The Effect of Arsenic Poisoning on Education Outcomes: Evidence from Indian Districts

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Abstract

While the effect of health on education outcomes is well documented in the literature, little is known about the effect of drinking contaminated water on children's cognitive skills. This paper assesses the effect of drinking arsenic contaminated water on education outcomes among children in districts across India. Using IHDS (2011-12) data and instrumental variable framework that exploits variation in soil textures across districts in India, we find that arsenic exposure beyond the threshold level (10ug/l) has negative and significant effect on school attendance and on mathematics scores.

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1 Introduction

Across the world, more than 2,000 children under the age of five die every day from diarrhoeal diseases. Out of these approximately 1,800 deaths are attributed to unsafe water consumption. India alone accounts for more than 24 percent of world's total child mortality, 90 per cent of which is linked to contaminated water.

More than 70 million people across 35 districts are exposed to alarming levels of arsenic in ground water (Khurana and Sen 2008). Chronic exposure to arsenic can cause adverse health effects including diseases of the skin, kidney, heart, mental illnesses and various types of cancers. Arsenic in groundwater is linked to more than 0.1 million deaths and nearly 0.3 million individuals falling sick (Central Ground Water Board 2006)

Bangladesh and India constitute the largest population in the world exposed to arsenic through drinking water with children comprising nearly 50% of the affected population. Despite huge prevalence of arsenic related health hazards, it is still an unrecognized and under-researched topic in India, particularly for children. While health consequences of arsenic contamination are well-documented for adults (Asadullah and Chaudhury 2011), little is known about the negative impact on children's developmental outcomes. Moreover, the relation between arsenic and educational outcomes for children is not yet understood, as there are very few other studies thus far.

Prolonged exposure to arsenic contaminated water affects the educational outcomes among children through cognitive impairment. Moreover, arsenic induced illnesses lead to school absenteeism or social exclusion as the visible symptoms of arsenic poisoning lead to social ostracization. Further, the negative effects of arsenic may intensify for children with poor health or nutritional status.

As noted earlier, arsenicosis is an epidemic in parts of Bangladesh and India and children under the age of 14 years form a huge segment of the arsenic exposed population. Therefore we study the effect of drinking arsenic-contaminated water on cognitive achievement and school attendance among children in districts across India. But to analyse such effect we cannot use simple Ordinary Least Squares (OLS) estimation, as this may lead to biased estimates due to the presence of endogeneity. The issue of endogeneity may arise due to existence of potential correlation between arsenic contamination in groundwater and patterns of cultivation, and therefore perhaps income and wealth. To circumvent this issue, analysis would use the variation in soil texture as an instrument for arsenic exposure.

Our findings suggest that arsenic exposure beyond the threshold level (10ug/l) has negative and significant effect on school attendance for children, net of parental characteristics, household and individual characteristics. Similar results are found using an alternative measure of educational outcomes, primary mathematics test scores. We argue that our estimates with state fixed effects are robust. Further, our results tend to substantiate the claims in existing literature that negative effect of arsenicosis symptoms on educational outcomes doesn’t differ across gender.

This study differs from existing studies on arsenic contamination and children’s well-being in India since it use for the first time a large, nationally representative sample of secondary school enrolled children. Therefore, it enables to exploit geographic variation in arsenic levels in groundwater to study the effect on children. Findings of this study would contribute in a way, since there is no study on arsenic exposure and children’s well-being for any developing country, which has used a large dataset of a cohort of secondary school going children and such rigorous empirical strategies.

The remainder of the paper is structured as follows. Section 2 provides a detailed background on arsenic poisoning, adverse socio-economic consequences and role of information. Section 3 introduces the empirical strategy to evaluate the underlying objectives. Section 4 presents the data and summary statistics. In section 5 we report the main results of this study. Section 6 provides the concluding remarks and summary of findings of our analysis.

2 Background

Rural India has witnessed dramatic increase in the usage of groundwater especially for drinking purposes (Jakariya et al. 2003). India has now become the biggest user of groundwater for agriculture in the world (Shah 2009). Approximately 80% of rural and 50% of urban population relies heavily on groundwater as the primary source of water (CGWB 2006).

Due to the higher dependency on groundwater resources, nearly 37.7 million people in India are suffering from lasting effects of waterborne diseases annually. Further, nearly 1.5 million children witness death due to diarrhoea alone (Khurana and Sen 2008). Quality issues in water such as presence of high levels of arsenic, nitrates, iron, salinity, fluoride and other heavy metals have been observed from several parts of the country. Arsenic contaminated water affects plant systems, soil quality, animals and human life. More than 0.1 million deaths have been associated with arsenic poisoning.

Exposure to elevated levels of inorganic arsenic is associated with various kinds of health hazards. The adverse effects arise because of resultant long term arsenic intake and leads to illnesses such as peripheral vascular disease, skin, lung and cardiovascular diseases, skin lesions, cancers of urinary bladder and adverse pregnancy outcomes (Del Razo et al. 2011; Tseng 2007; Aggarwal 2016).

Chronic exposure to arsenic not only affects health outcomes adversely but also leads to several socio-economic effects (Mazumder 2007). Arsenic exposure also creates a negative impact on the educational outcomes as the children exposed to arsenic contaminated water are more likely to have poorer cognitive skills (Asadullah and Chaudhury 2011; Wasserman et al. 2004; 2007). Children affected by pigmentation and/or keratosis due to chronic arsenic toxicity do not attend school for fear of ridicule (Mazumder 2007).

Moreover, the cost of treatment intensifies the burden of the disease on poor households. These families face financial risks from major illnesses both from the cost of medical care and from the loss of income associated with reduced labour supply and productivity (Carson et al.2010). For instance, children growing up in arsenic affected households and who suffer from poor nutritional status are highly prone to adverse health outcomes and therefore possess worse cognitive skills. Increased risks of skin lesions are commonly found in lower socioeconomic status categories (Argos et al., 2007).

Arsenic poisoning also leads to social exclusion and school absenteeism. The most dominant reason for children with keratosis getting socially ostracised at schools is mainly due to the belief that it is contagious, since people confuse the arsenicosis symptoms with leprosy. Few studies also argue that children with skin problems are often not sent to school in order to hide such problems (Hassan et al. 2005). Therefore arsenicosis can results in social exclusion and school absenteeism.

Murray and Sharmin (2015) estimate the effect of consuming arsenic affected water on primary school outcomes of Bangladeshi boys. The authors use two data sets: (i) Bangladesh

Multiple Indicator Cluster Survey (2006 MICS) and (ii) the National Hydro chemical Survey (NHS) of wells. Using Probit and fixed-effects regressions they find that forty-three percent of boys who grow up in unsafe water communities and who drink arsenic contaminated water lose half year of schooling. The authors also show that boys living in communities with unsafe water, but who consume safer sources of drinking water, do not suffer from such adverse educational outcome.

Similarly, Pitt et al. (2012) examine the relation between retained arsenic and measures of individual cognitive and physical capabilities, schooling attainment, health, occupational choice, entrepreneurship and income of rural Bangladesh population. They find that performance on a test assessing cognition was negatively and significantly associated with higher levels of retained arsenic. Further the significant negative effects on cognition lead to lower schooling attainment especially for young males.

Rosado et al. (2007) try to evaluate the effect of arsenic exposure on cognitive function for 557 children enrolled in schools in the city of Torreon, Mexico. Using linear and logistic regression framework, the authors find that higher level of arsenic concentration is significantly associated with lower cognitive development among children. Further, they also show that the negative effect of arsenic on cognitive abilities elevates more in the case of boys relative to girls. Similar analysis by Calderon et al. (2001) finds that exposure to arsenic accompanied by chronic malnutrition adversely affects children of 6-9 years of age who were enrolled in schools in Mexico. The authors also highlight that it can also have negative impact on verbal abilities and long-term memory.

Asadullah and Chaudhury (2011) use a sample of nonreligious as well as Islamic school students in Bangladesh. The authors examine the effect of arsenic exposure at home, on maths and well-being scores, controlling for school characteristics and past educational background of the student. They find negative and statistically significant effect of arsenic on maths score after controlling for parental and individual level factors. The results are consistent even after controlling for school fixed effects; for children who were not subject to dress codes. This is mainly due to the reason that in Madarasa Schools children follow a certain dress code and have lesser possibilities to get ostracised on the basis of his/her physical attributes.

Another study by Wasserman et al. (2004) examines the consequences of arsenic exposure on children’s health in Araihazar, Bangladesh. They find negative and significant association between arsenic contaminated water and intellectual functions raw score among 201 children under the age of 10 years. They also find that children in highest quartile of arsenic contaminated water scores 10 points lower in performance raw score than those in lower quartiles of arsenic contaminated water.

Wasserman et al. (2007) extended this analysis to 301 randomly selected 6 year old children whose parents participated in a survey in Bangladesh analysing the effect of arsenic poisoning. They find that children exposed to arsenic contaminated water have worse health outcomes and poorer cognitive skills.

Asadullah and Chaudhary (2008) estimate the effect of endogenous social effects (the behaviour of an individual is influenced by its peers) on mathematics score for children enrolled in eighth grade in rural Bangladesh. The authors use data for 321 schools from 60 unions in 2005. Using ordinary least square and fixed effect framework, authors finds that there exist significant variations in the mathematics test scores owing to arsenic exposure at home. The result remains consistent even after controlling for family and school level attributes.

Various authors also argues that arsenic not only affects development and educational abilities of children via direct consumption of arsenic contaminated water but it also affects indirectly by affecting the productivity of main earning member of the family owing to poor health.

A study by Carson et al. (2010) in Bangladesh evaluate the impacts of arsenic contamination on both the overall level of hours worked and the distribution of these hours within households. Using a large sample of 4,259 rural households matched to arsenic exposure and Cox-Proportional hazard model, they find that (*a*) overall household labour supply is 8% smaller due to arsenic exposure and (*b*) intra- household reallocation of work between males and females is used to self-insure against the risk induced by arsenic exposure. Therefore, the problem of skin manifestation obstructs the productivity of an individual (owing to ill health) and also affects the educational outcomes of children.

There is some evidence that providing information to households about unsafe water might even be more effective as compared to providing safe water to some households. Madajewicz et al. (2007) study the effectiveness of information in Araihazar district of Bangladesh. The information was mainly based on methods to reduce the health hazards arising from arsenic poisoning. As control groups for Araihazar, the authors also conducted surveys in four additional districts of Bangladesh. Using ordinary least square (OLS), they find that the response to information is large and rapid; knowing that the household's well water has an unsafe concentration of arsenic raises the probability that the household changes to another well within one year by 0.37. They also find that door-to-door information campaign is more effective as compared to the information provided by media. Therefore information campaigns can also bring positive change as in the case of Bangladesh.

Bennera et al. (2013) conducted a randomized controlled trial in rural Bangladesh to examine how household drinking-water choices were affected by two different messages about risk from arsenic poisoning. Households in both randomized treatment arms were informed about the arsenic level in their well and whether that level was above or below the Bangladesh standard for arsenic. Households in one group of villages were encouraged to seek water from wells below the national standard. Households in the second group of villages received additional information explaining that lower-arsenic well water is always safer and these households were encouraged to seek water from wells with lower levels of arsenic, irrespective of the national standard. A simple model of household drinking-water choice indicates that the effect of the emphasis message is theoretically ambiguous. They find that the richer message had a negative, but insignificant, effect on well-switching rates. The main policy implication of this finding is that a one-time oral message conveying richer information on arsenic risks, while inexpensive and easily scalable, is unlikely to be successful in reducing exposure relative to the status-quo policy.

Shastry et al. (2015) study the effect of campaign on mother's behaviour and infant's health. They also analyse the effect of breastfeeding on infant mortality in Bangladesh. The authors use differences-in-differences (DID) strategy, where the cluster of arsenic contaminated water areas were taken as treatment group and non-arsenic contaminated water areas were consider as control group. The authors find that mother's breastfeed their children longer in areas of arsenic contaminated water. They also find that the infants and young children raised in the areas of arsenic contaminated water are mostly breastfed. This behaviour change is consistent with the separate spheres model of intra-household bargaining where men have authority over certain decisions (which well to use, for instance), but women are able to influence other decisions (how to feed their children, for instance).

Arsenic is chronically toxic after prolonged low-level exposure and can lead to a range of diseases with likely fatal outcomes (WHO 2001). But such severe outcomes can be avoided if accompanied by awareness. Indeed information campaigns have proven to be a better remedy as compared to other measures of mitigation.

To summarize, there is a well-established literature on the effect of arsenic poisoning on several outcomes including educational outcomes in Bangladesh. However, despite the huge prevalence of arsenic in groundwater in India, most of the authors had an epidemiological focus. Limited studies in India addresses the adverse consequences of arsenicosis on educational achievements for children enrolled in schools. Our study is a major initiative to inform policy makers regarding the arsenic menace since creating awareness and providing information to households about unsafe water might even be more effective as compared to providing safe water to some households (Shashtry et al. 2015; Madajewicz et al 2007).

3 Empirical Framework

Consider the OLS regression equations.

$$\mathbf{Y_{ids} = \boldsymbol{\delta} Arsenic_{ds} + \boldsymbol{\gamma} X_{ids} + S + e_i} \qquad \mathbf{(1)}$$

As shown, equation 1 estimates the impact of arsenic on various educational outcomes (cognitive skills and school absenteeism) of children enrolled in schools using simple OLS regression framework. The main explanatory variable Arsenic_{ds} indicates the concentration level of arsenic in groundwater in particular district d and state s. X_{ids} is a vector of controls such as individual (age, gender), family background characteristics (parental education, religion, caste etc.) and district specific factors (sex ratio, literacy, rainfall etc.). S is state fixed effect.

In this analysis, we focus primarily on evaluating the effect of arsenic on children educational achievement in primary schools. Although the distribution of arsenic is highly variable geographically, there exists a potential correlation between arsenic contamination and patterns of cultivation, and therefore perhaps income and wealth. Hence, a simple Ordinary Least Squares (OLS) estimation can generate biased estimators. Our OLS estimates reported in result section, indicates insignificant relation between arsenic and school absenteeism. Similarly, the insignificance holds for mathematics test scores. The results seem to be biased due to the presence of endogeneity in the regression.

Therefore, to examine the proposed relation and avoid the endogeneity issue, it will use exogenous soil texture as an instrument for level of arsenic concentration. The physical soil characteristics define its permeability and do not vary over time. We exploit the variation in the fractions of loamy and clayey soil textures across districts within the same state to instrument for arsenic soil contamination (Carranza 2014). For instance in clayey districts, the level of arsenic is quite high owing to the inverse relation between permeability of soil and level of arsenic concentrations (Mac Arthur et al. 2001; Madajewicz et al. 2007). The identification strategy relies on the assumption that the exogenous soil texture fractions affect the educational outcomes only through the impact on the level of arsenic in groundwater, conditional on various set of controls[2]

Consider the regressions for Instrumental Variable estimation

$$\mathbf{Arsenic_{ds} = \beta Soil_{ds} + \Theta X_{ds} + S + v_{ds}} \qquad \mathbf{(2)}$$

Our first stage regression, express the relation between soil permeability and arsenic contamination for district d and state s. X_{ds} includes set of control variables such as temperature, rainfall etc. S represents state fixed effects. We exploit the variation in the fractions of loamy and clayey soil textures across districts within the same state to instrument for arsenic contamination. Our first stage regression estimates yields positive and statistically significant result, robust to state fixed effect, shown in Table 1.

On the basis of significant result of our first stage regression, we estimate the reduced form relation between texture of soil, level of arsenic and educational outcome of children.

$$\mathbf{Y_{ids} = \alpha_1 Soil_{ds} + \alpha_2 X_{ids} + S + e_{ids}} \qquad \mathbf{(3)}$$

Equation 3 estimates the impact of arsenic on academic achievement for children enrolled in schools using soil texture as an instrument for arsenic. Where $Soil_{ds}$ represents the fraction of clayey soil in districts d and state s. The existing literature claims that there can be a relation between soil texture and educational outcomes via sex ratio, pattern of cultivation, presence of other metals like fluoride (Mondal and Polya 2008; Carranza 2014; Bhattacharya et al. 2012). Thus we consider all such factors in our main regression. We also incorporate state

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[2] Controls consists of several district level factors such as rainfall, sex ratio, presence of other metal (fluoride), urbanisation, literacy and area under rice as well as wheat production. It is considered in order to satisfy the exclusion restriction. However, our result in table 1 shows that the instruments satisfy both the relevance as well as exclusion restrictions.

fixed effect so as to into account for the variation within the state that may affect the outcomes variable.

Table 1: Validity of Instrument (First stage regression)

	Arsenic
Clayey Soil	14.55*** (0.80)
Sex Ratio	0.541* (0.32)
Urbanisation	0.446* (0.26)
Literacy	-1.839 (1.22)
Ratio	-16.41*** (1.60)
Fluoride	-50.03*** (6.55)
Observations	2,932

Note: Standard errors in parentheses. *** Significant at 1%, ** significant at 5%, * significant at 10%. Regression includes state fixed effects.

4 Data

4.1 Description of sample from IHDS survey

We used the district level data (India Human Development Survey –II, 2011-12) which is conducted by National Council of Applied Economic Research (NCAER), New Delhi, India in collaboration with University of Maryland, in 2004-05. India Human Development Survey (IHDS) is a multi-topic survey which covers around 42,152 households and 204568 individuals in the selected 1,503 villages and 971 urban neighbourhoods across India. It provides information on the key variable[3] of interest such as school absenteeism[4] and cognitive skills[5] measured by test scores.

Moreover, IHDS data also allows us to control for individual attributes such as age and gender and family background characteristics such as highest female education and other household characteristics such as access to toilets, social group. Data on total area under rice

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[3] Note that number of observations under cognitive skills are 4,193 whereas for school absenteeism the number of observations are 8,791.

[4] It is measured in terms of number of days a child is not able to go to school due to illness in previous month.

[5] The test on mathematics was conducted in 13 languages and children were asked to take the test in their most comfortable language. Test scores was classified into four groups: (i) child cannot read numbers above 10 (ii) child can read numbers between 10 and 99 but not able to do more complex number manipulation; (iii) child can subtract a two digit number from another; (iv) child can divide a number between 100 and 999 by another number between 1 and 9.

and wheat production is obtained from Ministry of Agriculture and Farmer's Welfare. However, data for rainfall is provided by Indian Meteorological Department (IMD) at district level in India. To account for district level factors such as sex ratio, urbanization, literacy it uses 2011 Census of India data.

The data for level of arsenic and fluoride[6] in groundwater is provided by Central Ground Water Board. Following the WHO guidelines, the Bureau of Indian Standards (BIS) has notified a standard of 10 μgL−1 (microgram per litre) for arsenic in drinking water. This study mainly consists of those districts where the presence of arsenic is measured beyond the threshold limit.

The data on soil texture is generated from Harmonised World Soil Database (HWSD). It was established in July 2008 by Food and Agricultural Organisation (FAO) and International Institute for Applied System Analysis (IIASA). HWSD is global soil database framed within a Geographic Information System (GIS) and contains updated information on world soil resources. It provides the data on various attributes of soil such as texture, composition. In this paper, the data on soil has been broadly classified into two categories based on its permeability level: clayey soil and loamy soil (Carranza 2014).

4.2 Summary Statistics

Table 2 summarize the key variable of our analysis, the average level of arsenic is 102ug/l in India, remarkably higher than the threshold limit of 10ug/l as per the guidelines of BIS. However, in India, the presence of clayey soil is approximately 29 percent whereas percentage of loamy soil is approximately 71 percent. Am elementary measure of association between clayey soil and arsenic shows that there exists positive correlation between these variables. Whereas the association between loamy soil and arsenic is negative, as the former is more permeable and hence the level of arsenic would be less.

Figure 1 provides the visual evidence for the correlation between arsenic and soil texture. The left hand panel of figure 1 provide insight regarding the positive correlation that exists between arsenic and clayey soil. However, the right hand panel of figure 1 shows negative correlation for arsenic and loamy soil.

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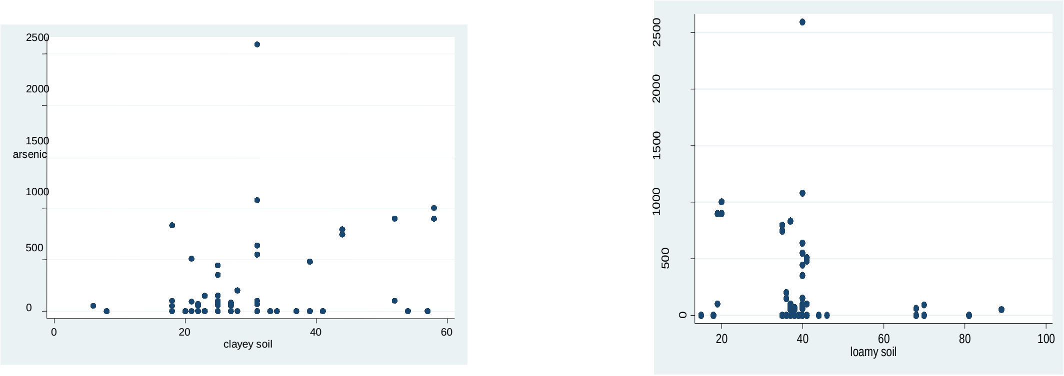
[6] The variable is continuous in nature and has been taken as control variable in all regressions.

Table 2: Descriptive statistics for sample of children currently enrolled in primary schools

Variable	Obs	Mean	Std. Dev.
Outcomes			
Maths Test Scores*	4193	1.559981	0.99799
No. Of Days Absent	9738	0.8411378	2.512478
Arsenic	9738	102.6424	273.5776
Clayey Soil	9386	29.46154	9.800648
Loamy Soil[7]	9386	70.53846	9.800648
Individual Attributes			
Age	9738	11.0954	1.381459
Gender*	9738	0.5234134	0.4994772
Family Background			
Female Education*	9683	4.361665	4.831914
Accessibility To Toilet*	9699	0.893288	1.01771
Social caste*	9732	1.214755	0.8461536
Social group*	9738	0.3309715	0.5912893
District Level Factors			
Ratio	8678	5.522427	13.67564
Urbanisation	9234	29.07789	32.58588
Sex ratio	9464	933.8969	45.25113
Fluoride	3570	2.599929	1.195122
Rainfall	9738	71.03111	64.89537

Note: a) Note that our sample consists of children below 14 years of age which are currently enrolled in schools. b) * indicates a categorical variable, except gender (dummy variable- 1 for males, 0 for females). c) The variable defined as no. of days absent in school is a count variable. Others variables are continuous in nature. d) The no. of observation for maths test scores is lesser than other variables since there were only 4,193 students present for the test in schools

Figure 1: Relation between Arsenic and Soil permeability



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[7] Loamy soil comprises of sandy and silty soil (Carranza 2014).

5 RESULTS

5.1 Arsenic poisoning and Cognitive skills of children (OLS Estimates)

Table 3 reports the results for OLS estimation using outcome for educational development (Cognitive skills) for children enrolled in schools. Three sets of estimates are reported in Table 3, namely for sample of girls, boys and entire sample. We also account for State Fixed Effects (F.E) this would yield the estimates of a child's exposure to arsenic net of State level exposure.

Table 3: Student's Cognitive skills (primary mathematics test) by gender (OLS estimates)

Cognitive skills	(1) Girls		(2) Boys		(3) Full Sample	
Arsenic	-0.000* (0.00)	-0.000** (0.00)	-0.000 (0.00)	-0.000 (0.00)	-0.000* (0.00)	-0.000** (0.00)
Age		0.153*** (0.04)		0.167*** (0.04)		0.017 (0.04)
Gender		-		-		-0.068 (0.11)
Female Education		0.060*** (0.01)		0.054*** (0.01)		-0.073*** (0.14)
Social group		-0.333*** (0.08)		-0.023 (0.07)		(0.12) (0.07)
Social caste		-0.130*** (0.04)		0.034 (0.05)		0.041 (0.07)
Household toilet		0.117*** (0.04)		0.062 (0.04)		0.085*** (0.03)
Sex ratio		0.001 (0.00)		-0.001 (0.00)		-0.001 (0.00)
Urbanisation		0.000 (0.00)		0.000 (0.00)		0.000 (0.00)
Literacy		-0.004 (0.01)		-0.013* (0.01)		-0.023** (0.01)
Ratio		-0.005 (0.01)		-0.007 (0.01)		-0.009 (0.01)
Rainfall		0.001 (0.00)		0.001 (0.00)		-0.003** (0.00)
Fluoride		0.072 (0.04)		0.049 (0.04)		-0.192*** (0.05)
Observations	2,012	1,654	2,181	1,755	4,193	3,409

Notes: Standard errors in parentheses. *** Significant at 1%, ** significant at 5%, * significant at 10%. All regressions accounts for state fixed effect.

Table 3 shows that arsenic has negligible effect on cognitive skills for children enrolled in schools (Model 3). We also analyse whether this effect varies across gender then again we find negligible impact of arsenic on test scores for girls as well as boys. Further, non significance of results holds when an alternative measure of educational outcome i.e. school absenteeism is used (Table4). Similarly, no effect of arsenic is visible across gender, as the outcome doesn't differ both for girls (Model 1) and boys (Model 2). Here, the OLS estimates fails to capture the true effect of arsenic on the outcome variable, due to the existence of endogeneity issue[8]. To circumvent the issue of endogeneity we use instrumental variable approach, as shown in next section.

Table 4: Educational outcome (School absenteeism) by gender (OLS estimates)

School Absenteeism	(1) Girls		(2) Boys		(3) Full Sample	
Arsenic	0.00 (0.00)	0.000 (0.00)	0.00 (0.00)	0.000 (0.00)	0.00 (0.00)	0.000 (0.00)
Observations	4,169	3,425	4,622	3,752	8,791	7,177
Controls	No	Yes	No	Yes	No	Yes
State Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes

Notes: a) Standard errors in parentheses. *** Significant at 1%, ** significant at 5%, * significant at 10%.
b) School absenteeism is defined as the number of days a child was unable to go to school due to illness.

5.2 Arsenic poisoning and Educational Outcomes (Instrumental Variable Estimates)

Our study addresses the issue of endogeneity, so in the following section we present the estimates for IV. Apparently our first stage regression highlights a positive and statistically significant relation between arsenic and soil texture (clayey soil[9]), after inclusion of all necessary controls and also state fixed effects. Thus soil texture appears to be a strong instrument as it satisfies both the relevance and exclusion restriction.

Unlike the OLS estimates, the IV estimates shows a positive and significant association between arsenic and school absenteeism. As shown in Model 3, arsenic and school absenteeism has positive and statistically significant association (0.2 percent), robust to state fixed effects. However, result for IV estimates holds after controlling for various individual, family characteristics and state level unobservable factors. Therefore, our findings suggest that children with arsenic exposure have 0.3 percent higher risk of missing the school in a

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[8] The issue of endogeneity may arise due to existence of potential correlation between arsenic contamination in groundwater and patterns of cultivation, and therefore perhaps income and wealth.

[9] As already mentioned earlier that the there exists an inverse relation between soil permeability and arsenic concentration level. Clayey soil is less permeable than loamy soil; hence the relation between clayey soil and arsenic must be positive.

month relative to children with no arsenic exposure (Model 4).

Hence, our results clearly points out that there exists a significant and positive association between arsenic and school absenteeism. But, such adverse affect of arsenic on the response variable remains same both for girls as well as boys, despite of the effect being significant (0.3 percent) for both the groups (girls- significant at 5 percent level of significance, boys- significant at 10 percent level of significance). Hence, we conclude that arsenic not only imposes a physical burden for the victims but also creates an additional burden by affecting the development of children adversely.

Table 5: Educational Outcomes (School Absenteeism) by gender (IV estimates)

School Absenteeism	**Girls (1)**	**Boys (2)**	**Full Sample (3)**	**Full Sample (4)**
Arsenic	0.003** (0.00)	0.003* (0.00)	0.002** (0.00)	0.003** (0.00)
Observations	3,406	3,728	8,492	7,134
Controls	Yes	Yes	No	Yes
State Fixed Effects	Yes	Yes	Yes	Yes

Notes: a) Standard errors in parentheses. *** Significant at 1%, ** significant at 5%, * significant at 10%. b) Model 1 consists of sample for female children, Model 2 consists for males and Model 3 accounts for entire sample. c) Each regression incorporates state fixed effects and contains dummy variable for religion, caste and gender.

5.3 Arsenic poisoning and Student's achievement

We also use an alternative measure of educational outcome such as children's performance in mathematics test. Table 7 reports the results for regression using the maths test scores for children enrolled in primary education. We find that prolong consumption of arsenic contaminated water leads to poor academic performance (0.1percent) for children (Model2), unlike for children in non-arsenic regions. Thus we conclude that arsenic not only imposes a physical burden but also creates an additional socio-economic burden for the society (Hassan et al. 2005; Asadullah and Chaudhary 2011).

Table 7: Student's Cognitive skills (primary mathematics test) using IV estimates

Cognitive Skills	Model 1	Model 2	Model 3
Arsenic	-0.001*** (0.00)	-0.001** (0.00)	-0.000 (0.00)
Observations	4,052	3,607	3,607
Additional Controls	No	Yes	Yes
State Fixed Effect	No	No	Yes

Standard errors in parentheses *** Significant at 1%, ** significant at 5%, * significant at 10%

However, the adverse effect of arsenic may arise due to the presence of arsenic in the food consumed. The accumulation of arsenic in rice paddy mainly takes place through irrigation, which is generally met by the use of groundwater especially in rural areas of India (Duxbury et al. 2003). As mentioned by Bhattacharya et al. (2012), rice is the most affected crop in arsenic accumulation relative to the other crops (wheat). Thus we also aim to study variations in rice/wheat production ratios across districts in India and hence study its effect on educational outcomes.

In order to analyse the above mentioned argument, we classify our sample into two groups; higher ratio (rice & wheat ratio above 5.53) and lower ratio (below 5.53[10]). Table 8 comprises of two sets of regression framework, namely Ordinary Least Squares (OLS) and Instrumental Variable (IV). Once again, the relation between arsenic exposure and test performance at school is negative and significant, after controlling for state level factors (Model 2)[11]. It shows that children with arsenic exposure have lower scores (0.6 percent) in mathematics than their peers in safer communities. Similarly, children living in arsenic bearing regions have 1.3 percent higher risk of missing the school due to illness relative to those living in non-arsenic regions. However, OLS estimates are biased contrary to our IV estimates, latter estimates are also robust to state fixed effects. Thus, we argue that prolong consumption of arsenic contaminated water beyond threshold limits have negative effect on children's educational achievements including school attendance and cognitive development (measured by test scores in mathematics), particularly for districts where rice consumption is greater than whet consumption.

Table 8: Determinants of Educational Achievements: OLS & IV Estimates

	Cognitive Skills		**School Absenteeism**	
	OLS (1)	**IV (2)**	**OLS (3)**	**IV (4)**
Arsenic	0.000 (0.00)	-0.006** (0.00)	-.003 (0.00)	0.013* (0.01)
Observations	732	732	1,630	1,630
Additional Controls	Yes	Yes	Yes	Yes

Notes: a) Standard errors in parentheses. *** Significant at 1%, ** significant at 5%, * significant at 10%. b) The sample consists of only those districts where ratio is higher than 5.53. c) Each regression incorporates state fixed effect and also contains dummy variable for religion, caste and gender.

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[10] Here, the threshold level of rice to wheat ratio has been set in accordance with the average value of ratio i.e. 5.53

[11] We haven't reported the regressions results for the districts where the ratio is below 5.53, but available from the authors if required.

6 Conclusion

Worldwide, arsenic poisoning is considered to be the second most important health hazard related to drinking water (Van Halem et al. 2009)**.** It poses a serious health hazard to 150 million individuals living in countries such as Nepal, Taiwan, Bangladesh, Vietnam, India, Cambodia, China, Myanmar and Laos but the severity is unprecedented in Bangladesh and India (Brammer and Ravenscroft 2009). In India, the problem of arsenic is less widespread as compared to other geogenic contamination elements such as fluoride, nitrate etc. But the severity of its consequences is more hazardous as compared to these elements. Arsenic is a major public health concern particularly for children and infants as well, still the literature witnesses a huge gap in addressing such issues in context of children under the age of 14 years, particularly in India. To fill the gap in literature, we will address the adverse educational consequences of arsenic for children enrolled in schools. To conduct the analysis we use secondary source of data from the India Human Development Survey –II (IHDS-II 2011-12).

Moreover, the study also tries to solve the issue of endogeneity that may arise due to correlation arsenic contamination in groundwater and patterns of cultivation, and therefore perhaps income and wealth. We argue that variation in soil texture could serve as an instrument for arsenic exposure, owing to an inverse and significant relation between soil permeability and level of arsenic in groundwater.

The aim of our study is to evaluate the effect of drinking arsenic-contaminated water on academic performance among children in districts across India. We find that children drinking arsenic contaminated water have (0.1 percent) poorer cognitive skills than their peers with no arsenic exposure. Our findings seem consistent even after controlling for various individual, parental background and district level factors. The negative and significant association (0.3 percent) between arsenic and school absenteeism still persists, net of various socio-demographic and state level unobservable factors.

Further, we also show that the negative impact of arsenic on these educational outcomes doesn’t vary across the gender. Finally when we classify the data on the basis of their relative consumption of rice over wheat then we find same results for both the outcomes, cognitive skills (0.6 percent) and school absenteeism (1.3 percent). This may be due to the reason that rice cultivation requires plenty of water for irrigation. In India, 90 percent of irrigation needs are met by using groundwater. Since the arsenic is present in groundwater, therefore it gets accumulated in the cultivated rice during the irrigation process (Bhattacharya et al. 2012). The accumulation levels of arsenic gets elevated further if it is cooked with arsenic contaminated water. Hence, the situation worsens further for rice consuming districts accompanied with higher arsenic levels.

The paper would examine the effect of arsenic poisoning on various educational outcomes at individual level. The study differs from existing studies on arsenic contamination and children's well-being in India since it use for the first time a large, nationally representative sample of secondary school enrolled children. Therefore, it allows exploiting of geographic variation in arsenic levels in groundwater to study the effect on children. Moreover, as discussed in the methods section, no other study has used rigorous econometric methodology to look at the implications of arsenicosis on education outcomes in India.

This study sheds light on the human capital costs of arsenic-related health problems and measures the value of accessibility to safer sources of drinking water in early childhood. Consequently, the results of this study will inform policy makers about the extent to which the reduction in arsenic concentration in water to a safe limit in affected areas can increase human capital.

Concluding, our study provides various ways in which further research on arsenic poisoning may develop better insight for policy makers so as to take appropriate remedial measures. Firstly, despite the huge prevalence of arsenic in groundwater in India, none of the data sets including IHDS-II (India Human Development Survey, 2011-12) provides information regarding the channels through which arsenic contamination could affect children's' outcomes. So a detailed survey on this aspect may highlight the issues of arsenic poisoning more effectively. Secondly, other measure of learning outcomes can be assessed so as to evaluate the intensity of arsenic poisoning.

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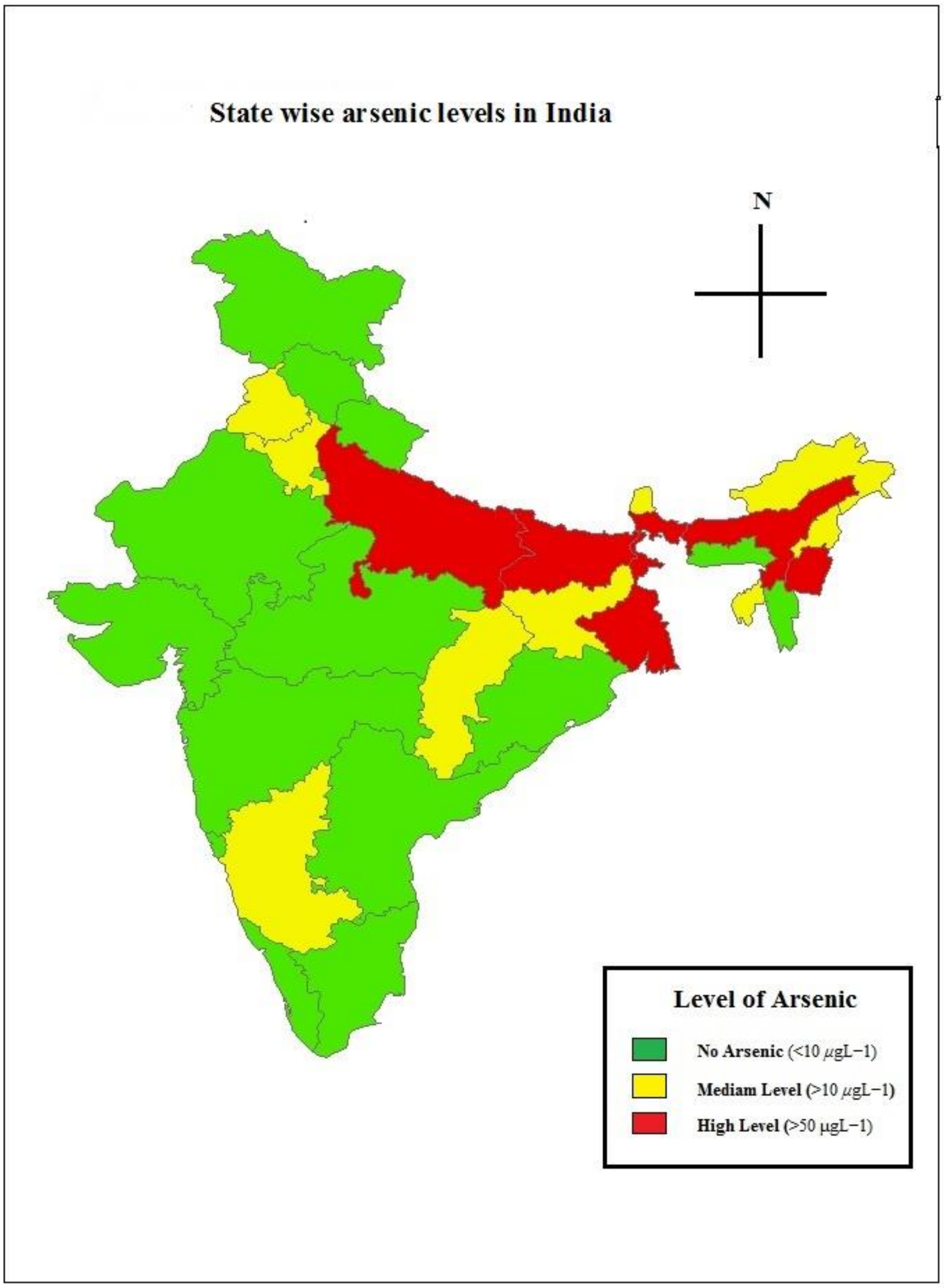
Appendix

A Map of India: Arsenic affected districts



Source: Author's calculation using Central Ground Water Board report data (2014-15)