects on the probability of mothers getting a tetanus injection (in column 2), regardless of the average arsenic level.

The rest of the columns (column 3 to column 6) examine the results for postnatal investments in vaccination. Examining the results in Panel A to Panel C, in general, we do not find statistically significant changes in vaccination behavior over time in areas with varying arsenic level, except for the decline in the probability of the child getting any DPT vaccination and any polio vaccination in districts with average arsenic level of 51-100 µg/L relative to districts with average arsenic level of 0-50 µg/L in the sample of children with non-educated household heads.

6 Conclusion and Discussion

This study examines the impact of arsenic exposure on child health. We used the geographic variation in groundwater arsenic level as well as the massive well-testing and awareness campaign in the late 1990s as sources of variation in child's exposure to arsenic. Children in areas with average arsenic level of 51-100 µg/L at the time of the massive well-testing campaign was launched experienced greater improvement in their height-for-age over time relative to children in areas with "safe" arsenic level based on Bangladesh's standards (0-50 μg/L). This result is robust to controlling for and addressing a variety of alternative hypotheses including differential migration, differential trends across areas, confounding with certain shocks and policies and lack of arsenic data on three areas in the country. We find the same patterns of results when we examine mother's health (body mass index) but not for maternal labor supply. We also find that mothers who became pregnant after the massive arsenic campaign has begun had better prenatal behavior in areas with average arsenic level of 51-100 μg/L, although we observe this behavior for both educated and non-educated households.

If exposure to the arsenic mitigation campaign did not vary systematically with any other unobserved factors not accounted for in the robustness checks and further tests conducted above, what might explain the lack of effect on the health of children in areas with average arsenic level of greater than 100 μg/L? We consider two possibilities: *First*, families in these areas have been exposed to dangerously high levels of arsenic for over 20 years prior to its discovery. Thus the debilitating effects of the arsenic poisoning and its health consequences on individuals may have kept these households from taking the appropriate actions to get access to safe water sources. As shown in Panel A and Panel B of Figure 2, even in 1996 (left-hand side graphs), children's health in these dangerously high arsenic zone already follows a different trajectory relative to children in other areas. *Second,* as shown in Figure 1, there is clustering of very high arsenic levels (red dots) in certain areas. This may have made it more difficult for families in those areas to find alternative sources of safe water. That is, it would have been more costly for them to find alternative sources of safe drinking water.

Our study is one of the few studies that examine the impact of arsenic (and in general, toxic substances) exposure on child human capital outcomes, and to our knowledge, the first to examine child height-for-age at the population level. In addition, we provide new evidence on the socioeconomic status-gradient in child health and on the steepening of the relationship between parental SES and child health for older children. An important implication of our study suggests the importance of educating women and ensuring that they have access to information at the level that they can comprehend.

It remains an open question whether the arsenic mitigation campaign which encouraged households to switch away from unsafe wells may have had long term effects on human capital outcomes. Investigating the long run consequences of this early life exposure to toxicity would be an important avenue of future research.

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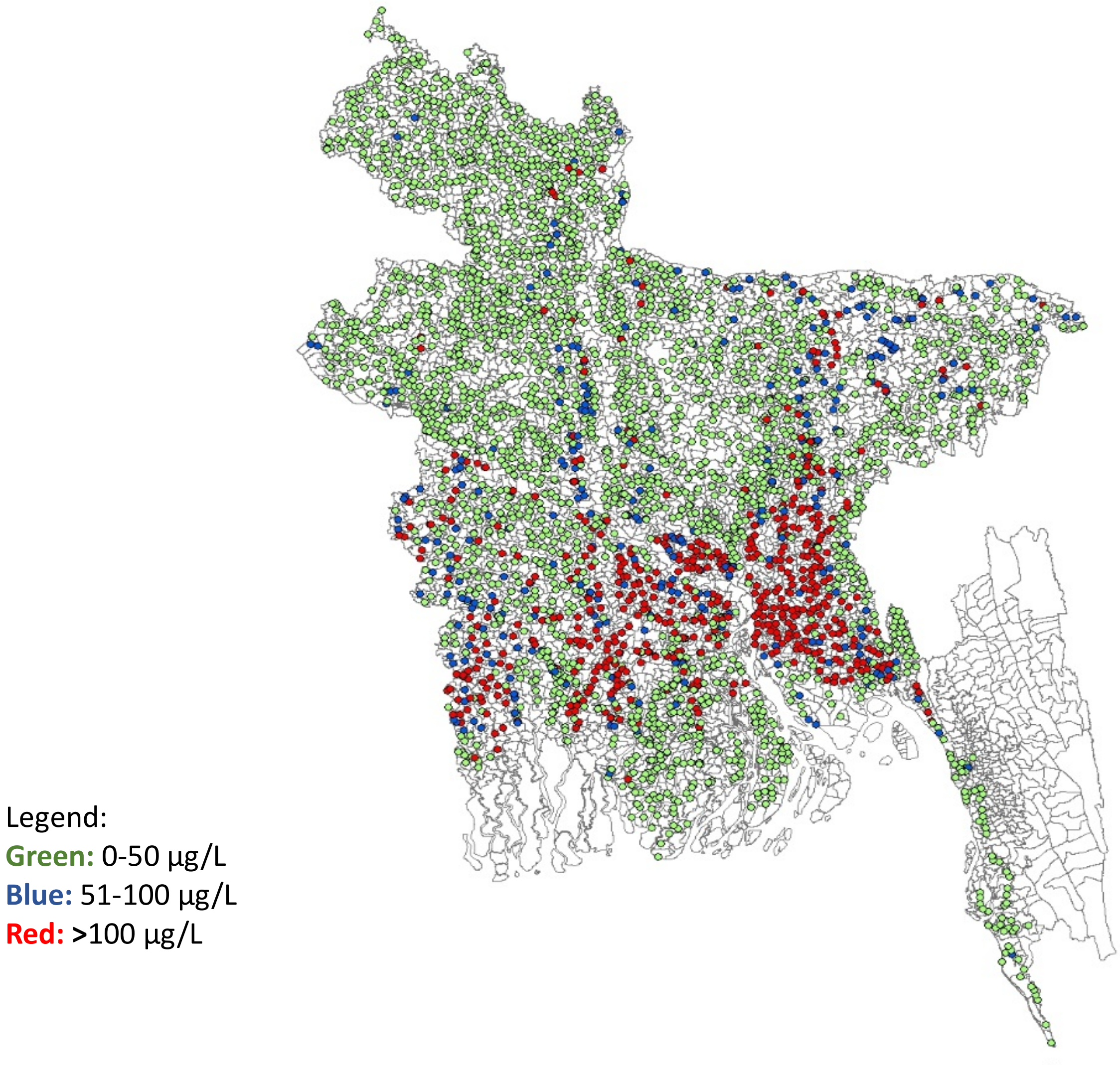
Figure 1. Geographic Variation in Arsenic Contamination across Bangladesh

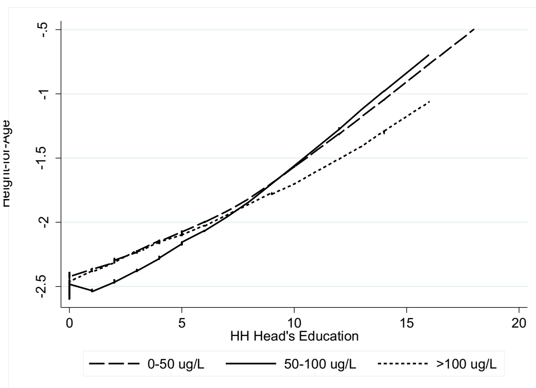


Source: GIS mapping by the authors based on data provided by the British Geological Survey (2000).

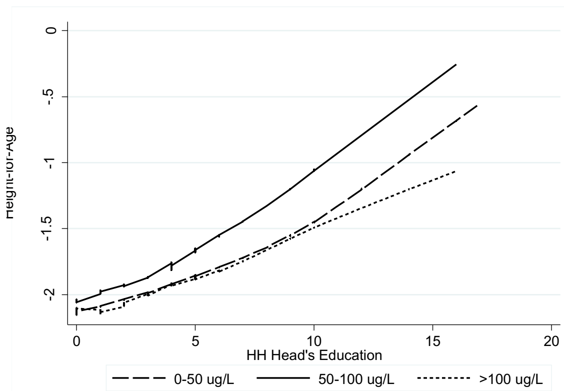
Figure 2. Height-for-Age of Children in Areas with Varying Average Arsenic Level

A. Pattern by Household (HH) Head's Education

Age 0-48 months in 1996

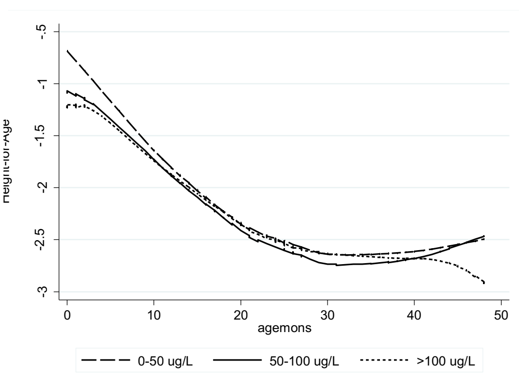


Age 0-48 months in 2004

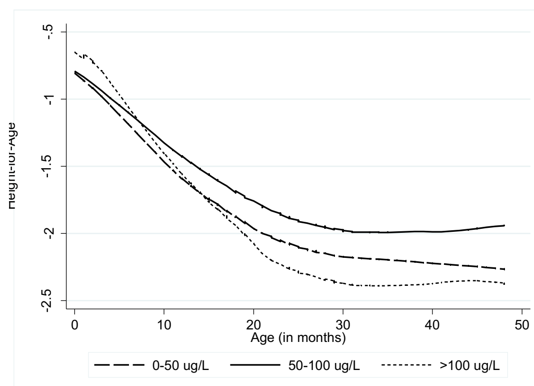


B. Pattern by Age (in months)

Age 0-48 months in 1996



Age 0-48 months in 2004



Notes. The graphs in Panel A runs a locally weighted regression of height-for-age on household head education using 1996 (left) and 2004 (right) data. The graphs in Panel B runs a locally weighted regression of height-for-age on child's age (in months) using 1996 (left) and 2004 (right) data.

Table 1. Descriptive Statistics

	Mean (Std. Dev) of Characteristics, DHS 1996				
Variable	**0 - 50 µg/L**	**51-100 µg/L**	**>100 µg/L**	**P-value**	**P-value**
	(1)	**(2)**	**(3)**	**(2) - (1)**	**(3) - (1)**
Height-for-age	-2.20	-2.30	-2.27	0.25	0.32
	(1.66)	(1.57)	(1.66)		
Recent diarrhea indicator	0.08	0.06	0.08	0.08*	0.90
	(0.27)	(0.23)	(0.28)		
Age (months)	23.63	23.99	23.85	0.63	0.72
	(14.22)	(14.23)	(14.41)		
Male	0.50	0.50	0.52	0.81	0.36
	(0.50)	(0.50)	(0.50)		
Mother has formal education	0.44	0.46	0.43	0.32	0.65
	(0.50)	(0.50)	(0.50)		
Mother's Age	25.38	25.65	26.11	0.41	0.01***
	(6.22)	(6.34)	(6.34)		
Mother's education (years)	2.41	2.22	2.20	0.27	0.13
	(3.43)	(3.04)	(3.18)		
HH head's education (years)	3.21	2.84	2.91	0.02*	0.08*
	(4.11)	(3.98)	(3.80)		
Mother's height	149.65	149.01	149.40	0.23	0.57
	(9.94)	(11.94)	(10.76)		
% Communities with secondary school	0.50	0.61	0.42	0.00***	0.00***
	(0.26)	(0.18)	(0.27)		
% Communities with health service providers	0.30	0.36	0.24	0.00***	0.00***
	(0.22)	(0.18)	(0.24)		
	2627	435	699		

Variable means displayed to the right of variable name. Standard deviations displayed in parentheses below the mean. Based on a sample of children aged 0-48 months in 1996 Demographic Health Survey (DHS 1996).

Table 2. Simple Difference-in-Differences for Height-for-Age and Indicator of Recent Diarrhea

	District-Averaged As Level				
Variable	**0 - 50 μg/L**	**51-100 μg/L**	**>100 μg/L**	**Diff**	**Diff**
	(1)	**(2)**	**(3)**	**(2) - (1)**	**(3) - (1)**
		A. Height-for-Age			
Age 0-48 months, 1996	-2.19	-2.30	-2.27	-0.10	-0.07
	(0.03)	(0.08)	(0.06)	(0.09)	(0.07)
Age 0-48 months, 2004	-1.91	-1.72	-1.94	0.19	-0.03
	(0.03)	(0.06)	(0.05)	(0.07)***	(0.06)
Diff (2004 vs 1996)	0.29	0.58	0.33	0.29	0.04
	(0.04)***	(0.09)***	(0.08)***	(0.11)***	(0.09)
		B. Indicator of Recent Diarrhea			
Age 0-48 months, 1996	0.08	0.06	0.08	-0.02	0.00
	(.01)	(.01)	(.01)	(.01)	(.01)
Age 0-48 months, 2004	0.09	0.09	0.07	0.00	-0.02
	(.01)	(.01)	0.01	(.01)	0.01
Diff (2004 vs 1996)	0.00	0.03	-0.01	0.03	-0.02
	(.01)	(0.02)*	(.01)	(0.02)	(0.02)

Means and standard errors for height-for-age and indicator of recent diarrhea, by categories of average arsenic level in the district and by cohorts.

Table 3. Arsenic Level and the Socioeconomic Gradient in Child Health: Basic Results

	All			HH Head Educated			HH Head Not Educated		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
A. Height-for-Age									
As 51-100*Yr2004	0.21***	0.13*	0.14**	0.28**	0.22**	0.24***	0.03	0.02	0.03
	[0.076]	[0.063]	[0.064]	[0.125]	[0.089]	[0.088]	[0.093]	[0.107]	[0.098]
As 100up*Yr2004	0.06	0.02	0	0.09	0.02	0.01	0.06	0.04	0.02
	[0.128]	[0.120]	[0.119]	[0.127]	[0.119]	[0.101]	[0.151]	[0.149]	[0.172]
Mean of dependent variable		-2.04			-1.83			-2.28	
Observations		8156			4258			3898	
B. Had Recent Diarrhea Indicator									
As 51-100*Yr2004	0.03	0.03*	0.04*	0.05***	0.05***	0.05***	0.01	0.01	0.01
	[0.019]	[0.018]	[0.019]	[0.017]	[0.017]	[0.018]	[0.027]	[0.026]	[0.027]
As 100up*Yr2004	-0.01	-0.01	-0.02	-0.01	-0.01	-0.01	-0.02	-0.02	-0.02
	[0.021]	[0.021]	[0.019]	[0.032]	[0.032]	[0.031]	[0.020]	[0.020]	[0.020]
Mean of dependent variable		0.08			0.08			0.09	
Observations		8156			4258			3898	
Birth year FE and District FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual and Parental Controls	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Time-varying Availability of Services in the District	No	No	Yes	No	No	Yes	No	No	Yes

Notes. As 51-100 is a dummy variable indicating whether or not the district has an average arsenic level of 51-100 µg/L while As 100up is a dummy variable indicating whether or not the district has an average arsenic level of greater than 100 µg/L. The districts with average arsenic level of 0-50µg/L comprise the comparison group. Yr2004 is a dummy variable which is equal to 1 if the child is born after the massive testing campaign has begun and equal to 0 otherwise. Individual and parental controls refer to child's age and gender, mother's age, height and education and father education. Time varying availability of services in the district refer to the time-varying percentage of secondary schools and health facilities available in the district. Heteroskedasticity-robust standard errors adjust for clustering at the district level.

Table 4. Robustness Checks and Alternative Specifications: Children with Educated and Non-Educated HH Head

A.	HH Head Educated					
	Restricted to those living in place of residence for at least 6 years	Add 1996 height-for-age*birth year dummies	Add Division by year FE	Interpolation (w/in 10 km) for 3 missing districts	Use four categories of As level	Compare 0-2 age cohorts in 1996 vs 1993 (trend check)
	(1)	(2)	(3)	(4)	(5)	(6)
I. Height-for-Age						
As 51-100*Yr2004	0.33***	0.18**	0.20*	0.21*	0.21**	-
	[0.116]	[0.086]	[0.116]	[0.111]	[0.091]	
As 100up*Yr2004	-0.06	-0.02	-0.09	0.04	-0.02	-
	[0.125]	[0.082]	[0.137]	[0.130]	[0.111]	
As 10below*Yr2004					-0.08	
					[0.169]	
Observations	2794	4258	4258	4271	4258	
II. Had Recent Diarrhea Indicator						
As 51-100*Yr2004	0.07***	0.05***	0.05	0.0	0.05***	-0.08**
	[0.021]	[0.019]	[0.031]	[0.023]	[0.018]	[0.031]
As 100up*Yr2004	0	-0.01	0.01	-0.01	-0.01	0.02
	[0.028]	[0.031]	[0.032]	[0.033]	[0.032]	[0.035]
As 10below*Yr2004					0.01	
					[0.025]	
Observations	2794	4258	4258	4271	4258	2977

Table 4. (Continued)

B.	HH Head Not Educated					
	Restricted to those living in place of residence for at least 6 years	Add 1996 height-for-age*birth year dummies	Add Division by Year FE	Interpolation (w/in 10 km) for 3 missing districts	Use four categories of As level	Compare 0-2 age cohorts in 1996 vs 1993 (trend check)
	(1)	(2)	(3)	(4)	(5)	(6)
I. Height-for-Age						
As 51-100*Yr2004	-0.03	0.00	0.18	0.03	0.02	-
	[0.102]	[0.119]	[0.130]	[0.119]	[0.106]	
As 100up*Yr2004	-0.03	-0.01	0.09	0.04	0	-
	[0.182]	[0.158]	[0.195]	[0.175]	[0.172]	
As 10below*Yr2004					-0.07	
					[0.130]	
Observations	2844	3898	3898	3906	3898	
II. Had Recent Diarrhea Indicator						
As 51-100*Yr2004	0.02	0.02	0	-0.02	0.01	-0.02
	[0.026]	[0.028]	[0.035]	[0.031]	[0.029]	[0.045]
As 100up*Yr2004	-0.03	-0.02	-0.03	-0.03	-0.02	0
	[0.022]	[0.020]	[0.024]	[0.017]	[0.024]	[0.024]
As 10below*Yr2004					-0.01	
Observations	2844	3898	3898	3906	3898	3186

Notes. As 51-100 is a dummy variable indicating whether or not the district has an average arsenic level of 51-100 μg/L while As 100up is a dummy variable indicating whether or not the district has an average arsenic level of greater than 100 μg/L. The districts with average arsenic level of 0-50 μg/L comprise the comparison group. Yr2004 is a dummy variable which is equal to 1 if the child is born after the massive testing campaign has begun and equal to 0 otherwise. All regressions control for child's age and gender, mother's age, height and education and father education as well as for time-varying percentage of secondary schools and health facilities available in the district. Heteroskedasticity-robust standard errors adjust for clustering at the district level.

Table 5. Arsenic Level and the Socioeconomic Gradient in Child Health: Results by Child's Age (in Months)

	HH Head Educated		HH Head Not Educated	
	Age 0-24 months (1)	Age 25-48 months (2)	Age 0-24 months (3)	Age 25-48 months (4)
A. Height-for-Age				
As 51-100*Yr2004	0.13	0.48***	0.02	0.07
	[0.123]	[0.146]	[0.113]	[0.157]
As 100up*Yr2004	-0.04	0.08	0.31	-0.37*
	[0.112]	[0.141]	[0.210]	[0.198]
Observations	2165	2093	1972	1926
B. Had Recent Diarrhea Indicator				
As 51-100*Yr2004	0.09**	0	-0.03	0.06
	[0.041]	[0.033]	[0.033]	[0.042]
As 100up*Yr2004	-0.02	0	-0.01	-0.02
	[0.047]	[0.027]	[0.031]	[0.023]
Observations	2302	2282	2164	2182

Notes. As 51-100 is a dummy variable indicating whether or not the district has an average arsenic level of 51-100 µg/L while As 100up is a dummy variable indicating whether or not the district has an average arsenic level of greater than 100 µg/L. The districts with average arsenic level of 0-50 µg/L comprise the comparison group. Yr2004 is a dummy variable which is equal to 1 if the child is born after the massive testing campaign has begun and equal to 0 otherwise. All regressions control for child's age and gender, mother's age, height and education and father education as well as for time-varying percentage of secondary schools and health facilities available in the district. Heteroskedasticity-robust standard errors adjust for clustering at the district level.

Table 6. Arsenic Level and Mother's Health and Employment Status

	All (1)	HH Head Educated (2)	HH Head Not Educated (3)
A. Mother's BMI			
As 51-100*Yr2004	0.53***	0.69***	0.26
	[0.165]	[0.189]	[0.177]
As 100up*Yr2004	-0.01	0.23	-0.34
	[0.212]	[0.268]	[0.212]
Observations	7345	3996	3349
B. Mother currently working			
As 51-100*Yr2004	0.02	-0.04	0.07
	[0.065]	[0.056]	[0.078]
As 100up*Yr2004	-0.07	-0.08	-0.05
	[0.043]	[0.049]	[0.060]
Observations	7427	4034	3393

Notes. As 51-100 is a dummy variable indicating whether or not the district has an average arsenic level of 51-100 μg/L while As 100up is a dummy variable indicating whether or not the district has an average arsenic level of greater than 100 μg/L. The districts with average arsenic level of 0-50 μg/L comprise the comparison group. Yr2004 is a dummy variable which is equal to 1 if the child is born after the massive testing campaign has begun and equal to 0 otherwise. All regressions control for mother's age, height and education as well as for time-varying percentage of secondary schools and health facilities available in the district. Heteroskedasticity-robust standard errors adjust for clustering at the district level.

Table 7. Knowledge/Awareness of the Government's Well-Safety Campaign

Binary Outcomes	Know what red-painted well means (1)	Know what green-painted well means (2)	Obtain water from green well (3)	Obtain water from unmark well (4)
Panel A. Using HH Head Education				
HH Head primary education level	0	0.04**	0.04**	-0.05**
(ref: no schooling)	[0.010]	[0.016]	[0.018]	[0.023]
HH Head at least secondary education level	0.01	0.08***	0.08***	-0.08***
(ref: no schooling)	[0.009]	[0.021]	[0.023]	[0.025]
As 51-100*HH head any education	-0.04	-0.01	0	0.05
	[0.033]	[0.040]	[0.037]	[0.053]
As 100up*HH head any education	-0.02	-0.03	-0.02	0.04
	[0.029]	[0.030]	[0.030]	[0.042]
Panel B. Using Mother's Education				
Mother has any schooling	0.01*	0.03*	0.02	-0.03*
(ref: no schooling)	[0.005]	[0.014]	[0.016]	[0.015]
As 51-100*Mother had any education	-0.02	0.09**	0.10**	-0.09
	[0.017]	[0.042]	[0.045]	[0.058]
As 100up*Mother had any education	0	0.01	0.02	-0.02
	[0.025]	[0.029]	[0.032]	[0.039]

Notes. Regressions are based on 2004 Demographic Health Survey (DHS 2004) cross-section data. As 51-100 is a dummy variable indicating whether or not the district has an average arsenic level of 51-100 µg/L while As 100up is a dummy variable indicating whether or not the district has an average arsenic level of greater than 100 µg/L. The districts with average arsenic level of 0-50 µg/L comprise the comparison group. *HH head any education* is a dummy variable which is equal to 1 if the HH head has any formal education and equal to 0 otherwise. *Mother had any education* is a dummy variable which is equal to 1 if the mother had any formal education and equal to 0 otherwise. All regressions control for household economic variables such as whether roof is made of wood, whether the wall is made of wood and whether the household has access to sealed-tank.

Table 8. Mother's Investments: Prenatal and Postnatal Health Behavior

Dependent Variables	No. of Antenatal Visits	Received TT Injections	BCG Vaccination	Any DPT Vaccination	Any Polio Vaccination	Measles Vaccination
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. Whole Sample						
As 51-100*yr2004	0.54**	0	0	-0.02	-0.02	-0.01
	[0.242]	[0.051]	[0.029]	[0.033]	[0.033]	[0.035]
As 100up*yr2004	-0.40**	0.02	0.01	0.01	0.03	0.01
	[0.168]	[0.040]	[0.036]	[0.038]	[0.031]	[0.052]
Observations	7555	7557	8154	8148	8149	8138
Panel B. HH Head Educated						
As 51-100*yr2004	0.43*	0.03	0.05	0.05	0.04	-0.01
	[0.227]	[0.059]	[0.039]	[0.040]	[0.046]	[0.048]
As 100up*yr2004	-0.66***	0.01	0.02	0.03	0.03	0
	[0.198]	[0.039]	[0.030]	[0.033]	[0.021]	[0.041]
Observations	3960	3965	4257	4254	4255	4249
Panel C. HH Head Not Educated						
As 51-100*yr2004	0.64**	-0.02	-0.04	-0.07**	-0.06**	0
	[0.270]	[0.051]	[0.026]	[0.031]	[0.028]	[0.038]
As 100up*yr2004	-0.06	0.04	0	-0.01	0.02	0.01
	[0.192]	[0.060]	[0.051]	[0.050]	[0.047]	[0.068]
Observations	3595	3592	3897	3894	3894	3889

Notes. As 51-100 is a dummy variable indicating whether or not the district has an average arsenic level of 51-100 μg/L while As 100up is a dummy variable indicating whether or not the district has an average arsenic level of greater than 100 μg/L. The districts with average arsenic level of 0-50 μg/L comprise the comparison group. Yr2004 is a dummy variable which is equal to 1 if the child is born after the massive testing campaign has begun and equal to 0 otherwise. All regressions control for mother's age, height and education as well as for time-varying percentage of secondary schools and health facilities available in the district. Heteroskedasticity-robust standard errors adjust for clustering at the district level.