# The Impact of River Water Quality on Children's Education: Evidence from 39 Districts in India

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**Abstract**

We investigate the effect of water quality on the educational outcomes of school-going children aged 8-11 in 39 districts in 5 states in the Ganges Basin of India. Using data from the Centre for Pollution Control Board of India and the Indian Human Development Survey (IHDS) 2011-12, we study the effect of water quality of river Ganges on the performance in three tests - maths, reading, and writing (N = 1147). Our evidence suggests that the effects of faecal coliform in water sources above safety levels on the reading and writing test scores are negative. The effect of Nitrate-N and Nitrite-N in the water appears to be weaker compared to faecal coliform's. The results establish that water pollution caused by excessive presence of faecal coliform is an important environmental factor in determining educational outcomes of children. High density of faecal coliform in the water could be lowering cognitive abilities of the pollution-affected children through the channel of water-borne diseases.

***Keywords—*** River Pollution, Water Quality, Pollution and Education, Cognitive Abilities, Children's education.

**JEL codes:** I21, Q53, O15

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# 1 Introduction

The Ganges is an immense natural resource covering approximately 26% of India's landmass and supporting nearly half of its population (Chakraborti et al., 2018). Its significance cannot be overstated, yet its water quality is rapidly deteriorating due to population growth, industrialisation, and urbanisation, making it one of the most polluted rivers in the world (Chaudhary and Walker, 2019). Urban populations living in the Ganges Basin near Ganges or its tributaries have surged by 30% in just a decade, between 2001 and 2011, promising a further increase in pollution loads (of India, 2011). Therefore, pollution in Ganges and its tributaries is not only an environmental issue but it has far-reaching impact on mortality and morbidity, long-run health outcomes, and other economic outcomes of the ever-growing population who live near it (Khan et al., 2016; Das and Birol, 2010; and others).

Numerous studies have established that polluted water poses a threat to public health and other economic outcomes. The impact of While Ganges is a major source of water, it is one of the most polluted rivers in the world (Chaudhary and Walker, 2019). Given that pollution-related ailments hinder children's physical development and water filtration systems do not always effectively eliminate pollutants, it's crucial to investigate the magnitude and mechanisms through which pollution impacts children's cognitive abilities and educational outcomes. In this paper, we examine the impact of water quality on the educational outcomes of school-going children aged 8-11 living in 39 districts in Ganges Basin. Using data from the Centre for Pollution Control Board of India (CPCB) and the Indian Human Development Survey (IHDS) 2011-12, we estimate the effect of organic and inorganic pollutants – which arise from industrial discharge, fertiliser runoff, sewage, and other waste matter – on test scores from the IHDS. Specifically, we test the hypothesis whether unsafe levels of two pollutants, faecal coliform and Nitrate-N + Nitrite-N, reduce cognitive abilities in children, as measured by reading, maths, and writing scores. Persistent exposure to high levels of pollution has the potential to lower cognitive abilities, which could steer students towards paths of lower-level educational attainment.

The Ganges Basin, characterised by its vast expanse, numerous tributaries including the major Ganges River, and its dense human settlements, holds a prominent position in the environmental and development literature due to the link between pollution in its waters and the consequent environmental and economic impacts. The Ganges river originates from the Gangotri glacier in the state of Uttarakhand in northern India and flows for 2,525 kilometers (1,569 mi) over 5 states and meets the Bay of Bengal. It supports the life of the people who live in the Ganges basin by providing for their basic water needs such as drinking, cooking, bathing, and irrigation. However, the ever-growing population and industrialisation have contaminated the most important river in the country with the continuous discharge of sewage, industrial waste, and agricultural runoff. A study conducted in Varanasi, a densely populated (15,000/$km^2$) city that discharges 200 million litres of sewage daily, showed that about 66% of diseases were water-borne, and were caused by using Ganges water for bathing, laundry, brushing teeth, and washing utensils (Hamner et al., 2006). A report by the Central Pollution Control Board states that 764 industries are directly discharging 500 million liters of wastewater every day into the river Ganges[1]. In addition to that, religious ceremonies are performed such as mass ritualistic bathing, idol immersion, cremation, etc., adding to the pollution. This increases heavy-metal contamination in the river and results in high levels of Biochemical Oxygen Demand, significantly above the standard set by the pollution board. Heavy metals are non-biodegradable, so high exposure to heavy metals can lead to kidney damage, cancer, even death (Lellis et al., 2019). Moreover, Nitrate-N + Nitrite-N contamination in the river's water increases from agricultural waste and sewage. Drinking nitrate-contaminated water can be detrimental to health and can increase the risk of cancer (Quist et al., 2018; Adimalla, 2020. Some experts also have found colonies of antibiotic-resistant bacteria in the water of the river Ganges (Reddy and Dubey, 2019).

Examination of Ganges water during *Maha Kumbh* festival shows that ritualistic mass bathing leads to an increase in biochemical oxygen demand, chemical oxygen demand, total suspended solids, and ammonia nitrogen surpassing the standard limit for outdoor bathing or swimming. A high amount of faecal coliform and total coliforms organism were also found in the water during the festival, which led to an increase in water-borne infections (Tyagi et al., 2013).

[1] Please see *Annual Progress Report of CPCB ENVIS, Centre on Control of Pollution* (2016–2017)

Figure 1 shows the states in India through which the river Ganges runs. Figures 2a and 2b show the average intensity of the pollution by faecal coliform and Nitrate-N + Nitrite-N in the districts where CPCB monitored different water sources including the River Ganges and its tributaries.

Several studies have shown that the water quality of the Ganges river is unsuitable to drink and bathing at many monitoring points (Mariya et al., 2019; Chauhan et al., 2009; Matta et al., 2017). This can pose a higher risk to human health (Chaudhri and Jha, 2012), and potentially can lead to lower cognitive abilities through the channel of health deterioration. When it comes of educational outcomes of children, researchers are more interested in socioeconomic and household conditions of factors (Edmonds et al., 2009; Nambissan, 2009; Chaudhri and Jha, 2012). A growing literature provides evidence that exposure to pollutants leads to lower educational outcomes in the US (Sanders, 2012; Roth, 2017; Rosofsky et al., 2014; Jasper et al., 2012; Evans et al., 2019; Mohai et al., 2011; Ebenstein et al., 2016). However, to the best of our knowledge, there has been no research in this area in the context of a developing country.

This paper addresses the lack of research on how pollution affects educational outcomes in the context of a developing country like India. Water pollution generates notable short- and long-term health repercussions, including negative cognitive effects arising from prolonged exposure. In addition, an increase in population density in areas with polluted water sources would mechanically increase welfare losses by diminishing the cognitive abilities of children residing there. Despite its significance, research on this aspect remains limited, partially due to the prioritisation of more immediate concerns such as child mortality and governmental focus on economic growth. Because of greater emphasis on economic growth by the governments in developing countries, pollution monitoring policies can be deemed less important which can lead to less stringent pollution monitoring policies. This is particularly true in the Indian context (Fuller et al., 2022). Furthermore, given the greater emphasis within development discourse on enhancing health outcomes and curbing child mortality and that some positive impact of pollution control laws like the Ganga Action Plan has been demonstrated in the literature (Dwivedi et al., 2018; Dutta et al., 2020), the scarcity of evidence regarding the

Figure 1: Five States of India within the Ganges Basin

long-term impacts of water pollution on outcomes like educational attainment may result in policymakers and the government overestimating social welfare improvements due to such laws.

Despite India's long history of environmental protection laws, such as the Water (Prevention and control of pollution) act in 1974, the Air (prevention and control of pollution) act in 1981, and the Environment (Protection) Act in 1986, India has been struggling to reduce pollution. The Central Pollution Control Board (CPCB), the State Pollution Control Boards (SPCBs) have been formed, and several environmental protection regulations have been adopted by the government of India in the last few decades. An unprecedented verdict by the supreme court in 1984 reduced Ganges pollution and led to a decrease in neonatal mortality rate (Do et al., 2018)[2], which paved the way to several initiatives to clean the river. In 1985, the Ganga action plan was launched to control the Ganges water pollution, which was later expanded into The National River Conservation Plan (NRCP) that included other rivers in India. However, due

[2]This case is titled M.C. Mehta vs. Union of India (1984).

to the lack of proper enforcement of the pollution regulations, it has been difficult for the government to keep pollution below the prescribed levels in many parts of India (Greenstone and Hanna, 2014).

Whether unsafe levels of faecal coliform and Nitrate-N + Nitrite-N deteriorate cognitive abilities is the research question we address in this paper. We have constructed binary variables to denote unsafe levels of faecal coliform and Nitrate-N + Nitrite-N. The binary variable for faecal coliform is set to 1 when its concentration exceeds 2500 MPN/100 ml. For Nitrate-N + Nitrite-N, the binary variable is assigned a value of 1 when the combined concentration of Nitrate and Nitrite in water surpasses 1 mg/l. While the Central Pollution Control Board (CPCB), India (2012) maintains that the Nitrate-N + Nitrite-N levels in the Ganges don't exceed the safety threshold of 10 mg/l, we have opted for a more conservative threshold for this pollutant[3]. As for other quality indicators monitored by the CPCB, the acceptable ranges are: pH between 6.5 and 8.5, Dissolved Oxygen of 4 mg/l or more, and a Biochemical Oxygen Demand of 3 mg/l or less.[4].

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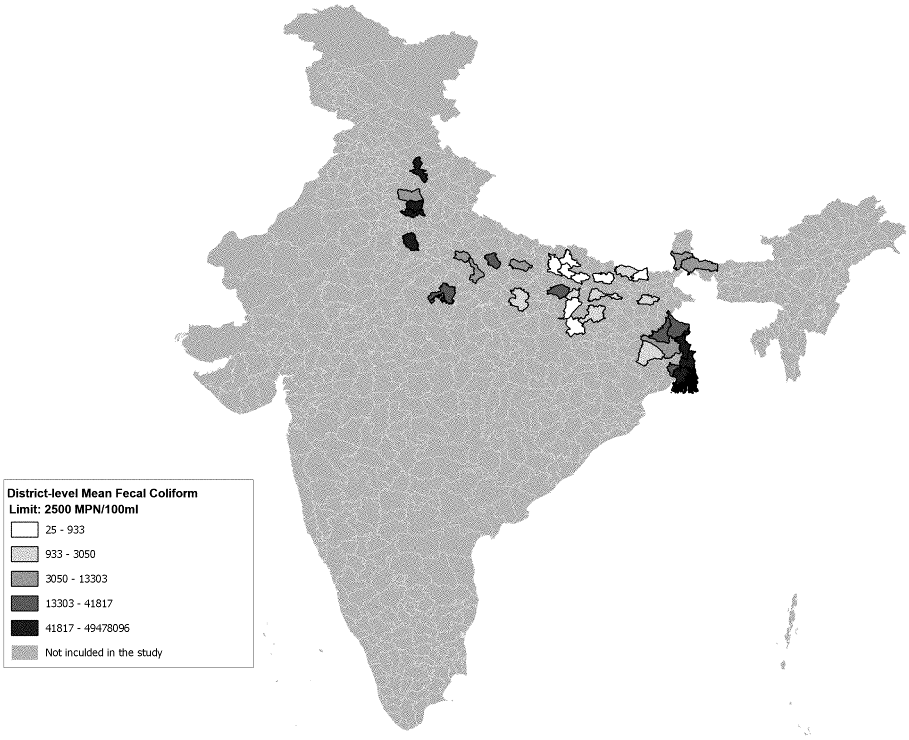
Our sample of focus includes children living in the districts adjacent to the River Ganges due to its alarmingly high pollution levels and the sizeable population residing in these neighbouring districts. The pollution factors in this paper are measured as the district-level average of the monitoring station readings in each district. In districts near the Ganges, CPCB also monitored in some cases, the groundwater, water from lakes and tributaries of Ganges, and water from the river Yamuna. The Yamuna is another major river in India. These water source indicators help us to create additional samples of districts that are subsets of the analytical sample we use. For succinctness, in the regression tables, we refer to the sample of districts near lakes and rivers (including the Ganges and its tributaries, as well as the Yamuna) as "river" and "lake" districts, respectively.

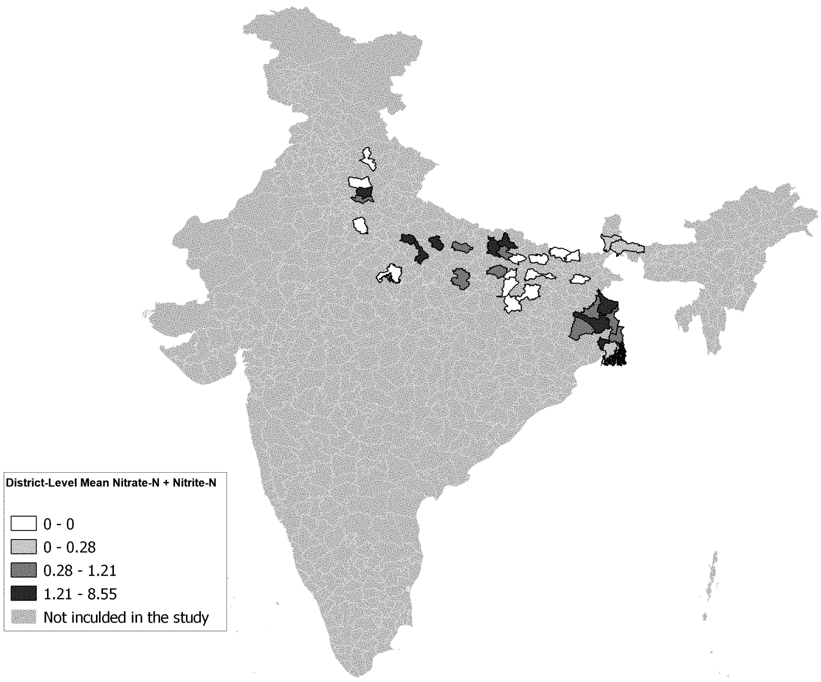
The immediate health risks posed by poor water quality manifests as short-term morbidity.

[3]In *Hardness in drinking-water: Background document for development of WHO guidelines for drinking-water quality* (2010), the safety level for Nitrate and Nitrite in water is 1 mg/l.

[4]For details, please see *Annual Progress Report of CPCB ENVIS, Centre on Control of Pollution*, 2016–2017 and Central Pollution Control Board, (CPCB), 2012.




(a) Mean faecal Coliform




(b) Mean Nitrate-N + Nitrite-N

Figure 2: Mean faecal Coliform and Mean Nitrate-N + Nitrite-N in the Sample Districts

Over a more extended period, however, consumption of poor quality water can lead to a gradual decline in cognitive functions (Tyler and Allan, 2014; Tolins et al., 2014; Vahter et al., 2020; Mostafa et al., 2009; Siegal and Share, 1990). Furthermore, Nitrate-N + Nitrite-N contamination increases from agricultural waste and sewage. Drinking nitrate-contaminated water can be detrimental to health and can increase the risk of cancer (Adimalla, 2020; Quist et al., 2018). Therefore, the possibility of a correlation between cognitive dysfunction reflected in poorer test scores and poor water quality deserves attention. If children experience recurring health issues over a long period time because of exposure to poor water quality then education may be negatively impacted. In this paper, we test the hypothesis that the presence of pollutants such as faecal coliform, Nitrate-N + Nitrite-N, and biochemical oxygen demand in water lowers cognitive abilities in children measured in test score.

Our study contributes to the literature in four ways. First, this is one of the few studies that shows the negative impact of water pollution on educational outcomes in the context of India. Second, from a policy perspective, the study suggests that any possible measure of the social cost of poor water quality based on only loss of public health and environmental damage underestimates the true cost by the amount the loss of human capital or decrease in educational outcomes. Third, our evidence complements the evidence of physiological literature on the negative impact of water pollutants on human cognitive abilities (Quist et al., 2018, Adimalla, 2020 and Koufman and Johnston, 2012). Lastly, our study allows a comparison of differences among the effects of different water quality indicators on educational outcomes.

## 2 Data

To assess the relationship between river Ganges water quality and the educational outcome of children, we combine two types of data: (1) household survey data, which includes information on children's educational outcome, and (2) water quality data, which includes multiple measures of water quality. The common geographic identifier between both data is district names. Below we discuss both data sources and a description of the variables we use to estimate our empirical model.

## 2.1 Indian Human Development Survey (IHDS)

The source of the household survey data for this paper is the Indian Human Development Survey (IHDS), a nationally representative data set[5]. The IHDS is a two-year panel survey conducted by researchers at the University of Maryland in collaboration with the National Council of Applied Economic Research, New Delhi. For this paper, we use the second round of the survey which was conducted between November 2011 and October 2012. 42,152 households in 1,503 villages and 971 urban neighbourhoods across India were interviewed in this round. Although the first wave was conducted in the 2004-05 period, it is not possible to include data from both base-year and second-round surveys in this study. The reason is that the educational outcomes are measured in the second round only. Most of the children in this survey were at most two years old in the 2004-05 period and not viable candidates for testing educational aptitude. Data were collected on several socioeconomic characteristics such as individual health, household employment, and income, school facilities, and staff. The interviews were administered on two sets of questionnaires, viz. income & social capital questionnaire (typically responded to by the male head of the household) and education and a health questionnaire (responded to by an ever-married woman). The collected data are assembled in fourteen modules[6], of which we will be using Individual, household, and school facilities modules for this study.

Most of the variables employed in our empirical analysis come from the IHDS survey module of individual members of respondent households. After merging all the data and dropping the missing values we retain 1147 observations corresponding to children aged 8-11 living in 39 districts of 5 states in Ganges Basin where water quality was monitored[7].

[5]This data set is made publicly available by Desai and Vanneman (2015)

[6]Individual, Household, Eligible Women, Birth History, Medical Staff, Medical Facilities, Non-Resident, School Staff, School Facilities, Wage and Salary, Tracking, Village, Village Panchayat, Village Respondent.

[7]After merging the data we have 204575 individual-level observations from 42152 households. Among these individuals, 27670 are below the age of 12. 11749 individuals below the age of 12 were administered maths, reading, and writing performance tests. After dropping missing values (approximately 100) in control variables, we retain 1147 children in the analytical sample who live in districts near Ganges and districts in the Ganges Basin where various water sources were monitored by CPCB.

## 2.2 Water Quality Data

We gathered water quality data for the districts in the Ganges basin for the years 2012 and 2013, drawing from the Central Pollution Control Board, (CPCB) (2012) database. This database operates under the Ministry of Environment, Forest, and Climate Change of the Indian Government. Along the river, there are 66 stations responsible for measuring water quality indicators such as Dissolved Oxygen (mg/l), pH, Biochemical Oxygen Demand (mg/l), faecal coliform (MNP/100ml), and total coliform organisms (MNP/100ml)[8]. pH is a measure of how acidic or alkaline the water is. The scale of measuring pH ranges from 0 to 14 if values under 7 are acidic and over 7 are alkaline. Water with a very low or high pH can be a sign of chemical or heavy metal pollution (U.S. Geological Survey, 2021). Higher levels of Biochemical Oxygen Demand or BOD is associated with lower Dissolved Oxygen or DO (Jouanneau et al., 2014). We further discuss transformations of these variables for facilitating our model to produce legible and policy-relevant estimates of the effect of water pollutants in Section 3.1.

The Central Pollution Control Board (CPCB) manages data collection at various monitoring sites situated in significant rivers, tributaries, lakes, and groundwater sources across India. This data is collected quarterly and monthly at these monitoring points, with CPCB publishing yearly averages for minimum, mean, and maximum levels of each water quality indicator. For example, at a specific monitoring point $j$ at time $t = 1$, the CPCB calculates the minimum, mean, and the maximum levels of faecal coliform, $F_{max,1,j}$, $F_{mean,1,j}$, $F_{min,1,j}$, respectively. By averaging these measurements over total $T$ periods, they create $\sum_{t=1}^{T} F_{max,t,j}/T$, $\sum_{t=1}^{T} F_{mean,t,j}/T$, and $\sum_{t=1}^{T} F_{min,t,j}/T$. If a district has $J$ monitors, monitor index is $j = 1, 2, 3, ..., J$ and data was collected by CPCB at $T$ times in 2012, then we calculate the district average as $\sum_{j=1}^{J} \sum_{t=1}^{T} F_{mean,t,j}/(T \times J)$. We use this averaging scheme for each district.[9]

The Central Pollution Control Board (CPCB) identifies various points along a river that likely

[8]Total coliforms organism and faecal coliform are very similar indicators. We only use faecal coliform in this study.

[9]We do not consider district-average of minimum and maximum levels of faecal coliform and Nitrate-N + Nitrite-N as covariates in our model, because the mean level has the highest frequency informing us of the most realist level of exposure of these pollutants.

contain varying amounts of key pollutants and are potentially turbid. Monitoring points located along the river within districts are occasionally reported to be either upstream or downstream of major well-known locations. Given that each monitoring point's specific location is provided, we determine which district is the nearest to a particular monitoring point. To elaborate, if a monitoring point is set up in the river, we assign it to the district that is situated right on the bank of the river. Subsequently, we calculate the district-average based on data from multiple monitoring points. Most of the districts in our sample are situated by a river or on the banks, Ganges and/or Yamuna, or one of their tributaries. Five districts in the sample had Ganges or Yamuna running through them. In two districts, Jhansi and Gaya, CPCB monitored data only from groundwater and lake water. To ensure that the results are not driven only by pollution measured in highly polluted areas in Ganges and to increase the within-state variation in water quality for states in the Ganges basin, we include districts that are adjacent their tributaries.

We primarily rely on water quality data from 2012, while using 2013 data to fill in any missing values. The missing readings for certain monitoring points in 2012 could lead to potential biases in the computation of average water quality variables. To handle this, we impute the missing values with their corresponding readings from 2013. We observed that readings from monitoring points available in both years show consistent water quality levels, with no instances of monitors transitioning from benign pollution levels in 2012 to hazardous readings in 2013. So, our process of filling in missing data ensures that the information stays accurate and true to the pollution levels in reality.

Our river pollution data from multiple monitoring points nearest to a district is averaged. This means that there is one value for each district. Further, we address the issue of upstream and downstream pollution. Pollution in upstream areas can often have significant consequences for downstream environments and communities. However, the factors influencing this pollution upstream are reasonably independent from the factors influencing negative consequences downstream. Later in Section 4, we instrument each district level pollution with its upstream counterpart provide results of the instrumented measure of faecal coliform. To do that, we track the course of the river and locate one neighbouring upstream district for each downstream district. We only select the upstream district that is also adjacent or is sharing administrative borders. This process is very simple because in the Ganges basin most rivers and tributaries are flowing from north-west to south-east. The sample used in this particular analysis excludes some districts whose upstream counterpart was not included in IHDS.

## 2.3 Descriptive Statistics

Table 1 shows the summary of the individual and socioeconomic characteristics of the children in our analytical sample which we use in our empirical model as explanatory and outcome variables divided by the district-specific water sources which CPCB monitored. Table 2 shows the analytical means of the same set of variables Table 1. In Table 2, the variable means are for districts where faecal coliform, biochemical oxygen demand, Nitrate-N + Nitrite-N, exceed the safety limits (2500 MPN/100ml, 3 mg/l, and 1 mg/l respectively), and dissolved oxygen does not reach the necessary level (6 mg/l). We use binary variables to indicate if water quality indicators are above or below desired levels. A value of 1 denotes unsafe or undesirable district-level average for each indicator.

We do not create binary variables defined at safety thresholds of pH. pH should be between 6.5 and 8.5 according to Central Pollution Control Board (CPCB), India (2012). Binary variables for pH would mix the effects of being above or below the threshold on the outcome variable. It is not also a water pollutant. So, we treat pH as a continuous variable in all regression models.

The main binary variables of interest are district-average 1[Mean faecal Coliform $>$ 2500 MPN/100 ml] and 1[Mean Nitrate-N + Nitrite-N $>$ 1 mg/1L]. For simplicity and to save sapce, we express these variables as $1[\overline{FCOLI} > limit]$ and $1[\overline{NIT} > limit]$ using Iverson notation, respectively. FCOLI and NIT are the shortened versions of 'faecal coliform' and 'Nitrate-N + Nitrite-N', respectively. The bars over FCOLI and NIT denote that they represent means. The term 'limit' is used to indicate their respective safe levels. Both variables indicate if the respective pollution amounts are above individual acceptable limits. Central Pollution Control Board (CPCB), India (2012) sets the acceptable limit of faecal coliform at 2500 MPN/100 ml[10]. The data from Central Pollution Control Board, (CPCB) (2012) does not include a limit for NITRATE- N+ NITRITE-N (mg/l). A report from the World Health Organization provides separate safety limits for Nitrate-N and Nitrate-N, which are 10mg/l and 1mg/l, respectively[11]. Using the 1mg/l limit, I create the binary indicator $1[\overline{NIT} > limit]$; the value 1 indicates the NITRATE-N + NITRITE-N level exceeds 1mg/1. Lastly, we use a binary variable as control that measures whether a district experiences low levels of dissolved oxygen than the necessary threshold. The Iverson notation for this variable is $1[\overline{D.O.} < threshold]$.

The use of binary variables, instead of raw pollution-measuring continuous variables, offers three distinct advantages. First, they enable a clear distinction between districts experiencing unsafe pollution levels and those that don't, based on the established safety limits for pollutant concentrations. Second, when it comes to interpreting the pollution variable, consideration is only necessary for the units in which the dependent variable is measured and not for the pollution-measuring variables. For example, a one MPN increase of faecal coliform in 100 ml of water might not lead to discernible changes in test scores. Lastly, identification of the effects of pollutants in a regression model can be challenging at extremely high values of the pollution-measuring continuous variables. This complexity arises because districts with the most significant river pollution are often both densely populated and economically advanced. It is easier for such districts to insure themselves against high levels of pollution by establishing superior water filtration systems.

In Table 1, district-level mean faecal coliform, mean Nitrate-N + Nitrite-N, mean Biochemical Oxygen Demand (B.O.D.), and Mean pH are shown specifically to different monitored water sources. There are considerable variations in the means of the water quality measures. For example, mean faecal coliform is highest in lakeside districts. Mean Nitrate-N + Nitrite-N is highest in districts by the Ganges. Reading, Maths, and Writing test scores vary across the columns too. In lakeside districts, the mean scores appear to be the highest. The individual characteristics, such as age, gender, height, weight, family consumption levels do not vary

[10] MPN means "most probable number". Its limit is set at 2500 MPN/100 ml by Central Pollution Control Board (CPCB), India (2012). They inspected whether, in 100 milliliters of water, the most probable number of coliform was above 2500.

[11] *Hardness in drinking-water: Background document for development of WHO guidelines for drinking-water quality* (2010) is published by the World Health Organization

Table 1: Analytical Sample Means of Key Variables

| Variables | (1) River | (2) Ganges | (3) Yamuna | (4) Lake | (5) GW | (6) Trib. | (7) All |
|---|---|---|---|---|---|---|---|
| Mean faecal Coliform (MPN/100 ml) † | 2.27 | 2.44 | 0.06 | 6.25 | 1.69 | 1.77 | 1.15 |
| Mean Nitrate-N/Nitrite-N (mg/l) | 1.13 | 1.22 | 0.33 | 0.49 | 1.05 | 0.65 | 0.89 |
| Mean Biochemical Oxygen Demand (mg/l) | 4.23 | 3.77 | 5.88 | 7.53 | 3.61 | 4.68 | 4.86 |
| Mean Dissolved Oxygen (mg/l) | 7.08 | 7.29 | 6.27 | 6.15 | 7.00 | 6.94 | 6.96 |
| Mean pH | 7.75 | 7.78 | 7.57 | 7.71 | 7.67 | 7.62 | 7.66 |
| $1[Faecal\ Coliform > 2500MPN/100ml]$ | 0.84 | 0.83 | 1.00 | 0.84 | 0.68 | 0.59 | 0.72 |
| $1[Nitrate-N+Nitrite-N > 1mg/l]$ | 0.78 | 0.76 | 1.00 | 0.81 | 0.64 | 0.70 | 0.77 |
| $1[B.O.D > 3mg/l]$ | 0.57 | 0.53 | 1.00 | 0.62 | 0.40 | 0.32 | 0.43 |
| $1[D.O. < 4mg/l]$ | 0.25 | 0.19 | 0.49 | 0.44 | 0.20 | 0.23 | 0.23 |
| $1[pH < 6.5mg/l\ or\ pH > 8.5mg/l]$ | 0.90 | 1.00 | 1.00 | 1.00 | 1.00 | 0.95 | 0.96 |
| Reading Test Z-Score | 0.16 | 0.21 | -0.11 | 0.32 | 0.19 | 0.13 | 0.13 |
| Maths Test Z-Score | 0.19 | 0.22 | -0.09 | 0.45 | 0.26 | 0.21 | 0.20 |
| Writing Test Z-Score | 0.17 | 0.22 | -0.12 | 0.43 | 0.22 | 0.18 | 0.16 |
| Age | 9.51 | 9.53 | 9.51 | 9.59 | 9.52 | 9.49 | 9.48 |
| Sex - 1 if Male | 0.49 | 0.50 | 0.53 | 0.55 | 0.52 | 0.53 | 0.52 |
| 1 if Majority Religious Group | 0.52 | 0.53 | 0.64 | 0.56 | 0.48 | 0.51 | 0.53 |
| 1 if Minority Religious group | 0.47 | 0.47 | 0.35 | 0.44 | 0.52 | 0.48 | 0.47 |
| Anthropometry - height | 128.06 | 128.15 | 129.00 | 126.43 | 126.60 | 126.32 | 127.13 |
| Anthropometry - weight | 25.73 | 25.87 | 25.30 | 26.36 | 25.63 | 25.17 | 25.32 |
| 1 if HH per capita expenditure $\leq$ 25th ptile | 0.23 | 0.25 | 0.27 | 0.17 | 0.27 | 0.27 | 0.25 |
| 1 if HH per capita expenditure $\leq$ 50th ptile | 0.25 | 0.45 | 0.46 | 0.48 | 0.39 | 0.53 | 0.54 |
| 1 if HH per capita expenditure $\leq$ 75th ptile | 0.69 | 0.70 | 0.70 | 0.68 | 0.77 | 0.88 | 0.75 |
| School Distance (kilometres) | 1.56 | 1.56 | 1.58 | 1.66 | 0.68 | 1.54 | 1.52 |
| School hours/week | 30.73 | 30.73 | 33.64 | 27.73 | 29.40 | 29.43 | 30.13 |
| Private Tuition hours/week | 3.86 | 4.06 | 1.23 | 5.33 | 5.12 | 4.62 | 4.11 |
| Books Uniform Cost (Rupees) | 892.61 | 889.50 | 1026.96 | 996.14 | 657.36 | 734.91 | 844.25 |
| Short-term Morbidity (days) | 1.22 | 1.28 | 1.01 | 1.01 | 1.01 | 0.96 | 1.07 |
| 1 if Water is purified in HH* | 0.10 | 0.11 | 0.05 | 0.15 | 0.09 | 0.77 | 0.09 |
| 1 if HH has Indoor Piped Water Supply | 0.15 | 0.16 | 0.07 | 0.23 | 0.11 | 0.90 | 0.11 |
| 1 if HH has Water Drinking Vessel** | 0.71 | 0.69 | 0.76 | 0.76 | 0.70 | 0.68 | 0.71 |
| 1 if Always Handwash*** | 0.75 | 0.72 | 0.76 | 0.77 | 0.75 | 0.69 | 0.72 |
| $N$ | 576 | 532 | 155 | 206 | 769 | 738 | 1147 |

The Columns (1) to (5) present means of variables specific to groups of districts, defined by the types of water sources CPCB monitored for pollution in 2012: districts along Ganges and Yamuna rivers (col. 1), districts along the Ganges river only (col. 2), districts along the Yamuna river only (col. 3), districts where lake water was monitored (col. 4), districts where ground water was monitored (col. 5), districts where water from tributary rivers of Ganges and Yamuna was monitored (col. 6), all districts (col. 7). The sample of districts adjacent to rivers and that adjacent to tributaries overlap, since tributaries are also rivers. However, in the "river" sample, we include districts adjacent to major rivers, Yamuna and Ganges, which are not part of the "tributary" sample.

† Mean faecal Coliform (MPN/100 ml), reported in millions.

* Household purifies water by boiling, filtering, aquaguard, or chemicals.

**Household has water storage vessel.

***Members of the households always wash hands after defecation.

Table 2: Analytical Sample Means of Key Variables

| **Binary Indicators for Water Quality** 1 = Districts where CPCB Safety Standard not met | **Binary Indicators for Water Quality** 1 = Districts where CPCB Safety Standard not met (1) FCOLI* | (2) NIT* | (3) D.O.* | (4) B.O.D.* | (5) pH* |
|---|---|---|---|---|---|
| (1) FCOLI* | 1 | 0.63 | 1 | 0.96 | 0.74 |
| (2) NIT* | 0.65 | 1 | 0.79 | 0.61 | 0.72 |
| (3) D.O.* | 0.32 | 0.24 | 1 | 0.44 | 0.24 |
| (4) B.O.D.* | 0.58 | 0.36 | 0.83 | 1 | 0.44 |
| (5) pH* | 1 | 0.96 | 1 | 1 | 1 |
| **Key Variables:** | | | | | |
| Mean faecal Coliform (Millions MPN/100 mL) † | 1.61 | 1.55 | 4.99 | 2.66 | 1.19 |
| Mean Nitrate-N/Nitrite-N (mg/l) | 1.20 | 0.21 | 0.64 | 1.58 | 0.92 |
| Mean Biochemical Oxygen Demand (mg/l) | 5.78 | 4.36 | 11.57 | 8.15 | 4.95 |
| Mean Dissolved Oxygen (mg/l) | 6.56 | 7.10 | 3.91 | 5.95 | 6.94 |
| Mean pH | 7.65 | 7.69 | 7.55 | 7.74 | 7.69 |
| Reading Score | 0.16 | 0.05 | 0.14 | 0.11 | 0.13 |
| Maths Score | 0.21 | 0.14 | 0.21 | 0.11 | 0.18 |
| Writing Score | 0.18 | 0.12 | 0.09 | 0.08 | 0.15 |
| Age | 9.49 | 9.44 | 9.46 | 9.54 | 9.47 |
| Sex - Male | 0.50 | 0.51 | 0.51 | 0.55 | 0.51 |
| 1 if Majority Religious Group | 0.49 | 0.58 | 0.53 | 0.57 | 0.52 |
| 1 if Minority Religious Group | 0.50 | 0.42 | 0.46 | 0.43 | 0.48 |
| Anthropometry - height | 127.15 | 127.38 | 1216.87 | 127.16 | 127.01 |
| Anthropometry - weight | 25.37 | 25.35 | 25.49 | 25.53 | 25.34 |
| 1 if HH per capita expenditure $\leq$ 25th ptile | 0.25 | 0.26 | 0.13 | 0.21 | 0.26 |
| 1 if HH per capita expenditure $\leq$ 50th ptile | 0.48 | 0.51 | 0.39 | 0.44 | 0.51 |
| 1 if HH per capita expenditure $\leq$ 75th ptile | 0.72 | 0.76 | 0.66 | 0.70 | 0.75 |
| School Distance | 1.66 | 1.57 | 1.68 | 1.65 | 1.56 |
| School hours/week | 29.38 | 30.86 | 29.28 | 30.97 | 30.26 |
| Private Tuition hours/week | 4.42 | 3.30 | 4.31 | 3.09 | 4.15 |
| Books Uniform Cost | 857.11 | 873.16 | 1002.63 | 983.03 | 822.01 |
| Short-term Morbidity (days) | 1.13 | 1.08 | 0.83 | 1.19 | 1.08 |
| Water Purification** | 0.10 | 0.09 | 0.08 | 0.75 | 0.09 |
| Indoor Piped Drinking Water | 0.15 | 0.11 | 0.14 | 0.16 | 0.12 |
| Water Drinking Vessel*** | 0.79 | 0.66 | 0.73 | 0.77 | 0.71 |
| Handwash**** | 0.72 | 0.69 | 0.75 | 0.77 | 0.72 |
| *N* | 821 | 841 | 492 | 264 | 1111 |

† Mean faecal Coliform (MPN/100 ml), reported in millions.

* FCOLI = 1[Mean faecal Coliform > 2500 MPN/100 mL], reported in millions, NIT = 1[Mean Nitrate-N + Nitrite-N > 1 mg/l], D.O. = 1[Mean D.O. < 4 mg/l], B.O.D. = 1[Mean B.O.D > 3 mg/l], pH = 1[Mean pH < 6.5 mg/l or pH > 8.5 mg/l]

** Binary variable. 1 means household purifies water by boiling, filtering, aqua-guard, or chemicals.

*** Binary variable. 1 means household has water storage vessel.

**** Binary variable. 1 means Members of the households always wash hands after defecation.

much across the monitored water source categories. On the other hand, means of binary variables - indoor piped water supply show - varies between 0.05 and 0.77 (7 to 90%). "whether a household purifies the water" also varies between 9% to 77%. One of the main ways to prevent many diseases is washing hands after defecation (Curtis and Cairncross, 2003). "whether household members always wash hands after defecation" varies between 0.69 to 0.77, only by 8 percentage points.

Table 2 shows that when mean faecal coliform is above the safe level, reading, maths and writing scores are higher than those where mean Nitrate-N + Nitrite-N is above the safe level. Table 2 also shows variable means when district-average levels of dissolved oxygen, biochemical oxygen demand, and pH do not meet the safety levels. We do not see noteworthy variations in variable means across the water quality categories. Intriguingly, the rate of water purification in households stands at 0.75 when the biochemical oxygen demand is above its safe threshold; indicating that 75% of households treat their water before consumption. This is considerably higher than the portions of the households in the sample that purify their water when mean faecal coliform, mean Nitrate-N+Nitrite-N, and pH do not meet their safe levels.

We focus on the educational outcome of children who live in districts adjacent to the River Ganges or one of its tributaries in the Ganges Basin. The survey includes tests on reading skills, writing skills, and arithmetic knowledge. The tests were administered to all available children aged 8-11 in the household. Participant children were allowed to choose from 13 languages in which the tests were available. As Table 1 shows, we treat the test scores as continuous variables. The reading test is categorised into 5 levels (from level 0 to 4) based on the child's ability to read a short story. In the analytical sample, 12.45% of children cannot read the story (level 0), 11.88% can only recognise the letters (level 1), 17.96% can read some words (level 2), 16.27% can read paragraphs (level 3), and 41.44% can read the entire story (level 4). The writing test comprises 3 categories: 27.44% cannot write at all (level 0), 29.14% write with one or two mistakes (level 1), and 43.42% produce error-free writing (level 2). The maths test evaluates computational skills: 19.52% cannot recognise any numbers (level 0), 30.98% can recognise numbers (level 1), 24.47% can perform subtractions (level 2), and 25.04% can execute divisions correctly (level 3).

These tests were collaboratively developed with researchers from PRATHAM[12], India, and were pretested to ensure comparability across languages. This allows us to study the education outcomes of school children. PRATHAM (2021)'s tests are the same for all children whereas every state in India has its standard school curriculum. The test scores are treated as continuous variables and are standardised, allowing for comparison of the effects of water quality across tests both within and between pollution-affected and non-pollution-affected districts. Therefore, standardising the test scores allow us to difference in the position of students in the test score distribution caused by being in pollution-affected districts[13].

# 3 Empirical Model

The empirical model observes the effect of water quality on test scores (Equation 1). The analytical sample contains unique children $i = 1,2,3...n$ living in $k = 1,2,3,...39$ districts.

$$Z_{ik} = \alpha_{ik} + \mathbf{W}'\Theta + \mathbf{X}'\Gamma + \chi_k + \varepsilon_{ik} \tag{1}$$

$\mathbf{W}$ is the vector of water quality variables $W_k$ and they vary across districts. $\mathbf{X}$ is a vector of $X_{ik}$ control variables and $\chi_k$ are district dummy variables. We employ the same right-hand-side variables for each of the outcomes. $Z_{ik}$ represents the outcome[14].

The main treatment variables, $1[\overline{FCOLI} > limit]$ and $1[\overline{NIT} > limit]$ vary only between districts and not within each district. The baseline model that we introduce uses random intercept regression. $\varepsilon_{ik}$ is the error term defined at the individual level. $Z_{ik}$ indicates our set of dependent variables are nested within cluster $k$, with each district representing a separate cluster.

[12] PRATHAM is a non-governmental organization involved in assisting social science research. Please see more at PRATHAM, 2021.

[13] We treat the test scores as continuous due to the extensive set of covariates we utilise. When testing the robustness of our primary coefficient estimates adding more control variables in the model, using the scores as ordinal or binary variables leads to convergence issues, especially if the model is estimated using multinomial logistic/probit models. Similar to our approach, Chudgar and Quin (2012), Spears (2012), Vibhu and Ambrish (2015), and Singhal and Das (2019) treat the test scores as continuous variables in their OLS model estimations, suggesting that no insight is lost by treating these scores as continuous variables.

[14] The score levels of maths, reading, and writing tests correspond to different tasks of different levels of difficulty. For example, maths level '2' means the child could do subtraction problems, and level '3' means the child could do division problems.

Since $1[\overline{FCOLI} > limit]$ and $1[\overline{NIT} > limit]$ vary across districts, we can interpret the coefficient estimates of these two variables as the average decline in the position within the test score distribution that children experience. This decline can be attributed to living in a district with water sources having unsafe levels of either faecal coliform or Nitrate-N + Nitrite-N[15].

The economic intuition behind random-effects model is that the district-level errors are not necessarily affecting $Z_{ik}$ through the observed variables. Communities in a district can invest in water treatment plant and water supply networks to insure against pollution. The wealthier districts (more urbanized) would pool their resources to invest in better water supply networks to insure against water pollution (Sarker et al., 2021). Since water supply networks are monopolies requiring initial fixed investment, and marginal cost of water supply to additional households is low, the households in a district would have the same quality of water supply network available for them irrespective of individual household-level wealth and income. In other words, the rich and the poor participate in the same water distribution network and are subject to similar levels of water quality. So, the unobserved heterogeneity due to water supply characteristics of a district can be considered random intercepts ($E(\mathbf{X}|\chi_k) = 0$) for the households and are not likely to drive (or be driven by) the household-level observed variables in $\mathbf{X}$. If $E(\mathbf{X}|\chi_k) \neq 0$ then we would have to resort to fixed-effects estimation of Equation 1. Therefore, we model district-level exposure to water quality as random district-level effects[16].

We run diagnostic tests developed by Hausman (1978) and Schaffer and Stillman (2006), which show the that random-effects model is preferred to the fixed-effects model[17]. In addition, we utilize the Breusch and Pagan (1980) test to show that the random-effects model is

[15] For example, let us assume, $1[\overline{FCOLI} > limit]$'s statistically significant estimated effect is -0.015 on maths test score, then the interpretation is that due to living in a district with unsafe levels of faecal coliform in its water sources, on average the district children see a -0.015 standard deviations loss in their position in the maths test score distribution - or on average they would move to the left of the maths test distribution by 0.015 standard deviations.

[16] In less-developed rural areas where (publicly funded) water supply networks are not established and water treatment plants are privately owned, then the ability to insure against low water quality is not invariant at the community-level but at the household level, which has been controlled for using water-supply related controls in our model.

[17] Schaffer and Stillman (2006) provide a test of over-identifying restrictions in random-effects versus fixed-effects models. The fixed effects estimator uses the orthogonality conditions that $X_i$ are uncorrelated with the idiosyncratic error $\varepsilon_{ik}$, i.e., $E(X_{it} \times \varepsilon_{ik}) = 0$. The random effects estimator uses the additional orthogonality conditions that the $X_{ik}$ are uncorrelated with the group-specific error $\chi_k$ (the "random effect"), i.e., $E(X_{ik} \times \chi_k) = 0$. These additional orthogonality conditions are overidentifying restrictions that we tested. The rest results suggest considering a random-effects model.

favored over a simple Ordinary Least Squares (OLS) model. Furthermore, we employ various Likelihood-Ratio (LR) tests show a random-effects model is preferred to a pooled model with district dummy controls. Mixed-models are more flexible in terms of allowing the researcher to choose between a random-intercept or a random-slope model or both. We conduct Likelihood Ratio (LR) tests for mixed-models with multiple-level intercepts and/or random slopes[18]. Overall the results point toward applying a random intercept (district-level) specification. In addition, we prefer a random-effects model over a model with district fixed-effects. This is because the fixed-effects model can introduce multicollinearity between the district-level dummy variables and the main binary treatment variables.

The control variables for the baseline regression are cover groups of factors that influence education production of children: (i) individual and family characteristics such as age, sex, height, weight, household per-capita consumption in a year; (ii) education-related information such as the distance between home and school, hours spent at school per week, hours spent doing homework per week, hours of tutoring per week and whether books and uniform are provided by the school; (iii) short-term morbidity-related information such as whether the expenses of medical treatment was covered by medical insurance and the number of days the child was disabled in the last 30 days (from date of data collection); (iv) information on water source and hygiene such as whether the household possesses water storage vessel at home, whether the household gets indoor piped drinking water directly, whether water is purified through some filtration system and lastly, how often the household members wash hands after defecation. Analytical sample means of these variables are in Tables 1 and 2.

In addition to the primary district-level water variables, which indicate the presence of unsafe levels of faecal coliform and Nitrate-N + Nitrite-N, we include Mean pH in the vector $W_k$ from 1. We also add a binary indicator set to 1 if the average dissolved oxygen level (D.O.) in the district does not meet the required standard. Biochemical oxygen demand (B.O.D) indicates the oxygen consumed by microorganisms. When more microorganisms are present in the water decomposing waste matter and propagating, dissolved oxygen levels decrease. Consequently,

[18] We have three outcomes and multiple water source-specific samples (districts by lakes, districts by Ganges, districts by Yamuna and Ganges tributaries, etc.). We conduct LR tests for each test score $\times$ water-source sample.

these two variables are highly correlated (Jouanneau et al., 2014)[19].

The binary variables indicating unsafe levels of faecal coliform and Nitrate-N + Nitrite-N are correlated with D.O., B.O.D., and pH to some degree as they all reflect water quality. We do not know the functional relationships that may exist between each other. Overall, water quality falls when faecal coliform and Nitrate-N + Nitrite-N surpass the safety limits. In that case, the estimated effect of main water pollution measures may be overestimated because it would capture both the effect of overall water quality and the pollution contents. However, turbidity of the water also is associated with poor quality. Hence it is necessary to include variables controlling for the effect of Mean B.O.D., Mean pH, and Mean D.O. in Equation 1. We may have over-controlled the effect of water quality, in that case, the estimates of the effect of unsafe levels of faecal coliform and Nirtate-N + Nitrate-N can be seen as "lower-bound" estimates.

## 3.1 Identification

Equation 1 follows the structure of a simple education production function. The educational production function prevalent in the literature of education economics maps educational inputs onto the space of educational outcomes, such as test scores, class ranking of students, etc. (see Hoxby, 1996; Krueger, 1999; Pritchett and Filmer, 1999; Coates, 2003; Hanushek, 2010; Hanushek, 2020 and others). We assume that water quality levels are "predetermined" factors that enter the children's education production i.e. its effects precedes the education production and therefore, the error term $\varepsilon_{ik}$ is uncorrelated with water quality or $E(W_k|\varepsilon_{ik}) = 0$. This is a strong assumption but later we relax this assumption and introduce propensity score matching model to estimate a causal effect of $1[\overline{FCOLI} > limit]$ and $1[\overline{NIT} > limit]$ on test scores.

River pollution is the outcome tied to economic activities, population density, and geographic characteristics of an area (Suthar et al., 2010). However, schooling is governed by state policies and government mandates in India, i.e. all children have to attend schools (Chhokar, 2010).

[19] Only results in Tables 3, 4, and 5 include Mean B.O.D. Adding both measures of B.O.D and D.O. in regression specifications leads to coefficient estimates of these two variables having ambiguous signs. To avoid confusing results, we only include both Mean B.O.D. and Mean D.O. in Tables 3, 4, and 5.

The government provides funding to the schools, dictates school curricula and related policies (Weiner et al., 1991; Kingdon, 2007). The average quality of education and outreach at a district is not subject to the aggregate factors which may drive river pollution. However, average education outcomes of the children may be driven by river pollution and other aggregate factors. Pollution would enter *education production* through the channel of environmental quality and water quality on short-term and long-term health because health is directly related to water quality and health is also related productive outcomes like educational attainment.

CPCB uses a rigourous set of criteria to select monitoring pointsBoard (2019). So, these monitoring points were selected non-randomly. Non-random choice of monitoring stations leads to non-random selection of districts into our analytical sample. So, We average the pollutant measurements from all monitoring points at district levels. If the sample distribution of the pollutants is shifted to the right, given Central Pollution Control Board (CPCB), India (2012) monitors more polluted areas, then the sample mean could be higher than the effective mean of pollution. However, we are looking at binary indicators that reflect whether mean monitored pollution levels crossed the safety limits. As there are districts in the sample with pollution levels below the unsafe level, it appears unlikely that Central Pollution Control Board (CPCB), India (2012) only picked the most polluted parts of a river for monitoring. Moreover, in the pollution data, some monitors picked up no discernible levels of faecal coliform and Nitrate-N + Nitrite-N. Hence, the selection of monitoring locations is unlikely to threaten the validity of treatment effect of the pollutants.

For robustness checks, the vector $X_{ik}$ in Equation 1 is extended to capture the effect of teaching quality, educational expenditure and schooling quality, short-term morbidity, use of technology, and personal hygiene of the household members. As we do not have any variable reflecting long-term morbidity throughout the children's lives, which may be associated with river pollution, we resort to using district-level short-term morbidity as a control. The loss of learning each of the skills - maths, reading, and writing - cannot be the outcome of random instances of sickness. Short-term morbidity does not inform us of how prone are the children are to sickness. Prolonged consumption of poor-quality - with or without causing illness - may incur losses in cognitive abilities in children. The reading, writing, and maths tests given by

PRATHAM (2021) reflect the average cognitive abilities of the students. Mean district-level morbidity hence is supposed to capture the spikes in short-term morbidity for unforeseen reasons, and the overall health of the children in the district, leaving out the channel of loss of cognition in children due to the presence of high-level pollutants in drinking water.

We are interested in investigating the possible channel of the loss of cognitive abilities in due pollutant contents in drinking water. Thus we further show that interaction terms between $1[\overline{FCOLI} > limit]$ and binary variables describing water supply and storage choices of households are statistically robust. This development is meant to detect the channel where the water pollutants not captured through water supply system - which may or may not be equipped with a filtration system - affect cognitive abilities of the children. Although we control for the effect of district-level short-term morbidity, this channel is possibly enmeshed with other externalities that may come with river pollution. For example, consumption of fish from a polluted river may affect the cognitive abilities of children in the long run too (Singh and Soma, 2014). The use of polluted water in irrigation may be another such externality that bypasses the water supply channel (Lu et al., 2015; Nagpoore et al., 2020).

If the household head has a low educational level, and if the household has limited resources and lower income, children are likely to achieve lower educational outcomes. Conversely, a well-educated household head, abundant household resources, and a higher household income can lead to better educational results for children. If we factor in the significant impact of high levels of water pollution on education and income, children with lower educational outcomes may end up in a vicious cycle of poverty. These children might struggle with low incomes and lack the resources or ability to move away from districts with low water quality. In such a scenario, the current household head's lower investment in children's education might be linked to lower investment $(P_k)$ in his/her education when he/she was a child and therefore, $E(P_k|\varepsilon_{ik}) \neq 0$. In addition, the observational data used here does not include individual or household-level instruments that could be used to infer causation between poor water quality and educational outcomes.

We define a binary treatment variable $T_f$ in the following way.

$$T_f = \begin{cases} 1 & \text{if } faecal\ coliform > \text{limit} \\ 0 & \text{otherwise} \end{cases}$$

Therefore, we estimate "Average Treatment Effect on the Treated" (ATT), which measures the difference between expected test scores of children in high-pollution districts $T_f = 1$ versus a counterfactual outcome expressed as:

$$ATT_f = E[Z_1 - Z_0 | T_f = 1] = E[Z_1 | T_f = 1] - E[Z_0 | T_f = 1] \tag{2}$$

In Equation 2, $Z_0$ and $Z_1$ are outcomes of the non-treated ($T_f = 0$) and the treated ($T_f = 1$). The subscript $f$ expresses that the treatment is unsafe levels of faecal coliform. $E[Z_0|T_f = 1]$ is the counterfactual state that we do not observe and estimate. By extension, the average treatment effect on the treated is also applicable for unsafe levels of Nitrate-N + Nitrite-N. If $T_n$ holds 1 for district-level mean Nitrate-N + Nitrite-N to be over the safe level, and 0 otherwise, then $ATT_n = E[Z_1 - Z_0|T_n = 1] = E[Z_1|T_n = 1] - E[Z_0|T_n = 1]$. The subscript $n$ expresses that the treatment is unsafe levels of Nitrate-N + Nitrite-N. Identification is dependent on the assumption of conditional independence - if we control for the household and individual factors that drive educational outcomes, then the treatment effect can be considered random. For this non-experimental exercise, we use the widely-known propensity score matching (PSM) developed by Rosenbaum and Rubin (1983).[20]

Finally, we introduce an additional model to tackle the concern regarding the extent to which the impact of water quality was influenced by pollution originating from upstream districts. In this model, we employ district-level pollution as an instrumental variable, using the pollution levels of districts upstream and those sharing borders as counterparts. A comparable strategy is adopted by Do et al. (2018) to untangle localised unobserved variables from measurements of river water pollution. It's worth noting that pollution originating in upstream regions can negatively impact downstream environments and communities. The factors influencing this

[20] We implement propensity-score matching using the algorithm described in Chapter 24 of Cameron and Trivedi (2022).

upstream pollution are generally independent of the observed and unobserved factors that contribute to pollution in the downstream. So, for this analysis we update our initial model into the following:

$$Z_{ik} = \alpha_{ik} + \widehat{MeanFCOLI}_k + \widetilde{\mathbf{W}}'\Theta + \mathbf{X}'\Gamma + \chi_k + \varepsilon_{ik} \tag{3}$$

$$MeanFCOLI_k = \beta_1 + \widetilde{\mathbf{W}}'\Psi + \mathbf{X}'\Delta + upstream\_MeanFCOLI_k + \omega_k + u_{ik} \tag{4}$$

with the assumption that $E(upstream\_MeanFCOLI|\omega_k) = 0$. $\widetilde{\mathbf{W}}$ is the vector of water quality indicators except faecal coliform. Testing the validity of instruments becomes more complex with binary endogenous variables. Standard overidentification tests and tests for endogeneity might not apply in a straightforward way. Therefore, we use the district-level mean faecal coliform measures, $MeanFCOLI_k$ and $upstream\_MeanFCOLI_k$, instead of binary measures. Unlike $1[\overline{FCOLI} > limit]$, $\widehat{MeanFCOLI}_k$ cannot be interpreted in a way that makes economic sense. As an additional robustness check, this exercise serves to show if faecal coliform instrumented by its upstream measure still affects test scores, when it is disentangled from the district-level unobserved factors through instrumentation. For this development, we do lose some observations because not every district has an adjacent counterpart part district along the same river that has also been included in the IHDS survey by Desai and Vanneman (2015). For this part we use random-effects generalized 2SLS methods to estimate the instrumented model.

# 4 Results

The baseline regression results are in Tables 3, 4, and 5. These three tables present the estimated coefficients associated with the river pollution variables. Besides the water quality variables, the baseline regression includes control variables related to (1) individual characteristics of the children like age, sex, height, weight; (2) household characteristics, (3) schooling-related information, (4) household water sources and basic hygiene, and short-term morbidity.

Table 3: Baseline Regression - The Effect of Water Pollution on Reading Test Score

| | (1)<br>Reading<br>Score | (2)<br>Reading<br>Score | (3)<br>Reading<br>Score | (4)<br>Reading<br>Score | (5)<br>Reading<br>Score | (6)<br>Reading<br>Score |
|---|---|---|---|---|---|---|
| AGE | 0.0949 | 0.122 | 0.0980 | 0.0908 | 0.0913 | 0.120 |
| | (0.0252) | (0.0597) | (0.0354) | (0.0253) | (0.0356) | (0.0318) |
| FEMALE | 0.00724 | 0.0586 | 0.0229 | 0.0144 | 0.0138 | 0.0154 |
| | (0.0479) | (0.0641) | (0.0856) | (0.0596) | (0.0796) | (0.0519) |
| HEIGHT | 0.00275 | 0.00138 | -0.00244 | 0.00117 | -0.00141 | 0.000889 |
| | (0.00272) | (0.00562) | (0.00428) | (0.00233) | (0.00448) | (0.00257) |
| WEIGHT | 0.0140 | 0.00848 | 0.0198 | 0.0154 | 0.0221 | 0.0128 |
| | (0.00514) | (0.00915) | (0.00613) | (0.00562) | (0.00638) | (0.00670) |
| HH Con.$\leq$ 75th ptile. | -0.0125 | 0.216 | -0.0561 | 0.0953 | -0.0305 | 0.0147 |
| | (0.0720) | (0.0963) | (0.114) | (0.111) | (0.103) | (0.103) |
| HH Con.$\leq$ 50th ptile. | -0.0965 | -0.357 | -0.150 | -0.116 | -0.168 | -0.0951 |
| | (0.0673) | (0.139) | (0.0982) | (0.106) | (0.0930) | (0.132) |
| HH Con.$\leq$ 25th ptile. | -0.278 | -0.196 | -0.294 | -0.286 | -0.198 | -0.285 |
| | (0.0680) | (0.136) | (0.0814) | (0.132) | (0.109) | (0.137) |
| INDOOR PIPED WATER | 0.225 | 0.101 | 0.244 | 0.241 | 0.261 | 0.288 |
| | (0.0882) | (0.123) | (0.0955) | (0.114) | (0.0996) | (0.137) |
| $1[\overline{FCOLI} > limit]$ | -0.129 | -0.749 | -0.234 | -0.0689 | -0.245 | -0.0578 |
| | (0.0933) | (0.313) | (0.115) | (0.134) | (0.124) | (0.0814) |
| $1[\overline{NIT} > limit]$ | -0.0812 | -0.0459 | -0.0650 | -0.193 | -0.119 | -0.140 |
| | (0.104) | (0.103) | (0.170) | (0.0607) | (0.172) | (0.0999) |
| $1[\overline{D.O.} < threshold]$ | -0.0752 | -0.0169 | 0.131 | -0.171 | 0.0688 | -0.0318 |
| | (0.0987) | (0.327) | (0.0896) | (0.203) | (0.138) | (0.165) |
| Mean B.O.D | 0.00291 | 0.00647 | 0.0190 | 0.0312 | 0.00126 | 0.00130 |
| | (0.00434) | (0.00925) | (0.00805) | (0.0233) | (0.0255) | (0.00375) |
| Mean pH | -0.160 | -1.603 | -0.171 | -0.167 | 0.0684 | -0.233 |
| | (0.123) | (0.613) | (0.109) | (0.197) | (0.177) | (0.198) |
| $N$ | 1147 | 206 | 532 | 769 | 576 | 738 |
| Overall $R^2$ | 0.27 | 0.33 | 0.30 | 0.53 | 0.31 | 0.51 |
| Sample | All | Lake | Ganges | GW | River | Trib. |

Robust standard errors clustered at district level in parentheses. FCOLI = Faecal Coliform and NIT = Nitrate-N + Nitrite

- HH Con. = Household Consumption per capita. ptile = perccentile. GW = Ground Water. Trib. = Tributaries.
- **Pollutants**: **FCOLI** = faecal Coliform; **NIT** = Nitrate-N + Nitrite-N; **D.O.** = Dissolved Oxygen; **Mean B.O.D.** numerical, mean Biochemical Oxygen Demand; **Mean pH** numerical, Mean pH level.
- **Explanatory variables not reported** : Numerical variables such as "hours spent at school per week", "hours spend doing homework per week", "hours spent being tutored per week", "distance from school to home", "number of days the child spent disabled because of short-term morbidity in the last 30 days". Binary Variables such as "Rupees spent on books and uniform > Rs. 500", "1 = water storage vessel available at home", "1 = water is purified at home though some mode of filtration or boiling", "1 = household members always wash hands after defecation".

The baseline regression results in Tables 3, 4, and 5 can be combined to provide a picture of the negative impact of river pollution on children's test outcomes. When all the districts are considered - Column 1 in each of the three Tables - the pollution variables do not appear to generate a statistically significant effect on the test scores[21]. Only the sample of Ganges and River unsafe levels of faecal coliform generate a statistically significant negative impact[22]. The largest impact of faecal coliform is on writing test and the smallest on reading when the sample "river" and "Ganges" are considered (Columns 1 and 5 in Tables 3, 4, and 5). Overall, faecal coliform has a negative impact on test outcomes. Unsafe levels of Nitrate-N + Nitrite-N only has a significant impact on reading tests when *ground water* districts are considered. Among other variables, age, height, and weight have some estimated positive impact on the test scores as expected. Binary indicators of household consumption is coded 1 if per-capita consumption expenditure of household is at the 25th, 50th, and 75th percentile of the distribution or below. The estimated effects of these variables, when statistically significant, are negative.

Having an indoor piped water supply is also estimated to have a positive impact on children's reading test scores (Column 1, and 3 to 6 in Table 3), and also on Maths and Reading test scores in districts near tributaries (Column 6 in Table 4 and in Table 5). The differences in the estimated results across the types of monitoring at the level of districts are also interesting. For example, in districts where groundwater and nearby tributaries were monitored for pollution, the effect of unsafe levels of faecal coliform and Nitrate-N + Nitrite are statistically indistinguishable from zero[23]. We explore if the interaction between unsafe levels of faecal coliform and households having indoor piped water supply has any statistically significant effect. Although indoor piped water has little effect directly on test scores, Column 6, Table S.15 shows that in *river* districts the positive effect of indoor piped water (+0.818) on writing score is almost fully negated by its interaction with the faecal coliform variable (-0.803). Therefore, we see some evidence that faecal coliform can negatively affect cognitive abilities of children

[21] We want to remind the readers that Central Pollution Control Board (CPCB) of India monitored groundwater and lakes in some districts. We consider all districts where any water source is monitored and which are in states through which the river Ganges flows through.

[22] The sample of districts near rivers include those districts adjacent to Ganges, Yamuna, and tributaries of Ganges.

[23] We cannot provide estimates separately for the districts adjacent to the river Yamuna where its water was tested for pollution because Nitrate-N + Nitrite-N and faecal coliform have no variation for those districts.

Table 4: Baseline Regression - The Effect of Water Pollution on Maths Test Score

| | (1)<br>Score | (2)<br>Score | (3)<br>Score | (4)<br>Score | (5)<br>Score | (6)<br>Score |
|---|---|---|---|---|---|---|
| AGE | 0.0667 | 0.0231 | 0.0999 | 0.0689 | 0.0875 | 0.0653 |
| | (0.0256) | (0.0411) | (0.0468) | (0.0325) | (0.0448) | (0.0241) |
| FEMALE | -0.0685 | 0.0543 | -0.0294 | -0.0553 | -0.0306 | -0.0458 |
| | (0.0414) | (0.154) | (0.0783) | (0.0643) | (0.0753) | (0.0719) |
| HEIGHT | 0.00394 | 0.0149 | -0.000741 | 0.00267 | 0.000194 | 0.00473 |
| | (0.00281) | (0.00295) | (0.00427) | (0.00353) | (0.00406) | (0.00329) |
| WEIGHT | 0.0148 | 0.00479 | 0.0222 | 0.0124 | 0.0241 | 0.0130 |
| | (0.00645) | (0.00700) | (0.00659) | (0.00884) | (0.00623) | (0.00891) |
| HH Con.$\leq$ 25th ptile. | -0.259 | -0.474 | -0.370 | -0.259 | -0.273 | -0.226 |
| | (0.0898) | (0.203) | (0.0675) | (0.127) | (0.0988) | (0.131) |
| HH Con.$\leq$ 50th ptile. | -0.0245 | -0.0155 | -0.0206 | -0.0489 | -0.0365 | -0.0000922 |
| | (0.0969) | (0.127) | (0.150) | (0.128) | (0.137) | (0.141) |
| HH Con.$\leq$ 75th ptile. | -0.246 | -0.115 | -0.379 | -0.250 | -0.315 | -0.238 |
| | (0.0919) | (0.133) | (0.152) | (0.106) | (0.144) | (0.0976) |
| INDOOR PIPED WATER | 0.138 | 0.169 | 0.0510 | 0.158 | 0.0687 | 0.220 |
| | (0.0896) | (0.227) | (0.140) | (0.106) | (0.133) | (0.0799) |
| $1[\overline{FCOLI} > limit]$ | -0.146 | -0.669 | -0.322 | -0.0913 | -0.342 | -0.131 |
| | (0.128) | (0.311) | (0.132) | (0.126) | (0.138) | (0.0911) |
| $1[\overline{NIT} > limit]$ | -0.0493 | 0.112 | 0.0868 | 0.0168 | 0.0282 | -0.0912 |
| | (0.160) | (0.175) | (0.107) | (0.114) | (0.111) | (0.127) |
| $1[\overline{D.O.} < threshold]$ | -0.0545 | -0.0524 | 0.115 | -0.137 | 0.0611 | 0.00650 |
| | (0.163) | (0.357) | (0.167) | (0.230) | (0.156) | (0.189) |
| Mean B.O.D. | 0.000479 | 0.000237 | 0.0123 | 0.0176 | -0.00489 | -0.00351 |
| | (0.00391) | (0.0117) | (0.0161) | (0.0237) | (0.0285) | (0.00374) |
| Mean pH | -0.372 | -1.468 | -0.335 | -0.326 | -0.111 | -0.488 |
| | (0.196) | (0.484) | (0.178) | (0.262) | (0.238) | (0.172) |
| $N$ | 1147 | 206 | 532 | 769 | 576 | 738 |
| Overall $R^2$ | 0.28 | 0.56 | 0.34 | 0.27 | 0.33 | 0.26 |
| Sample | All | Lake | Ganges | GW | River | Trib. |

Robust standard errors clustered at district level in parentheses.

- HH Con. = Household Consumption per capita. ptile = perccentile. GW = Ground Water. Trib. = Tributaries.
- **Pollutants**: **FCOLI** = faecal Coliform; **NIT** = Nitrate-N + Nitrite-N; **D.O.** = Dissolved Oxygen; **Mean B.O.D.** numerical, mean Bio-chemical Oxygen Demand; **Mean pH** numerical, Mean pH level.
- **Explanatory variables not reported**: Numerical variables such as "hours spent at school per week", "hours spend doing homework per week", "hours spent being tutored per week", "distance from school to home", "number of days the child spent disabled because of short-term morbidity in the last 30 days". Binary Variables such as "Rupees spent on books and uniform > Rs. 500", "1 = water storage vessel available at home", "1 = water is purified at home though some mode of filtration or boiling", "1 = household members always wash hands after defecation".

measured in test scores even when households get indoor piped water supply.

Results in columns 3 and 5 in Table 4 are based on districts along Ganges and where the groundwater was monitored. Comparison across the districts grouped by water sources where pollution was monitored the Tables 3, 4, and 5 support that the impact of unsafe levels of faecal coliform is primarily driven by the pollution in the river Ganges. Our other binary variable of interest about Nitrate-N + Nitrite-N has an only significant impact on reading test scores when the districts where groundwater is monitored are chosen.

The baseline regression results are estimated by including both variables measuring D.O. and B.O.D. in the regression equation. Since both variables deal with oxygen content in the water, the first expresses the availability for dissolved oxygen the latter expresses the dissolved oxygen demanded by microorganisms in the water (Jouanneau et al., 2014), we keep only $1[\overline{D.O.} < threshold]$ in the regression equation starting with Table 6 and skip B.O.D.

Next, we look at the impact faecal coliform and Nitrate-N + Nitrite-N have on the boys versus girls in Table 6. Most of the columns in this Table do not provide estimates that are statistically distinguishable from zero. Comparison in the effect of $1[\overline{FCOLI} > limit]$ is only possible between Column 9 and Column 12, where it has a less than 0.095 standard deviations greater estimated effect on boys in writing tests. This shows that we cannot assume the effect of poor water quality should be homogeneous across genders[24].

We additionally check if in the girls in the sample received disproportionately smaller investment in their education, and if poor water quality and water pollution mitigating technology adoption differentially affected them compared to the boys in the sample. In Tables, S.13 and S.14, we include some interaction terms to check for such possibilities. The estimated effect of the interaction terms between being female and faecal coliform being over safety level, cost of books and uniform incurred by the household, and lastly, whether household has indoor pump can be seen in Table S.13. Although the interaction effect of *female* and *cost of books and uniform in 1000 Rupees* are statistically significant in Column 7, 10, and 11, we cannot interpret

[24] The analytical sample means in Table S.3 show that boys do not consistently outperform girls in tests across districts with unsafe pollutant levels. Yet, in districts with safe levels of both pollutants, boys typically score higher. This disparity may arise because areas with safe faecal coliform levels tend to be rural, where girls might face more discrimination in educational investment and more barriers to education.

Table 5: Baseline Regression - The Effect of Water Pollution on Writing Test Score

| | (1) Score | (2) Score | (3) Score | (4) Score | (5) Score | (6) Score |
|---|---|---|---|---|---|---|
| AGE | 0.0951 | 0.0429 | 0.114 | 0.106 | 0.103 | 0.128 |
| | (0.0281) | (0.0541) | (0.0434) | (0.0313) | (0.0421) | (0.0374) |
| FEMALE | 0.0536 | 0.140 | 0.0266 | 0.0717 | 0.00104 | 0.101 |
| | (0.0348) | (0.0829) | (0.0607) | (0.0424) | (0.0609) | (0.0478) |
| HEIGHT | 0.00206 | 0.00317 | 0.00217 | 0.00367 | 0.00342 | 0.00103 |
| | (0.00278) | (0.00819) | (0.00399) | (0.00256) | (0.00408) | (0.00313) |
| WEIGHT | 0.00759 | 0.0120 | 0.00544 | 0.00378 | 0.00820 | 0.00161 |
| | (0.00507) | (0.00883) | (0.00724) | (0.00525) | (0.00775) | (0.00614) |
| HH Con.$\leq$ 25th ptile. | -0.326 | -0.586 | -0.344 | -0.280 | -0.261 | -0.288 |
| | (0.0952) | (0.294) | (0.0985) | (0.123) | (0.123) | (0.127) |
| HH Con.$\leq$ 50th ptile. | -0.0394 | -0.0116 | -0.168 | -0.0335 | -0.153 | -0.0539 |
| | (0.0613) | (0.190) | (0.0968) | (0.0912) | (0.0869) | (0.0858) |
| HH Con.$\leq$ 75th ptile. | -0.0342 | 0.0235 | -0.132 | -0.0278 | -0.0577 | 0.0335 |
| | (0.0865) | (0.138) | (0.0736) | (0.104) | (0.0898) | (0.132) |
| INDOOR PIPED WATER | 0.168 | -0.0467 | 0.0863 | 0.125 | 0.104 | 0.339 |
| | (0.0888) | (0.140) | (0.110) | (0.114) | (0.103) | (0.126) |
| $1[\overline{FCOLI} > limit]$ | -0.170 | -0.341 | -0.351 | 0.00234 | -0.364 | -0.0119 |
| | (0.110) | (0.326) | (0.178) | (0.136) | (0.183) | (0.154) |
| $1[\overline{NIT} > limit]$ | 0.109 | -0.0870 | 0.0851 | 0.00774 | 0.0307 | 0.0798 |
| | (0.149) | (0.206) | (0.172) | (0.0932) | (0.186) | (0.136) |
| $1[\overline{D.O.} < threshold]$ | -0.137 | -0.116 | -0.0176 | -0.218 | -0.0700 | -0.147 |
| | (0.107) | (0.377) | (0.142) | (0.110) | (0.162) | (0.127) |
| Mean B.O.D. | 0.00236 | 0.0156 | 0.0183 | 0.0175 | 0.00139 | 0.000363 |
| | (0.00280) | (0.0112) | (0.00758) | (0.0220) | (0.0249) | (0.00248) |
| Mean pH | -0.111 | -0.627 | -0.125 | 0.0458 | 0.108 | -0.233 |
| | (0.0948) | (0.520) | (0.138) | (0.174) | (0.177) | (0.155) |
| $N$ | 1147 | 206 | 532 | 769 | 576 | 738 |
| Overall $R^2$ | 0.20 | 0.31 | 0.26 | 0.31 | 0.44 | 0.23 |
| Sample | All | Lake | Ganges | GW | River | Trib. |

Robust standard errors clustered at district level in parentheses.

- HH Con. = Household Consumption per capita. ptile = perccentile. GW = Ground Water. Trib. = Tributaries.
- **Pollutants**: **FCOLI** = faecal Coliform; **NIT** = Nitrate-N + Nitrite-N; **D.O.** = Dissolved Oxygen; **Mean B.O.D.** numerical, mean Biochemical Oxygen Demand; **Mean pH** numerical, mean pH level.
- **Explanatory variables not reported** : Numerical variables such as "hours spent at school per week", "hours spend doing homework per week", "hours spent being tutored per week", "distance from school to home", "number of days the child spent disabled because of short-term morbidity in the last 30 days". Binary Variables such as "Rupees spent on books and uniform > Rs. 500", "1 = water storage vessel available at home", "1 = water is purified at home though some mode of filtration or boiling", "1 = household members always wash hands after defecation".

Table 6: Impact of Water Pollutants - Differences between Genders

| **All Districts** | (1) Score Reading | (2) Score Maths | (3) Score Writing | (4) Score Reading | (5) Score Maths | (6) Score Writing |
|---|---|---|---|---|---|---|
| $1[\overline{FCOLI} > limit]$ | -0.0726 | -0.284 | -0.112 | -0.128 | -0.0508 | -0.110 |
| | (0.104) | (0.176) | (0.116) | (0.106) | (0.119) | (0.159) |
| $1[\overline{NIT} > limit]$ | -0.192 | -0.174 | -0.0387 | -0.0833 | 0.0943 | 0.116 |
| | (0.0867) | (0.196) | (0.0981) | (0.141) | (0.144) | (0.155) |
| $1[\overline{D.O.} < threshold]$ | -0.114 | 0.00571 | -0.0914 | 0.0379 | -0.0609 | -0.180 |
| | (0.0983) | (0.155) | (0.100) | (0.109) | (0.137) | (0.118) |
| Mean pH | -0.102 | -0.190 | -0.0373 | -0.199 | -0.526 | -0.242 |
| | (0.123) | (0.245) | (0.0806) | (0.150) | (0.172) | (0.146) |
| $N$ | 592 | 592 | 592 | 555 | 555 | 555 |
| Gender | Male | Male | Male | Female | Female | Female |
| Overall $R^2$ | 0.30 | 0.27 | 0.27 | 0.19 | 0.26 | 0.29 |
| **Districts near Rivers** | (7) Score Reading | (8) Score Maths | (9) Score Writing | (10) Score Reading | (11) Score Maths | (12) Score Writing |
| $1[\overline{FCOLI} > limit]$ | 0.0329 | -0.183 | -0.464 | -0.534 | -0.582 | -0.369 |
| | (0.164) | (0.165) | (0.216) | (0.105) | (0.153) | (0.182) |
| $1[\overline{NIT} > limit]$ | 0.0214 | 0.151 | -0.0944 | -0.231 | -0.0863 | 0.153 |
| | (0.149) | (0.113) | (0.203) | (0.237) | (0.162) | (0.202) |
| $1[\overline{D.O.} < threshold]$ | -0.171 | -0.0856 | 0.0712 | 0.281 | 0.155 | -0.159 |
| | (0.187) | (0.200) | (0.223) | (0.174) | (0.185) | (0.211) |
| Mean pH | -0.120 | -0.118 | 0.130 | 0.190 | -0.149 | 0.0942 |
| | (0.242) | (0.293) | (0.210) | (0.189) | (0.246) | (0.164) |
| $N$ | 285 | 285 | 285 | 291 | 291 | 291 |
| Gender | Male | Male | Male | Female | Female | Female |
| Overall $R^2$ | 0.35 | 0.36 | 0.27 | 0.31 | 0.34 | 0.38 |

Robust standard errors clustered at district level in parentheses.

Pollutants: FCOLI = faecal coliform, NIT = Nitrate-N + Nitrite-N, D.O. = Dissolved Oxygen

- **Explanatory variables not reported** : Numerical variables such as Age, Height, Weight, "hours spent at school per week", "hours spend doing homework per week", "hours spent being tutored per week", "distance from school to home", "number of days the child spent disabled because of short-term morbidity in the last 30 days". Binary Variables such as Sex, "Rupees spent on books and uniform $>$ Rs. 500", "household consumption per capita $\leq$ 25th percentile", "household consumption $\leq$ 50th percentile", "household consumption $\leq$ 75th percentile", "1 = water storage vessel available at home", "1 = water is purified at home though some mode of filtration or boiling", "1 = household members always wash hands after defecation".

them because the main effect of *female* are not statistically significant in these columns. We explore some interaction between *female* and water availability and water purification related controls in Table S.14. However, most of the estimated coefficients of these interaction terms are statistically indistinguishable from zero. It is possible that girls receive disproportionately less attention and investment by households when it comes to their education and in the same way, are more affected due to changes in water availability and exposure to water pollution but our regressions discussed in Table S.13 and S.14 do not find enough statistical evidence to support that.

IHDS (2011-12) data also provides religious and caste categories. Access to water supply and many public goods can be heterogeneous across different religious communities and castes (Hoff, 2016). However, splitting the samples based on religion/caste identities leaves small numbers of observations which produce mostly null results and so do not allow us to observe whether there is heterogeneity across religious or caste groups in the effect of faecal coliform and Nitrate-N + Nitrite-N[25]. Table S.4 shows whether the effect of $1[\overline{FCOLI} > limit]$ varies across states. In this Table, the coefficient for $1[\overline{NIT} > limit]$ for the sample of West Bengal is not identified as it has no variations in that state.

## 4.1 Robustness Checks

We extend the scope of the baseline regression in terms of controlling for possible unobserved effects by adding more variables on the right-hand side of Equation 1. The baseline regression includes a vector of control variables covering individual characteristics, household characteristics, water source information, short-term morbidity information, and school-related information, denoted by $X'_{ik}\Gamma$. We check the robustness of the effects of water quality variables in several ways. In the first, we include more variables in $X'_{ik}\Gamma$ that cover more factors related to individual characteristics, household characteristics, water source information, short-term morbidity, and schooling[26]. The results in Tables 7 show if the effects of unsafe levels of faecal

[25]The six religious groups and castes have very different social statuses and relations with one another. Joining multiple groups to increase the number of observations in each sample can give us misleading conclusions.

[26]The additional control variables cover more information. We include dummy variables (school-type dummy variables (EGS, Government, Government-aided, Private, Convent, Islamic school or "Madrassa", Other/Open

Table 7: Robustness Check with Additional Education-related and Short-term Morbidity-related Controls

| | (1) Reading Score | (2) Maths Score | (3) Writing Score | (4) Reading Score | (5) Maths Score | (6) Writing Score |
|---|---|---|---|---|---|---|
| $1[\overline{FCOLI} > limit]$ | -0.0435 | -0.196 | -0.113 | -0.297 | -0.0372 | -0.356 |
| | (0.0671) | (0.141) | (0.0839) | (0.130) | (0.121) | (0.182) |
| $1[\overline{NIT} > limit]$ | -0.164 | -0.0538 | -0.00910 | 0.114 | 0.0259 | 0.0590 |
| | (0.0792) | (0.171) | (0.0754) | (0.0952) | (0.0916) | (0.177) |
| $1[\overline{D.O.} < threshold]$ | -0.0319 | 0.0713 | -0.0661 | -0.00994 | -0.156 | -0.0722 |
| | (0.0971) | (0.162) | (0.101) | (0.136) | (0.115) | (0.205) |
| Mean pH | 0.0276 | 0.217 | -0.237 | -0.0533 | -0.0313 | 0.175 |
| | (0.0988) | (0.164) | (0.129) | (0.202) | (0.0932) | (0.191) |
| School distance | -0.0162 | -0.0218 | 0.0199 | 0.0105 | -0.00142 | 0.0180 |
| | (0.0121) | (0.0176) | (0.0101) | (0.0154) | (0.0132) | (0.0191) |
| School hrs/week | -0.00590 | -0.0138 | -0.00482 | -0.00288 | -0.00991 | -0.0192 |
| | (0.00383) | (0.00447) | (0.00385) | (0.00451) | (0.00484) | (0.00567) |
| Homework hrs/week | 0.0259 | 0.0277 | 0.0272 | 0.0276 | 0.0290 | 0.0311 |
| | (0.00506) | (0.00750) | (0.00577) | (0.00684) | (0.00443) | (0.00616) |
| Pvt. Tuition hrs/week | 0.0108 | 0.0187 | 0.0214 | 0.0249 | 0.0251 | 0.0329 |
| | (0.00590) | (0.00893) | (0.00877) | (0.0112) | (0.00751) | (0.0119) |
| Cost Books, uniform | 0.323 | 0.269 | 0.222 | 0.176 | 0.326 | 0.245 |
| | (0.0570) | (0.0796) | (0.0539) | (0.0949) | (0.0554) | (0.0889) |
| STM days disabled† | 0.00610 | -0.0155 | -0.00430 | 0.0126 | -0.0272 | -0.0258 |
| | (0.0131) | (0.0163) | (0.0144) | (0.0246) | (0.00937) | (0.0210) |
| Indoor Piped Water | 0.109 | -0.0764 | 0.0510 | -0.202 | 0.0267 | -0.0852 |
| | (0.0831) | (0.0960) | (0.0710) | (0.108) | (0.0842) | (0.0884) |
| 1 to 4 years of Edu. | 0.646 | 0.737 | 0.577 | 0.662 | 0.486 | 0.571 |
| | (0.117) | (0.194) | (0.0888) | (0.0898) | (0.121) | (0.157) |
| $N$ | 1147 | 576 | 1147 | 576 | 1147 | 576 |
| Sample | All | River | All | River | All | River |
| Overall $R^2$ | 0.30 | 0.27 | 0.27 | 0.19 | 0.26 | 0.29 |

- Robust standard errors clustered at district level in parentheses.
- Pollutants: FCOLI = faecal coliform, NIT = Nitrate-N + Nitrite-N, D.O. = Dissolved Oxygen.
  †STM = short-term morbidity.
- **Explanatory variables not reported** :Numerical variables such as Age, Sex, Height, Weight, "household consumption per capita $\leq$ 25th percentile", "household consumption $\leq$ 50th percentile","household consumption $\leq$ 75th percentile", "1 = water storage vessel available at home", "1 = water is purified at home though some mode of filtration or boiling", "1 = household members always wash hands after defecation".
- **Additional Controls for Robustness checks**: Private Tuition child receives hours/week, Short-term morbidity expenditure, 1 = Water availability is normal/adequate, Completed Years of schooling, 1 = Primary respondent of household owns mobile, 1 = Primary respondent of household uses a computer, Short-term morbidity - total cost, short-term morbidity - number of days ill in the last 30 days, Number of days with fever in the last 30 days, Number of days with cough in the last 30 days, Cost of treatment - travelling to health centre, cost of treatment - tests, medicines, miscellaneous.

Table 8: Robustness Check with Teaching quality Controls

| | (1) Reading Score | (2) Maths Score | (3) Writing Score | (4) Reading Score | (5) Maths Score | (6) Writing Score |
|---|---|---|---|---|---|---|
| $1[\overline{FCOLI} > limit]$ | -0.0459 | -0.150 | -0.132 | -0.294 | -0.0382 | -0.359 |
| | (0.0864) | (0.174) | (0.0820) | (0.132) | (0.146) | (0.210) |
| $1[\overline{NIT} > limit]$ | -0.161 | -0.0611 | -0.00779 | 0.0772 | 0.0259 | 0.0393 |
| | (0.0817) | (0.157) | (0.0803) | (0.0664) | (0.102) | (0.156) |
| $1[\overline{D.O.} < threshold]$ | 0.0130 | 0.145 | -0.0150 | 0.131 | -0.115 | 0.0826 |
| | (0.0881) | (0.163) | (0.0938) | (0.108) | (0.121) | (0.197) |
| Mean pH | 0.0819 | 0.276 | -0.227 | -0.0393 | -0.0350 | 0.224 |
| | (0.0945) | (0.153) | (0.107) | (0.118) | (0.122) | (0.201) |
| T Fair | -0.146 | -0.153 | -0.163 | -0.203 | 0.00382 | 0.0135 |
| | (0.0863) | (0.112) | (0.0963) | (0.131) | (0.0886) | (0.156) |
| PTA Participation | 0.0713 | 0.0471 | 0.138 | 0.277 | 0.0936 | 0.233 |
| | (0.0773) | (0.0812) | (0.0687) | (0.0743) | (0.0802) | (0.0881) |
| T Biased | -0.0996 | -0.184 | 0.0839 | -0.0448 | 0.00904 | 0.438 |
| | (0.117) | (0.213) | (0.1000) | (0.147) | (0.127) | (0.182) |
| Local T | 0.152 | 0.212 | 0.175 | 0.211 | 0.174 | 0.167 |
| | (0.0489) | (0.0855) | (0.0689) | (0.0838) | (0.0837) | (0.115) |
| Female T | 0.0490 | -0.0568 | 0.0438 | 0.0328 | 0.0421 | -0.134 |
| | (0.0434) | (0.0513) | (0.0634) | (0.0838) | (0.0738) | (0.0711) |
| T Attendance Regular | 0.0824 | 0.170 | 0.0201 | 0.116 | 0.0494 | 0.101 |
| | (0.0583) | (0.0917) | (0.0751) | (0.0826) | (0.0791) | (0.0784) |
| S Admission difficult | -0.0590 | -0.134 | 0.101 | 0.0412 | 0.0649 | -0.0115 |
| | (0.0908) | (0.112) | (0.0966) | (0.161) | (0.0892) | (0.128) |
| $N$ | 1147 | 576 | 1147 | 576 | 1147 | 576 |
| Sample | All | River | All | River | All | River |

- Robust standard errors clustered at district level in parentheses.
- T = teacher. S = School. PTA = Parent-Teacher Association. FCOLI = faecal coliform, NIT = Nitrate-N + Nitrite-N, D.O. = Dissolved Oxygen
- The regression specifications corresponding the results in columns 1 to 6 include all explanatory variables used for results in Table 7

Table 9: Average Treatment Effect on the Treated

| | (1) Reading Score | (2) Maths Score | (3) Writing Score | (4) Reading Score | (5) Maths Score | (6) Writing Score |
|---|---|---|---|---|---|---|
| $T_f$ (1 vs. 0) | -0.0882 | -0.265 | -0.143 | | | |
| | (0.0412) | (0.0762) | (0.0120) | | | |
| $T_n$ (1 vs. 0) | | | | -0.314 | -0.256 | -0.119 |
| | | | | (0.0648) | (0.0825) | (0.0844) |
| $N$ | 1147 | 1147 | 1147 | 1147 | 1147 | 1147 |

- Abadie and Imbens (2016) robust standard errors in parentheses.
- $T_f$ = 1 means that the household is in district that received the treatment of exposure to unsafe levels of faecal coliform and $T_f$ =0 means untreated. $T_n$ = 1 means that the household is in district that received the treatment of exposure to unsafe levels of Nitrate-N + Nitrite-N and $T_n$ =0 means untreated.
- Average treatment effect on the treated has been estimated by propensity-score matching. We consider a logit treatment model. Conditioning variables in the treatment model: Demographic identities, age, height, weight, consumption expenditure by households, and individual-level variables: household per-capita income, school distance, school hours/week, homework hours/week, private tuition hours/week, expenditure on books and uniform, short-term morbidity (days of disability in the previous thirty days before the survey interview), Binary: whether the household boils water for purification (1=yes), whether household members wash hands after defecation (1=yes).

coliform and Nitrate-N + Nitrite-N on reading and writing are robust even after the inclusion of a long list of control variables. Compared to the estimated effects in Tables 3 and 5, the effect of $1[\overline{FCOLI} > limit]$ on reading and writing test scores are approximately 0.005 standard deviations smaller in Table 7. In addition, in Column 1 in Table 7 the estimated effect of $1[\overline{NIT} > limit]$ is statistically significant when all districts are considered. The effect of $1[\overline{FCOLI} > limit]$ is not statistically significant on maths and writing test scores.

In Table 9, we present average treatment effect on the treated (ATT) by estimating a propensity-score matching model outlined in Equation 2. The estimated ATT shows causal impact of the main pollution treatments. The results show that when the full samples are considered, $T_f$ has

School)) indicating the standard, year, or the grade the child is studying in, and binary control variables indicating whether the child gets free uniform from school, whether the child gets free books from school, whether the government pays school fees for the child, the amount of money the child received under scholarship, the amount of money the household spends on the child's bus fare. Moreover, we include control variables that inform of the type of technology the household may be familiar with (whether the household respondent owns a mobile, whether the household respondent uses a computer, whether the household member has computer knowledge. Further, We include more control variables regarding short-term morbidity such as short-term morbidity related total cost in the last 30 days (inpatient/outpatient e.g. doctor, hospital, surgery), the number of days the child was ill in the last 30 days, short-term morbidity related cost for medicines/tests/expense not included in doctor/hospital fees, cost of traveling for treatment, whether the child had a cough in the last 30 days and whether the child had a fever in the last 30 days.

a statistically significant causal impact on reading, maths, and writing score. $T_n$ also has a negative impact on reading and maths score.

The results in Table 8 are estimated by adding indicators related to teaching quality to the regression specification in addition to the set of explanatory variables corresponding to the results in Table 7. These teaching quality variables include binary indicators such as “whether the teacher is fair to the child”, “whether parents participate in PTA”, “whether the teacher is biased”, “whether the teacher is female”, “whether teacher attendance is regular”, and “whether school admission is difficult” and they are coded 1 for positive answers. The estimated effect of faecal coliform above safe level on reading and writing scores is still robust in Table 8.

The channel through which water pollution affects educational outcomes is the deterioration of the child’s health primarily followed by a decrease in cognitive abilities. We only control for short-term morbidity and do not have any measure of long-term morbidity. As a control for the district-wide morbidity level, we create a measure of the district-average short-term morbidity of the children within a district. As a control variable it should control for the average effect of district-level short-term morbidity, caused by water pollution. Controlling for the channel of short-term morbidity may leave the secondary channel of decrease in cognitive abilities through long-term morbidity or recurring short-term morbidity open. We observe that short-term morbidity, when included in the model, weakens the effect of $1[\overline{FCOLI} > limit]$ on writing test scores in districts where water was monitored (Column 6 in Table S.7, compared to Column 6 in Table 7). The effect of $1[\overline{FCOLI} > limit]$ on reading scores in districts along rivers and that of $1[\overline{NIT} > limit]$ on reading scores in the all-district sample remain robust statistically.

If state-specific policies in pollution control and education provision are connected through the channel of quality governance, then the pollution treatment effects would be underestimated. So, we add state fixed effects to our model and estimate the results in Table S.7. Table S.8 present the change in the coefficient estimates of unsafe levels of faecal coliform and Nitrate-N + Nitrite-N after to the inclusion of state-fixed effects. We can see that the effect of $1[\overline{NIT} > limit]$ in column 1 or Table S.8, compared to column 1 in Table S.7, is now indistinguishable from zero. On the other hand, the estimated effect of $1[\overline{FCOLI} > limit]$ remains statistically significant for writing (Columns 3 and 6), reading (Column 1) and, maths (Column 5). The state dummy for Jharkhand is not identified because the only district in Jharkhand in our analytical sample, Palamu, is not situated by a river. Overall, we find maths score to be less responsive to pollution. According to Ashraf (2020), Babu (2012), and due resource constraints faced by rural and/or public schools and poorer sections of the urban population, teaching maths compared to other subjects is more difficult. This difficulty likely results in low variations in the maths test score and therefore sees little effect of factors like river pollution.

We estimate the baseline results using mixed-model specifications as a sensitivity analysis, where the random effects is interpreted as district-specific random intercepts. The results are in Table 10. For the three educational outcomes in Table 10, I use the same set of explanatory variables are used to derive results in the Tables, 3, 4 and 5. The estimated effect of $1[\overline{FCOLI} > limit]$ in Table 10 are similar to those in Tables, 3, 4 and 5, which allows us to conclude that the change in specification does not affect the key results. Additional robustness checks are based on a multilevel random-intercept approach. Table S.5 and S.6 contain the effect $1[\overline{FCOLI} > limit]$ and $1[\overline{NIT} > limit]$ estimated in this approach. The results in S.5 consider village and/or neighbourhoods as levels where the surveyed children are "nested". In addition to that, the results in Table S.6 also consider the household as another level. The three-level (Table S.6) and two-level (Table S.5) random-intercept approach both produce estimated effects of $1[\overline{FCOLI} > limit]$ and $1[\overline{NIT} > limit]$ which are statistically robust.

As the data used in this paper is cross-sectional, there is little opportunity to detect and control for seasonality for multiple years. Table S.9 shows how the effect of faecal coliform above the safe level changes in the presence of extensive controls for seasonality. Therefore, we include interaction terms - $State\_ID \times Disctrict\_Mean\_Morbidity \times Survey\_Month$ - in the empirical model and present the results in Table S.9. These interaction terms control for survey-month specific variations in district-level average child short-term morbidity "in the last thirty days from the date of survey month" by states. Faecal coliform effects for Writing and Maths in the first column (full sample) of Table S.9 are statistically significant after including these interaction terms.[27]

Water pollution is not the sole environmental factor negatively impacting educational outcomes. Other sources of pollution, like land and air pollution, might overlap with water pollution. These can be proxied by a common measure of economic activities and consumption[28]. Data on density of light during nighttime or night lights reflects the amount of economic activity and consumption takes place in a geographical location[29]. The sum of the economic activities in a location is linked to the level of aggregate amount of pollutants released into the environment. We can consider overall pollution as a function of economic activities generating night light[30]. Table S.10 shows how the estimated effect of water pollution - $1[\overline{FCOLI} > limit]$ and $1[\overline{NIT} > limit]$ - on test scores change when we control for night lights. Unfortunately, inclusion of this variable reduces the size of our analytical sample by 100 observations approximately. We could not find data of every district in our analytical sample. Table S.10 shows the estimated effect of $1[\overline{FCOLI} > limit]$ for the full available sample is statistically significant for maths and writing but not for reading. We are not sure if that is due to removal of some observations or due to inclusion of the night lights variable. Lastly, the negative effect of unsafe levels of faecal coliform on maths and writing scores for the sampled districts by Ganges (Column 3, Table S.10) are highly significant.

Considering the possibility that nightlights can be negatively correlated to air pollution when air pollution is generated by crop burning as Chakrabarti et al., 2019 found, we replace the

[27]These interaction terms are viable controls under the assumption that within a state, district-level average short-term morbidity in different months remain unchanged over 2011 and 2012 - the two years when the last wave of the survey took place - and that in the months when the survey was not conducted - July, August, and September - seasonal variation in district-level average short-term morbidity does not exceed that of the previous and subsequent months.

[28]AAs developing countries undergo rapid urbanization and population growth, the demand for lighting and infrastructure surges. This leads to elevated energy consumption and intensified nighttime lighting, especially in bustling or industrial zones, potentially causing heightened pollution levels. Considering that 764 factories are situated along the main stem of the Ganges river, employing night-time light data in this study is pertinent Central Pollution Control Board, (CPCB) (2013).

[29]The unit of the DMSP nighttime lights or night light data is radiance, which is a measure of the amount of light emitted by a surface per unit area per unit time. The DMSP nighttime lights or night light data is usually expressed in units of watts per square meter per steradian (W/$m^2$/sr), which is a standard unit for measuring radiance. This unit describes the amount of light energy radiated from a surface in a particular direction per unit area per unit solid angle, and takes into account the angle at which the light is emitted (National Oceanic and Atmospheric Administration (NOAA) (1992–2013)).

[30]Since we do not know this functional form, the estimated effect of nighttime lights cannot be directly interpreted.

Table 10: Mixed-effects Specifications - Random Intercepts

| | (1) Reading Score | (2) Reading Score | (3) Reading Score | (4) Reading Score | (5) Reading Score | (6) Reading Score |
|---|---|---|---|---|---|---|
| $1[\overline{FCOLI} > limit]$ | -0.109 | -0.582 | -0.234 | -0.0290 | -0.288 | 0.0170 |
| | (0.0777) | (0.308) | (0.112) | (0.135) | (0.161) | (0.114) |
| $1[\overline{NIT} > limit]$ | -0.129 | -0.0563 | -0.0650 | -0.104 | -0.00507 | -0.0621 |
| | (0.0805) | (0.196) | (0.0974) | (0.115) | (0.146) | (0.124) |
| $N$ | 1147 | 206 | 532 | 769 | 576 | 738 |
| Sample | All | Lake | Ganges | GW | River | Trib. |
| | (7) Maths Score | (8) Maths Score | (9) Maths Score | (10) Maths Score | (11) Maths Score | (12) Maths Score |
| $1[\overline{FCOLI} > limit]$ | -0.145 | -0.669 | -0.322 | 0.106 | -0.192 | -0.0420 |
| | (0.0874) | (0.267) | (0.119) | (0.197) | (0.180) | (0.121) |
| $1[\overline{NIT} > limit]$ | -0.0444 | 0.112 | 0.0868 | -0.000282 | 0.163 | -0.166 |
| | (0.0925) | (0.178) | (0.104) | (0.177) | (0.164) | (0.131) |
| $N$ | 1147 | 206 | 532 | 769 | 576 | 738 |
| Sample | All | Lake | Ganges | GW | River | Trib. |
| | (13) Writing Score | (14) Writing Score | (15) Writing Score | (16) Writing Score | (17) Writing Score | (18) Writing Score |
| $1[\overline{FCOLI} > limit]$ | -0.157 | -0.341 | -0.355 | -0.00710 | -0.378 | -0.103 |
| | (0.0944) | (0.278) | (0.150) | (0.111) | (0.175) | (0.120) |
| $1[\overline{NIT} > limit]$ | 0.0878 | -0.0870 | 0.119 | 0.0242 | 0.112 | 0.0907 |
| | (0.102) | (0.186) | (0.134) | (0.0945) | (0.160) | (0.128) |
| $N$ | 1147 | 206 | 532 | 769 | 576 | 738 |
| Sample | All | Lake | Ganges | GW | River | Trib. |

- Robust standard errors clustered at district level in parentheses.
- FCOLI = Faecal Coliform, NIT = Nitrate-N + Nitrite-N
- The regression specifications corresponding the results in columns 1 to 18 include all explanatory variables used for results in Tables 3, 4, and 5.

nightlight variable with district-average PM2.5 in an additional robustness check[31]. PM2.5 refers to particulate matter in the air that are less than 2.5 micrometers in diameter. Table S.11 provides results where we can observe the effect of unsafe levels of faecal coliform and Nitrate-N + Nitrite-N and PM2.5 in 2012. Even after the inclusion of PM2.5 as a control variable, the effect of unsafe levels of faecal coliform on writing score are statistically significant for the full sample (Column 1, Table S.11), and the sample of districts along tributaries (Column 6, Table S.11). The effect of unsafe levels of faecal coliform was also found to be statistically significant in (Column 15 and 17, Table S.11) on Writing score. PM2.5 itself had statistically significant negative effect on only maths test score in Columns 7 and 11.

Finally, we analyse an additional model that instruments the district-average level of faecal coliform for a district with its upstream adjacent district's average level of faecal coliform. This instrumentation relies on one important fact: an upstream district's pollution generation would affect the downstream neighbouring district's environment but not the other way around, and that the observable and unobservable determinants of pollution of a downstream district will not be tied to those of its upstream neighbour. Unfortunately, we did not find data for upstream and border-sharing districts of 2 districts in Bihar, 2 districts in West Bengal, 1 district in Uttarakhand, and 3 districts in Uttar Pradesh. For accuracy, we instrument the a district's faecal coliform level only with that of a border-sharing upstream district. This choice is made considering that pollution generated by more distant districts tends to decay to some extent, potentially weakening the anticipated effect on downstream pollution levels. This portion of the analysis only discusses results from the instrumentation of district-average level of faecal coliform and not district-average level of Nitrate-N + Nitrite-N. Overall, we have seen little effect of Nitrate-N + Nitrite-N on test scores; therefore, an additional analysis with the upstream district-average level of Nitrate-N + Nitrite-N as an instrument has been skipped

[31] PM2.5, also known as particulate matter 2.5, refers to tiny airborne particles with a diameter of 2.5 microns or less. These particles are commonly measured in micrograms per cubic meter (µg/m³) to determine their concentration in the air. To ensure a safe and healthy environment, health regulations and standards are established to control and restrict the levels of PM2.5 present in the atmosphere. Presently, the WHO guidelines advocate for an annual average PM2.5 concentration of 5 micrograms per cubic meter (µg/m³) of air (*WHO global air quality guidelines: particulate matter (PM2. 5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide*, 2021). Our records encompass the yearly mean PM2.5 data at the district level. We collect this data from "Air Quality Life Index Database" (2023)

in this section.

The outcomes of this instrumental variable (IV) analysis are detailed in Table S.12. We present the results from both the random-effects model and the random-effects model with instrumentation, side by side for easy comparison. The results in columns labelled RE-IV are estimated using G2SLS random-effects methods. Results in Columns 1 to 6 are based on all-district sample, Columns 7 to 12 for districts along rivers, and Columns 12 to 18 for districts along tributaries. Applying upstream faecal coliform measure as an instrument reveals a statistically significant impact of the district-average faecal coliform level on reading scores in three samples: all districts, river-adjacent districts, and tributary-adjacent districts. We also see instrumented *MeanFCOLI* has some weak effect on maths test scores in the all-district sample and the tributary-adjacent-district sample. The effect of instrumented *MeanFCOLI* on writing score is not statistically robust, which could be due to fewer observations in this analysis. Interestingly, for the sample of districts by tributaries, the coefficient on district-average level of faecal coliform remains almost the same for any of the test scores after instrumentation (Columns 13 to 18). The IV analysis, employing upstream faecal coliform levels, serves as a supplementary robustness check to our core findings.

# 5 Conclusion

This study focuses on the effect of water quality on the educational outcomes of school-going children aged 8-11 in 39 districts in the Ganges Basin of India. Water is an important natural resource for production and consumption and polluted water can have long-term impacts on human health, life expectancy, and cognitive functions through many different channels. Using data from the Centre for Pollution Control Board of India (CPCB) and the Indian Human Development Survey (IHDS) 2011-12, we estimate the effect of water quality on performance in three tests that the children aged 8-11 took as a part of IHDS. We find evidence that the faecal coliform over safety limits has a consistently robust negative effect on the reading and writing test scores. In several extended specifications and sensitivity analyses, the effect of faecal coliform on maths score was not found to be statistically robust. The negative effect of Nitrate-

N + Nitrite-N was found to be statistically indistinguishable from zero in some robustness checks. Overall, the effect of faecal coliform in water sources on reading and writing scores remains largely robust even after including additional controls like district-average short-term (thirty-days) morbidity in children, teaching quality controls, and in propensity-score matching model. From this we deduce that faecal coliform could be lowering cognitive abilities of pollution-affected children who are subject to water-borne diseases for a long period of time (more than thirty days). Future research with larger data sets with water pollution identified at much smaller geographic unit levels could improve the precision of the estimated effect of water pollutants like faecal coliform and Nitrate-N + Nitrite-N.

## Declaration of Competing Interests

The authors declare none.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## Data Availability Statement

Data from the Indian Human Development Survey are openly available at Inter-university Consortium for Political and Social Research, Ann Arbor, Michigan, The United States (URL: https://doi.org/10.3886/ICPSR36151.v6).

The water quality data is derived from the publicly available source at URL: https://cpcb.nic.in/nwmp-data-2012/. This data is collected and maintained by Central Pollution Control Board (CPCB), Ministry of Environment, Forests and Climate Change, Government of India.

# References

Abadie, A., & Imbens, G. W. (2016). Matching on the estimated propensity score. *Econometrica*, *84*(2), 781–807.

Adimalla, N. (2020). Spatial distribution, exposure, and potential health risk assessment from nitrate in drinking water from semi-arid region of south india. *Human and Ecological Risk Assessment: An International Journal*, *26*(2), 310–334.

Air quality life index database. (2023). https://aqli.epic.uchicago.edu/the-index/

*Annual Progress Report of CPCB ENVIS, Centre on Control of Pollution* (tech. rep.). (2016–2017). Center for Pollution Control Board, Government of India, Ministry of Environment, Forest  Climate Change.

Ashraf, A. (2020). Challenges and possibilities in teaching and learning of calculus: A case study of india. *Journal for the Education of Gifted Young Scientists*, *8*(1), 407–433.

Babu, S. (2012). Indigenous traditions and the colonial encounter: A historical perspective on mathematics education in india. *Mathematics education in India: Status and outlook*, 37–62.

Board, C. P. C. (2019). Water quality criteria. https://cpcb.nic.in/water-quality-criteria/

Breusch, T. S., & Pagan, A. R. (1980). The lagrange multiplier test and its applications to model specification in econometrics. *The review of economic studies*, *47*(1), 239–253.

Cameron, A. C., & Trivedi, P. K. (2022). *Microeconometrics using stata: Volume ii: Nonlinear models and causal inference methods*. Stata Press.

Central Pollution Control Board, (CPCB). (2012). Central pollution control board, (cpcb). https://cpcb.nic.in/nwmp-data-2012/

Central Pollution Control Board, (CPCB). (2013). Pollution assessment: Ganga [Accessed on March 22, 2023].

Central Pollution Control Board (CPCB), India. (2012). *Annual report*. Retrieved September 20, 2020, from http://www.cpcbenvis.nic.in/annual_report_main.html

Chakrabarti, S., Khan, M. T., Kishore, A., Roy, D., & Scott, S. P. (2019). Risk of acute respiratory infection from crop burning in india: Estimating disease burden and economic welfare from satellite and national health survey data for 250 000 persons. *International journal of epidemiology*, *48*(4), 1113–1124.

Chakraborti, D., Singh, S. K., Rahman, M. M., Dutta, R. N., Mukherjee, S. C., Pati, S., & Kar, P. B. (2018). Groundwater arsenic contamination in the ganga river basin: A future health danger. *International journal of environmental research and public health*, *15*(2), 180.

Chaudhary, M., & Walker, T. (2019). River ganga pollution: Causes and failed management plans (correspondence on dwivedi et al. 2018. ganga water pollution: A potential health threat to inhabitants of ganga basin. environment international 117, 327–338). *Environment International*, *126*, 202–206.

Chaudhri, D. P., & Jha, R. (2012). Child poverty and compulsory elementary education in india: Policy insights from household data analysis. *Indian Journal of Human Development*, *6*(1), 5–30.

Chauhan, V. S., Nickson, R., Chauhan, D., Iyengar, L., & Sankararamakrishnan, N. (2009). Ground water geochemistry of ballia district, uttar pradesh, india and mechanism of arsenic release. *Chemosphere*, *75*(1), 83–91.

Chhokar, K. B. (2010). Higher education and curriculum innovation for sustainable development in india. *International Journal of Sustainability in Higher Education*.

Chudgar, A., & Quin, E. (2012). Relationship between private schooling and achievement: Results from rural and urban india. *Economics of Education Review*, *31*(4), 376–390.

Coates, D. (2003). Education production functions using instructional time as an input. *Education Economics*, *11*(3), 273–292.

Curtis, V., & Cairncross, S. (2003). Effect of washing hands with soap on diarrhoea risk in the community: A systematic review. *The Lancet infectious diseases*, *3*(5), 275–281.

Das, S., & Birol, E. (2010). Estimating the value of improved wastewater treatment: The case of river ganga, india. *Journal of Environmental Management*, *91*(11), 2163–2171.

Desai, S., & Vanneman, R. (2015). [data] india human development survey ii, 2011-12. doi.org/10.3886/ICPSR36151.v2

Do, Q.-T., Joshi, S., & Stolper, S. (2018). Can environmental policy reduce infant mortality? evidence from the ganga pollution cases. *Journal of Development Economics*, *133*, 306–325.

Dutta, V., Dubey, D., & Kumar, S. (2020). Cleaning the river ganga: Impact of lockdown on water quality and future implications on river rejuvenation strategies. *Science of the Total Environment*, *743*, 140756.

Dwivedi, S., Mishra, S., & Tripathi, R. D. (2018). Ganga water pollution: A potential health threat to inhabitants of ganga basin. *Environment international*, *117*, 327–338.

Ebenstein, A., Lavy, V., & Roth, S. (2016). The long-run economic consequences of high-stakes examinations: Evidence from transitory variation in pollution. *American Economic Journal: Applied Economics*, *8*(4), 36–65.

Edmonds, E. V., Topalova, P., & Pavcnik, N. (2009). Child labor and schooling in a globalizing world: Some evidence from urban india. *Journal of the European Economic Association*, *7*(2-3), 498–507.

Evans, A. E., Mateo-Sagasta, J., Qadir, M., Boelee, E., & Ippolito, A. (2019). Agricultural water pollution: Key knowledge gaps and research needs. *Current Opinion in Environmental Sustainability*, *36*, 20–27.

Fuller, R., Landrigan, P. J., Balakrishnan, K., Bathan, G., Bose-O'Reilly, S., Brauer, M., Caravanos, J., Chiles, T., Cohen, A., Corra, L., et al. (2022). Pollution and health: A progress update. *The Lancet Planetary Health*, *6*(6), e535–e547.

Greenstone, M., & Hanna, R. (2014). Environmental regulations, air and water pollution, and infant mortality in india. *American Economic Review*, *104*(10), 3038–72.

Hamner, S., Tripathi, A., Mishra, R. K., Bouskill, N., Broadaway, S. C., Pyle, B. H., & Ford, T. E. (2006). The role of water use patterns and sewage pollution in incidence of water-borne/enteric diseases along the ganges river in varanasi, india. *International Journal of Environmental Health Research*, *16*(2), 113–132.

Hanushek, E. A. (2010). Education production functions: Evidence from developed countries. *Economics of Education*, 132–136.

Hanushek, E. A. (2020). Education production functions. In *The economics of education* (pp. 161–170). Elsevier.

*Hardness in drinking-water: Background document for development of who guidelines for drinking-water quality* (tech. rep.). (2010). World Health Organization.

Hausman, J. A. (1978). Specification tests in econometrics. *Econometrica: Journal of the econometric society*, 1251–1271.

Hoff, K. (2016). Caste system. *World Bank policy research working paper*, (7929).

Hoxby, C. M. (1996). How teachers' unions affect education production. *The Quarterly Journal of Economics*, *111*(3), 671–718.

Jasper, C., Le, T.-T., & Bartram, J. (2012). Water and sanitation in schools: A systematic review of the health and educational outcomes. *International Journal of Environmental Research and Public Health*, *9*(8), 2772–2787.

Jouanneau, S., Recoules, L., Durand, M., Boukabache, A., Picot, V., Primault, Y., Lakel, A., Sengelin, M., Barillon, B., & Thouand, G. (2014). Methods for assessing biochemical oxygen demand (bod): A review. *Water Research*, *49*, 62–82.

Khan, M. Y. A., Gani, K. M., & Chakrapani, G. J. (2016). Assessment of surface water quality and its spatial variation. a case study of ramganga river, ganga basin, india. *Arabian Journal of Geosciences*, *9*(1), 28.

Kingdon, G. G. (2007). The progress of school education in india. *Oxford Review of Economic Policy*, *23*(2), 168–195.

Koufman, J. A., & Johnston, N. (2012). Potential benefits of ph 8.8 alkaline drinking water as an adjunct in the treatment of reflux disease. *Annals of Otology, Rhinology & Laryngology*, *121*(7), 431–434.

Krueger, A. B. (1999). Experimental estimates of education production functions. *The Quarterly Journal of Economics*, *114*(2), 497–532.

Lellis, B., Fávaro-Polonio, C. Z., Pamphile, J. A., & Polonio, J. C. (2019). Effects of textile dyes on health and the environment and bioremediation potential of living organisms. *Biotechnology Research and Innovation*, *3*(2), 275–290.

Lu, Y., Song, S., Wang, R., Liu, Z., Meng, J., Sweetman, A. J., Jenkins, A., Ferrier, R. C., Li, H., Luo, W., et al. (2015). Impacts of soil and water pollution on food safety and health risks in china. *Environment international*, *77*, 5–15.

Mariya, A., Kumar, C., Masood, M., & Kumar, N. (2019). The pristine nature of river ganges: Its qualitative deterioration and suggestive restoration strategies. *Environmental monitoring and assessment*, *191*(9), 1–33.

Matta, G., Srivastava, S., Pandey, R., & Saini, K. (2017). Assessment of physicochemical characteristics of ganga canal water quality in uttarakhand. *Environment, development and sustainability*, *19*(2), 419–431.

Mohai, P., Kweon, B.-S., Lee, S., & Ard, K. (2011). Air pollution around schools is linked to poorer student health and academic performance. *Health Affairs*, *30*(5), 852–862.

Mostafa, G., El-Shahawi, H., & Mokhtar, A. (2009). Blood lead levels in egyptian children from high and low lead-polluted areas: Impact on cognitive function. *Acta Neurologica Scandinavica*, *120*(1), 30–37.

Nagpoore, N., Chand, J., Lehri, A., & Singh, V. (2020). Monitoring and assessment of pollution load in surface water of river ganga around kanpur, india: A study for suitability of this water for different uses. *Environmental Technology Innovation*, *18*, 100676. https://doi.org/https://doi.org/10.1016/j.eti.2020.100676

Nambissan, G. B. (2009). *Exclusion and discrimination in schools: Experiences of dalit children*. Indian Institute of Dalit Studies; UNICEF.

National Oceanic and Atmospheric Administration (NOAA). (1992–2013). DMSP OLS Nighttime Lights Time Series [Retrieved on March 22, 2023]. https://ngdc.noaa.gov/eog/dmsp/downloadV4composites.html

of India, C. (2011). Census tables. https://censusindia.gov.in/census.website/data/census-tables

PRATHAM. (2021). Pratham. http://www.pratham.org

Pritchett, L., & Filmer, D. (1999). What education production functions really show: A positive theory of education expenditures. *Economics of Education review*, *18*(2), 223–239.

Quist, A. J., Inoue-Choi, M., Weyer, P. J., Anderson, K. E., Cantor, K. P., Krasner, S., Freeman, L. E. B., Ward, M. H., & Jones, R. R. (2018). Ingested nitrate and nitrite, disinfection by-products, and pancreatic cancer risk in postmenopausal women. *International journal of cancer*, *142*(2), 251–261.

Reddy, B., & Dubey, S. K. (2019). River ganges water as reservoir of microbes with antibiotic and metal ion resistance genes: High throughput metagenomic approach. *Environmental Pollution*, *246*, 443–451.

Rosenbaum, P. R., & Rubin, D. B. (1983). The central role of the propensity score in observational studies for causal effects. *Biometrika*, *70*(1), 41–55.

Rosofsky, A., Lucier, C. A., London, B., Scharber, H., Borges-Mendez, R., & Shandra, J. (2014). Environmental ascription in worcester county, ma: Toxic pollution and education outcomes. *Local Environment*, *19*(3), 283–299.

Roth, S. (2017). Air pollution, educational achievements, and human capital formation. *IZA World of Labor*.

Sanders, N. J. (2012). What doesn't kill you makes you weaker prenatal pollution exposure and educational outcomes. *Journal of Human Resources*, *47*(3), 826–850.

Sarker, B., Keya, K. N., Mahir, F. I., Nahiun, K. M., Shahida, S., Khan, R. A., et al. (2021). Surface and ground water pollution: Causes and effects of urbanization and industrialization in south asia. *Scientific Review*, *7*(3), 32–41.

Schaffer, M. E., & Stillman, S. (2006). Xtoverid: Stata module to calculate tests of overidentifying restrictions after xtreg, xtivreg, xtivreg2, xthtaylor. *Statistical Software Components*.

Siegal, M., & Share, D. L. (1990). Contamination sensitivity in young children. *Developmental Psychology*, *26*(3), 455.

Singh, A. K., & Soma, G. (2014). Assessment of human health risk for heavy metals in fish and shrimp collected from subarnarekha river, india. *International journal of environmental health research*, *24*(5), 429–449.

Singhal, K., & Das, U. (2019). Revisiting the role of private schooling on children learning outcomes: Evidence from rural india. *South Asia Economic Journal*, *20*(2), 274–302.

Spears, D. (2012). Height and cognitive achievement among indian children. *Economics & Human Biology*, *10*(2), 210–219.

Suthar, S., Sharma, J., Chabukdhara, M., & Nema, A. K. (2010). Water quality assessment of river hindon at ghaziabad, india: Impact of industrial and urban wastewater. *Environmental monitoring and assessment*, *165*(1), 103–112.

Tolins, M., Ruchirawat, M., & Landrigan, P. (2014). The developmental neurotoxicity of arsenic: Cognitive and behavioral consequences of early life exposure. *Annals of global health*, *80*(4), 303–314.

Tyagi, V. K., Bhatia, A., Gaur, R. Z., Khan, A. A., Ali, M., Khursheed, A., Kazmi, A. A., & Lo, S.-L. (2013). Impairment in water quality of ganges river and consequential health risks on account of mass ritualistic bathing. *Desalination and Water Treatment*, *51*(10-12), 2121–2129.

Tyler, C. R., & Allan, A. M. (2014). The effects of arsenic exposure on neurological and cognitive dysfunction in human and rodent studies: A review. *Current environmental health reports*, *1*(2), 132–147.

U.S. Geological Survey, W. S. S. (2021). Ph and water.

Vahter, M., Skröder, H., Rahman, S. M., Levi, M., Hamadani, J. D., & Kippler, M. (2020). Prenatal and childhood arsenic exposure through drinking water and food and cognitive abilities at 10 years of age: A prospective cohort study. *Environment international*, *139*, 105723.

Vibhu, T., & Ambrish, D. (2015). Impact of private tutoring on learning levels. *Economic and Political Weekly*, *50*(41), 72–80.

Weiner, M., et al. (1991). *The child and the state in india: Child labor and education policy in comparative perspective*. Princeton University Press.

*Who global air quality guidelines: Particulate matter (pm2. 5 and pm10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide*. (2021). World Health Organization.

# Supplementary Tables

Table S.1: Districts with Unsafe Levels of Water Pollutants

| District | (1)<br>$1[\overline{FCOLI} > limit]$<br>District | (2)<br>$1[\overline{NIT} > limit]$<br>District | (3)<br>Obs. |
|---|---|---|---|
| *Location* | | | |
| Bihar - Purbi Champaran | 1 | 1 | 49 |
| Bihar - Madhubani | 0 | 1 | 51 |
| Bihar - Supaul | 0 | 1 | 17 |
| Bihar - Muzaffarpur | 0 | 1 | 56 |
| Bihar - Siwan | 0 | 1 | 32 |
| Bihar - Saran | 0 | 1 | 7 |
| Bihar - Bhagalpur | 1 | 1 | 43 |
| Bihar - Patna | 0 | 1 | 10 |
| Bihar - Buxar | 1 | 1 | 11 |
| Bihar - Rohtas | 0 | 1 | 58 |
| Bihar - Gaya | 0 | 1 | 13 |
| Uttar Pradesh - Muzaffarnagar | 1 | 1 | 33 |
| Uttar Pradesh - Meerut | 1 | 0 | 11 |
| Uttar Pradesh - Ghaziabad | 1 | 0 | 28 |
| Uttar Pradesh - Mathura | 1 | 1 | 44 |
| Uttar Pradesh - Budaun | 0 | 1 | 17 |
| Uttar Pradesh - Lucknow | 1 | 0 | 12 |
| Uttar Pradesh - Kannauj | 1 | 0 | 23 |
| Uttar Pradesh - Kanpur Nagar | 1 | 0 | 47 |
| Uttar Pradesh - Jhansi | 1 | 1 | 16 |
| Uttar Pradesh - Prayagraj | 1 | 1 | 67 |
| Uttar Pradesh - Faizabad | 1 | 1 | 51 |
| Uttar Pradesh - Gorakhpur | 0 | 0 | 19 |
| Uttar Pradesh - Deoria | 0 | 1 | 10 |
| Uttar Pradesh - Varansi | 1 | 1 | 44 |
| Uttarakhand - Dehradun | 1 | 1 | 11 |
| West Bengal - Darjiling | 1 | 1 | 22 |
| West Bengal - Jalpaiguri | 1 | 1 | 33 |
| West Bengal - Murshidabad | 1 | 0 | 38 |
| West Bengal - Birbhum | 1 | 0 | 31 |
| West Bengal - Barddhaman | 1 | 0 | 63 |
| West Bengal - Nadia | 1 | 1 | 30 |
| West Bengal - North 24 Parganas | 1 | 1 | 26 |
| West Bengal - Hugli | 1 | 0 | 19 |
| West Bengal - Bankura | 1 | 1 | 6 |
| West Bengal - Haora | 1 | 0 | 15 |
| West Bengal - Kolkata | 1 | 1 | 36 |
| West Bengal - South 24 Parganas | 1 | 1 | 12 |
| Jharkhand - Palamu | 0 | 1 | 36 |
| N | | | 1147 |

- FCOLI = Faecal Coliform, and NIT = Nitrate-N + Nitrite-N, Obs. = Observations.
- Columns 1 and 2 indicate whether a district listed in the table experiences, on average, unsafe levels of faecal coliform and Nitrate-N + Nitrite-N, respectively. Districts experiencing unsafe levels of a pollutant are assigned a 1, and zero otherwise. Column 3 displays the number of observations for each district.

Table S.2: Analytical Sample Means of Additional Control Variables

| *Variable* | (1) $1[\overline{FCOLI} > limit]$ Districts | (2) $1[\overline{NIT} > limit]$ Districts | (3) River Districts | (4) All Districts |
|---|---|---|---|---|
| **Short-term Morbidity (STM)** | | | | |
| If **STM** is | | | | |
| covered by Medical insurance (*Yes* =1) | 0.12 | 0.12 | 0.17 | 0.09 |
| **STM:** Total cost*** | 47.12 | 51.121 | 58.81 | 49.77 |
| **STM:** Days ill in last 30 days | 1.65 | 1.46 | 1.71 | 1.53 |
| **STM:** Days with fever in last 30 days | 1.65 | 1.45 | 1.70 | 1.53 |
| **STM:** Days with Cough in last 30 days | 0.22 | 0.19 | 0.23 | 0.20 |
| **STM:** Additional costs ♢ | 0.22 | 0.19 | 0.23 | 0.20 |
| **STM:** Additional costs(2) ♢♢ | 0.22 | 0.19 | 0.23 | 0.20 |
| **Water Supply** | | | | |
| Water supply adequate (*Yes* =1) | 0.95 | 0.98 | 0.98 | 0.96 |
| **Use of Technology in the HH** | | | | |
| HH respondent has mobile phone | 0.36 | 0.28 | 0.40 | 0.32 |
| HH uses computer | 0.05 | 0.04 | 0.07 | 0.05 |
| **Schooling and Teaching-related** | | | | |
| If child gets free uniform (Yes = 1) | 0.29 | 0.33 | 0.26 | 0.31 |
| If child gets free uniform (Yes = 1) | 0.29 | 0.33 | 0.26 | 0.31 |
| Years of Education completed: None | 0.079 | 0.084 | 0.081 | 0.086 |
| Years of Education completed: 1-4 | 0.73 | 0.73 | 0.73 | 0.73 |
| Years of Education completed: primary or 5 | 0.11 | 0.11 | 0.12 | 0.12 |
| Years of Education completed: 6-9 | 0.069 | 0.059 | 0.069 | 0.063 |
| Scholarship Amount | 76.98 | 75.60 | 76.63 | 75.76 |
| School Fees(In thousand Rupees) | 1.6 | 1.4. | 1.8 | 1.4. |
| Child's teacher **(CT)** | | | | |
| **(CT)** fair to him/her (*Yes* = 1) | 0.10 | 0.15 | 0.11 | 0.13 |
| Parents attended PTA meeting (*Yes* = 1) | 0.41 | 0.36 | 0.45 | 0.37 |
| **(CT)** biased towards him/her (*Yes* = 1) | 0.38 | 0.06 | 0.38 | 0.06 |
| **(CT)** is local? (*Yes* = 1) | 0.44 | 0.52 | 0.51 | 0.50 |
| **(CT)** female | 0.36 | 0.37 | 0.39 | 0.37 |
| School Admission was difficult (*Yes* = 1) | 0.28 | 0.32 | 0.26 | 0.31 |
| Short-term Morbidity ♢♢♢ | 1.69 | 0 8 | 1.70 | 1.55 |
| Urban = 1 and Rural = 0 | 0.36 | 0.31 | 0.44 | 0.36 |
| N | 821 | 841 | 576 | 1147 |

***Mean Short-Term Morbidity Total cost for inpatient/outpatient (doctor and hospital).

• Column 1 shows means for the sample of districts with unsafe levels of faecal coliform, Column 2 shows means for the sample of districts with unsafe levels of Nitrate-N + Nitrite-N, Column 3 shows means for the sample of districts along rivers, and Column 4 shows means for the sample of all districts.

• FCOLI = Faecal Coliform, NIT = Nitrate-N + Nitrite, and HH = Household.

♢ Mean short-term Morbidity additional costs including medicines/tests/expenses which are not included in item (***).

♢♢ Mean short-term Morbidity travel expenses.

♢♢♢ District-wise average number of days spent disabled due to short-term morbidity.

Table S.3: Comparison of Male and Female Test Scores by District-level Prevalence of Water Pollution

| | Score | $1[\overline{FCOLI} > limit]$ Districts | $1[\overline{NIT} > limit]$ Districts |
|---|---|---|---|
| **Sex** | | | |
| Male | Reading | 0.155<br>(0.929) | 0.373<br>(0.816) |
| Male | Maths | 0.234<br>(1.02) | 0.432<br>(0.984) |
| Male | Writing | 0.147<br>(0.999) | 0.281<br>(0.945) |
| **Sex** | | | |
| Female | Reading | 0.177<br>(0.929) | 0.346<br>(0.828) |
| Female | Maths | 0.194<br>(1.007) | 0.265<br>(0.943) |
| Female | Writing | 0.212<br>(0.993) | 0.302<br>(0.910) |

| **Sex** | Score | $0[\overline{FCOLI} \leq limit]$ Districts | $0[\overline{NIT} \leq limit]$ Districts |
|---|---|---|---|
| Male | Reading | 0.09<br>(0.891) | 0.051<br>(0.938) |
| Male | Maths | 0.256<br>(0.945) | 0.171<br>(0.999) |
| Male | Writing | 0.133<br>(0.997) | 0.092<br>(0.945) |
| **Sex** | | | |
| Female | Reading | 0.025<br>(0.948) | 0.59<br>(0.962) |
| Female | Maths | 0.042<br>(0.964) | 0.112<br>(1.014) |
| Female | Writing | 0.103<br>(1.01) | 0.139<br>(1.026) |

- Reading, Writing, and Maths Test Scores have been Z-scored for the entire sample. Standard Deviations in parentheses.
- FCOLI = Faecal Coliform, NIT = Nitrate-N + Nitrite-N.
- Column 1 and 2 show test score means for districts with unsafe levels of faecal coliform and Nitrate-N + Nitrite-N, respectively.

Table S.4: Differences in River Pollution Effect across States

| Test | (1) Reading Score | (2) Maths Score | (3) Writing Score | (4) Reading Score | (5) Maths Score | (6) Writing Score | (7) Reading Score | (8) Maths Score | (9) Writing Score |
|---|---|---|---|---|---|---|---|---|---|
| $1[\overline{FCOLI} > limit]$ | -0.235 | -0.203 | -0.287 | -0.0905 | -0.0519 | -0.448 | 0.192 | 3.752 | -2.431 |
| | (0.130) | (0.0820) | (0.184) | (0.175) | (0.164) | (0.0880) | (2.269) | (2.375) | (2.096) |
| $1[\overline{NIT} > limit]$ | -0.0767 | -0.131 | 0.219 | – | -10.14 | -6.934 | -0.0343 | 0.0556 | -0.0547 |
| | (0.173) | (0.119) | (0.164) | – | (7.918) | (5.931) | (0.0734) | (0.166) | (0.0810) |
| $1[\overline{D.O.} < threshold]$ | 0.0336 | -0.0674 | -0.249 | -0.485 | -0.487 | 0.129 | 0.105 | 0.0888 | -0.0112 |
| | (0.186) | (0.153) | (0.197) | (0.118) | (0.127) | (0.0722) | (0.0998) | (0.167) | (0.106) |
| Mean pH | 0.0122 | -0.399 | -0.0383 | 1.472 | 1.023 | 0.707 | -0.125 | -0.573 | 0.355 |
| | (0.170) | (0.135) | (0.230) | (1.076) | (1.014) | (0.751) | (0.268) | (0.329) | (0.248) |
| $N$ | 422 | 422 | 422 | 347 | 347 | 347 | 367 | 367 | 367 |
| States | UP | UP | UP | WB | WB | WB | BJ | BJ | BJ |

Robust standard errors clustered at district level in parentheses. FCOLI = Faecal Coliform and NIT = Nitrate-N + Nitrite

- UP = Uttar Pradesh, BJ = Bihar and Jharkhand, and WB = West Bengal.
- **The results in columns 1 to 9 are estimated by including the following control variables in the regression equation** : Numerical variables such as Age, Sex, Height, Weight, "hours spent at school per week", "hours spend doing homework per week", "hours spent being tutored per week", "distance from school to home", "number of days the child spent disabled because of short-term morbidity in the last 30 days". Binary Variables such as Sex, "Rupees spent on books and uniform $>$ Rs. 500", "household consumption per capita $\leq$ 25th percentile", "household consumption $\leq$ 50th percentile", "household consumption $\leq$ 75th percentile", "1 = water storage vessel available at home", "1 = water is purified at home though some mode of filtration or boiling", "1 = household members always wash hands after defecation".

Table S.5: Baseline Model Estimated with Random Intercepts at Two Levels, District and Village

| Test | (1) Reading Score | (2) Maths Score | (3) Writing Score | (4) Reading Score | (5) Maths Score | (6) Writing Score |
|---|---|---|---|---|---|---|
| $1[\overline{FCOLI} > limit]$ | -0.0412 | -0.161 | -0.142 | -0.281 | -0.0839 | -0.365 |
| | (0.0788) | (0.148) | (0.0865) | (0.133) | (0.0989) | (0.173) |
| $1[\overline{NIT} > limit]$ | -0.134 | -0.0196 | -0.00644 | 0.110 | 0.102 | 0.0785 |
| | (0.0777) | (0.135) | (0.0862) | (0.118) | (0.106) | (0.158) |
| $1[\overline{D.O.} < threshold]$ | -0.0448 | 0.0353 | -0.0536 | 0.0204 | -0.144 | -0.0254 |
| | (0.0754) | (0.145) | (0.0823) | (0.130) | (0.0935) | (0.173) |
| Mean pH | 0.0618 | 0.247 | -0.198 | -0.0956 | -0.0712 | 0.0944 |
| | (0.104) | (0.192) | (0.114) | (0.161) | (0.131) | (0.223) |
| $N$ | 1147 | 576 | 1147 | 576 | 1147 | 576 |
| Districts | All | River | All | River | All | River |

Robust standard errors clustered at district level in parentheses.
"Uttarakhand" is the reference State to the State dummy variables.

- **The results in columns 1 to 6 are estimated by including all the control variables used for table S.7 results except Mean District-level Short-term Morbidity.**

Table S.6: Baseline Regression - Random Intercepts at Three Levels (District, Village, and Household)

| Test | (1) Reading Score | (2) Maths Score | (3) Writing Score | (4) Reading Score | (5) Maths Score | (6) Writing Score |
|---|---|---|---|---|---|---|
| $1[\overline{FCOLI} > limit]$ | -0.0452 | -0.163 | -0.131 | -0.275 | -0.0823 | -0.361 |
| | (0.0800) | (0.147) | (0.0887) | (0.135) | (0.100) | (0.170) |
| $1[\overline{NIT} > limit]$ | -0.134 | -0.0187 | -0.0167 | 0.108 | 0.0904 | 0.0702 |
| | (0.0787) | (0.134) | (0.0885) | (0.120) | (0.107) | (0.156) |
| $1[\overline{D.O.} < threshold]$ | -0.0314 | 0.0389 | -0.0548 | 0.0210 | -0.131 | -0.00979 |
| | (0.0767) | (0.144) | (0.0846) | (0.132) | (0.0951) | (0.170) |
| Mean pH | 0.0520 | 0.241 | -0.187 | -0.0915 | -0.0771 | 0.103 |
| | (0.105) | (0.190) | (0.117) | (0.164) | (0.132) | (0.218) |
| $N$ | 1147 | 576 | 1147 | 576 | 1147 | 576 |
| Districts | All | River | All | River | All | River |

Robust standard errors clustered at district level in parentheses. DO = Dissolved Oxygen. "Uttarakhand" is the reference State to the State dummy variables.

- **The results in columns 1 to 6 are estimated by including all the control variables used for table S.7 results except Mean District-level Short-term Morbidity.**

Table S.7: Robustness Check with District-level Morbidity as Control

| Test | (1) Reading Score | (2) Maths Score | (3) Writing Score | (4) Reading Score | (5) Maths Score | (6) Writing Score |
|---|---|---|---|---|---|---|
| $1[\overline{FCOLI} > limit]$ | -0.0120 | -0.147 | -0.106 | -0.295 | 0.0413 | -0.303 |
| | (0.0832) | (0.172) | (0.0813) | (0.128) | (0.130) | (0.191) |
| $1[\overline{NIT} > limit]$ | -0.154 | -0.0554 | 0.00218 | 0.0854 | 0.0347 | 0.0443 |
| | (0.0774) | (0.159) | (0.0824) | (0.0774) | (0.0896) | (0.159) |
| $1[\overline{D.O.} < threshold]$ | -0.0548 | 0.0341 | -0.0750 | 0.0295 | -0.216 | -0.0759 |
| | (0.0948) | (0.159) | (0.0920) | (0.116) | (0.117) | (0.209) |
| Mean pH | 0.0422 | 0.195 | -0.249 | -0.0887 | -0.0561 | 0.202 |
| | (0.0882) | (0.141) | (0.114) | (0.145) | (0.0985) | (0.167) |
| Mean Morbidity | -0.00502 | 0.00481 | -0.00852 | -0.00318 | -0.0710 | -0.0874 |
| | (0.0155) | (0.0298) | (0.0181) | (0.0305) | (0.0175) | (0.0323) |
| $N$ | 1147 | 576 | 1147 | 576 | 1147 | 576 |
| Districts | All | River | All | River | All | River |

Robust standard errors clustered at district level in parentheses. DO = Dissolved Oxygen
T = teacher. S = School. PTA = Parent-Teacher Association

- **The results in columns 1 to 6 are estimated by including all the control variables used for table 8 results.**

Table S.8: Robustness Check with State Fixed Effects

| Test | (1) Reading Score | (2) Maths Score | (3) Writing Score | (4) Reading Score | (5) Maths Score | (6) Writing Score |
|---|---|---|---|---|---|---|
| $1[\overline{FCOLI} > limit]$ | -0.212 | -0.202 | -0.171 | -0.186 | -0.254 | -0.545 |
| | (0.0911) | (0.189) | (0.0966) | (0.161) | (0.147) | (0.245) |
| $1[\overline{NIT} > limit]$ | -0.0774 | -0.0146 | 0.0345 | 0.0973 | 0.126 | 0.152 |
| | (0.0721) | (0.138) | (0.0909) | (0.0905) | (0.0853) | (0.108) |
| $1[\overline{D.O.} < threshold]$ | -0.0366 | -0.00498 | -0.0703 | 0.00795 | -0.132 | -0.166 |
| | (0.0799) | (0.138) | (0.0987) | (0.119) | (0.108) | (0.138) |
| Mean pH | 0.0914 | 0.206 | -0.223 | -0.115 | 0.134 | 0.234 |
| | (0.123) | (0.143) | (0.163) | (0.161) | (0.149) | (0.142) |
| Uttar Pradesh | 0.358 | 0.215 | 0.739 | 0.633 | 0.484 | 0.307 |
| | (0.0989) | (0.156) | (0.144) | (0.172) | (0.136) | (0.171) |
| Bihar | 0.116 | 0.0396 | 0.809 | 0.862 | 0.0904 | -0.0496 |
| | (0.162) | (0.252) | (0.162) | (0.175) | (0.150) | (0.241) |
| West Bengal | 0.555 | 0.168 | 1.109 | 0.814 | 0.719 | 0.666 |
| | (0.179) | (0.232) | (0.172) | (0.194) | (0.162) | (0.182) |
| Jharkhand | 0.00586 | - | 0.611 | - | 0.424 | - |
| | (0.238) | - | (0.227) | - | (0.201) | - |
| $N$ | 1147 | 576 | 1147 | 576 | 1147 | 576 |
| Districts | All | River | All | River | All | River |

Robust standard errors clustered at district level in parentheses. DO = Dissolved Oxygen
"Uttarakhand" is the reference State to the State dummy variables.

- **The results in Columns 1 to 6 are estimated by including all the control variables used for Table S.7 results except Mean District-level Short-term Morbidity.**

Table S.9: Checking for Seasonality
*State_ID* $\times$ *District_Mean_Morbidity* $\times$ *Survey_Month*

| | (1) Reading Score | (2) Reading Score | (3) Reading Score | (4) Reading Score | (5) Reading Score | (6) Reading Score |
|---|---|---|---|---|---|---|
| $1[\overline{FCOLI} > limit]$ | -0.303 | -0.0974 | 0.0433 | -0.302 | 0.00431 | -0.722 |
| | (0.0831) | (0.410) | (0.201) | (0.161) | (0.198) | (0.113) |
| $1[\overline{NIT} > limit]$ | -0.0542 | -0.346 | 0.404 | 0.0162 | 0.379 | -0.172 |
| | (0.0731) | (0.200) | (0.283) | (0.0756) | (0.317) | (0.0777) |
| *N* | 1147 | 206 | 532 | 769 | 576 | 738 |
| Sample | All | Lake | Ganges | GW | River | Trib. |

| | (7) Maths Score | (8) Maths Score | (9) Maths Score | (10) Maths Score | (11) Maths Score | (12) Maths Score |
|---|---|---|---|---|---|---|
| $1[\overline{FCOLI} > limit]$ | -0.246 | -0.132 | -0.230 | -0.156 | -0.235 | -0.319 |
| | (0.106) | (0.274) | (0.116) | (0.156) | (0.129) | (0.116) |
| $1[\overline{NIT} > limit]$ | 0.0115 | -0.181 | 0.245 | 0.0943 | 0.185 | -0.0665 |
| | (0.0788) | (0.134) | (0.532) | (0.0761) | (0.138) | (0.115) |
| *N* | 1147 | 206 | 532 | 769 | 576 | 738 |
| Sample | All | Lake | Ganges | GW | River | Trib. |

| | (13) Writing Score | (14) Writing Score | (15) Writing Score | (16) Writing Score | (17) Writing Score | (18) Writing Score |
|---|---|---|---|---|---|---|
| $1[\overline{FCOLI} > limit]$ | -0.160 | -0.181 | -0.437 | -0.0540 | -0.436 | 0.0596 |
| | (0.143) | (0.349) | (0.205) | (0.115) | (0.203) | (0.162) |
| $1[\overline{NIT} > limit]$ | 0.0698 | 0.101 | 0.0529 | 0.0531 | -0.00564 | 0.164 |
| | (0.110) | (0.186) | (0.258) | (0.0845) | (0.254) | (0.137) |
| *N* | 1147 | 206 | 532 | 769 | 576 | 738 |
| Sample | All | Lake | Ganges | GW | River | Trib. |

- Robust standard errors clustered at district level in parentheses.
- The regression specifications corresponding the results in columns 1 to 18 include all explanatory variables used for results in Tables 3, 4, and 5 with additional controls for (1) whether respondent child receives scholarship for education, (2) year-round water availability (1=adequate, 0=inadequate), (3) drinking water storage vessel (1=the household has storage vessel, 0=none), (4) Whether the HH boils water to purify water (1=does, 0=does not), (5) frequency of washing hands after defecation, (6) completed years of education, (7) Binary: Whether household has mobile phones, (8) Binary: Whether household has computer, (9) Short-term morbidity controls - the number of days the child was disabled in the last thirty days, the number of days the child showed certain symptoms like fever and coughing, and the amount of medical cost due to the short-term morbidity in the last thirty days, (10) school fees, whether the child gets free uniform (binary), costs of books, (11) Whether the household head considers the child's class teacher to be fair, parents' PTA participation (binary), child's teacher's gender, whether the child's admission to school was difficulty, frequency of child's teacher being absent at school.

Table S.10: Robustness checks: Proxying for Economic Acitivities using Nightlight

| | (1) Reading Score | (2) Reading Score | (3) Reading Score | (4) Reading Score | (5) Reading Score | (6) Reading Score |
|---|---|---|---|---|---|---|
| $1[\overline{FCOLI} > limit]$ | -0.160 | -0.656 | -0.163 | 0.0940 | -0.195 | -0.507 |
| | (0.122) | (1.206) | (0.291) | (0.174) | (0.259) | (0.188) |
| $1[\overline{NIT} > limit]$ | 0.0725 | 0.0597 | 0.00520 | 0.173 | -0.0425 | -0.162 |
| | (0.8060) | (0.285) | (0.369) | (0.0757) | (0.354) | (0.118) |
| Nightlight | 0.000383 | -0.00271 | 0.00191 | -0.000251 | -0.00357 | 0.0120 |
| | (0.00239) | (0.0133) | (0.00464) | (0.00178) | (0.00500) | (0.00451) |
| | 1048 | 157 | 515 | 687 | 559 | 656 |
| Sample | All | Lake | Ganges | GW | River | Trib. |
| | (7) Maths Score | (8) Maths Score | (9) Maths Score | (10) Maths Score | (11) Maths Score | (12) Maths Score |
| $1[\overline{FCOLI} > limit]$ | -0.246 | -0.132 | -0.230 | -0.156 | -0.235 | -0.319 |
| | (0.106) | (0.274) | (0.116) | (0.156) | (0.129) | (0.116) |
| $1[\overline{NIT} > limit]$ | 0.0115 | -0.181 | 0.245 | 0.0943 | 0.185 | -0.0665 |
| | (0.0788) | (0.134) | (0.532) | (0.0761) | (0.138) | (0.115) |
| Nightlight | 0.000578 | 0.0171 | 0.000912 | -0.000431 | -0.00287 | 0.00906 |
| | (0.00169) | (0.0217) | (0.00277) | (0.00189) | (0.00325) | (0.00408) |
| $N$ | 1048 | 157 | 515 | 687 | 559 | 656 |
| Sample | All | Lake | Ganges | GW | River | Trib. |
| | (13) Writing Score | (14) Writing Score | (15) Writing Score | (16) Writing Score | (17) Writing Score | (18) Writing Score |
| $1[\overline{FCOLI} > limit]$ | -0.418 | -1.012 | -0.900 | -0.0855 | -0.903 | -0.499 |
| | (0.177) | (1.076) | (0.282) | (0.175) | (0.254) | (0.270) |
| $1[\overline{NIT} > limit]$ | -0.232 | -0.120 | -0.491 | -0.148 | -0.530 | -0.389 |
| | (0.0924) | (0.510) | (0.151) | (0.0531) | (0.153) | (0.141) |
| Nightlight | -0.00164 | -0.00325 | -0.00444 | -0.00168 | -0.00781 | 0.00657 |
| | (0.00205) | (0.0191) | (0.00226) | (0.00222) | (0.00288) | (0.00444) |
| $N$ | 1048 | 157 | 515 | 687 | 559 | 656 |
| Sample | All | Lake | Ganges | GW | River | Trib. |

- Robust standard errors clustered at district level in parentheses.
- The regression specifications corresponding the results in columns 1 to 18 include all explanatory variables used for results in Tables 3, 4, and 5 with additional controls for (1) whether respondent child receives scholarship for education, (2) year-round water availability (1=adequate, 0=inadequate), (3) drinking water storage vessel (1=the household has storage vessel, 0=none), (4) Whether the HH boils water to purify water (1=does, 0=does not), (5) frequency of washing hands after defecation, (6) completed years of education, (7) Binary: Whether household has mobile phones, (8) Binary: Whether household has computer, (9) Short-term morbidity controls - the number of days the child was disabled in the last thirty days, the number of days the child showed certain symptoms like fever and coughing, and the amount of medical cost due to the short-term morbidity in the last thirty days, (10) school fees, whether the child gets free uniform (binary), costs of books, (11) Whether the household head considers the child's class teacher to be fair, parents' PTA participation (binary), child's teacher's gender, whether the child's admission to school was difficulty, frequency of child's teacher being absent at school. Lastly, district-level average short-term morbidity, state fixed effects, and survey month controls are also included to estimate each result.

Table S.11: Robustness checks: Proxying for Air Pollution using PM2.5 in 2012

| | (1) Reading Score | (2) Reading Score | (3) Reading Score | (4) Reading Score | (5) Reading Score | (6) Reading Score |
|---|---|---|---|---|---|---|
| $1[\overline{FCOLI} > limit]$ | -0.245 | -1.088 | -0.0874 | -0.265 | -0.160 | -0.448 |
| | (0.0868) | (0.805) | (0.157) | (0.164) | (0.187) | (0.129) |
| $1[\overline{NIT} > limit]$ | 0.0579 | 0.307 | 0.0410 | -0.0132 | 0.124 | 0.0218 |
| | (0.0833) | (0.262) | (0.271) | (0.0775) | (0.265) | (0.0721) |
| PM 2.5 in 2012 | -0.00141 | -0.0144 | 0.0119 | 0.00686 | -0.00764 | 0.00748 |
| | (0.00371) | (0.0193) | (0.01610) | (0.00768) | (0.00502) | (0.00830) |
| *N* | 1147 | 206 | 532 | 769 | 576 | 738 |
| Sample | All | Lake | Ganges | GW | River | Trib. |
| | (7) Maths Score | (8) Maths Score | (9) Maths Score | (10) Maths Score | (11) Maths Score | (12) Maths Score |
| $1[\overline{FCOLI} > limit]$ | -0.209 | 0.769 | -0.0521 | -0.236 | -0.122 | -0.320 |
| | (0.105) | (1.125) | (0.160) | (0.168) | (0.179) | (0.148) |
| $1[\overline{NIT} > limit]$ | 0.00927 | -0.0162 | -0.0194 | -0.0437 | 0.0474 | 0.000753 |
| | (0.0828) | (0.275) | (0.117) | (0.117) | (0.135) | (0.0892) |
| PM 2.5 in 2012 | -0.00772 | 0.0297 | 0.00138 | -0.0121 | -0.0114 | -0.00720 |
| | (0.00326) | (0.0274) | (0.00673) | (0.00775) | (0.00471) | (0.00612) |
| *N* | 1147 | 206 | 532 | 769 | 576 | 738 |
| Sample | All | Lake | Ganges | GW | River | Trib. |
| | (13) Writing Score | (14) Writing Score | (15) Writing Score | (16) Writing Score | (17) Writing Score | (18) Writing Score |
| $1[\overline{FCOLI} > limit]$ | -0.213 | -0.937 | -0.472 | -0.00802 | -0.525 | -0.0339 |
| | (0.158) | (1.316) | (0.229) | (0.118) | (0.228) | (0.185) |
| $1[\overline{NIT} > limit]$ | -0.126 | -0.279 | -0.156 | -0.0586 | -0.102 | -0.241 |
| | (0.101) | (0.379) | (0.207) | (0.0705) | (0.228) | (0.112) |
| PM 2.5 in 2012 | -0.00134 | 0.00350 | 0.0130 | 0.000578 | -0.00293 | 0.000297 |
| | (0.00408) | (0.0307) | (0.01732) | (0.00556) | (0.00534) | (0.00801) |
| *N* | 1147 | 206 | 532 | 769 | 576 | 738 |
| Sample | All | Lake | Ganges | GW | River | Trib. |

- Robust standard errors clustered at district level in parentheses.
- The regression specifications corresponding the results in columns 1 to 18 include all explanatory variables used for results in Tables 3, 4, and 5 with additional controls for (1) whether respondent child receives scholarship for education, (2) year-round water availability (1=adequate, 0=inadequate), (3) drinking water storage vessel (1=the household has storage vessel, 0=none), (4) Whether the HH boils water to purify water (1=does, 0=does not), (5) frequency of washing hands after defecation, (6) completed years of education, (7) Binary: Whether household has mobile phones, (8) Binary: Whether household has computer, (9) Short-term morbidity controls - the number of days the child was disabled in the last thirty days, the number of days the child showed certain symptoms like fever and coughing, and the amount of medical cost due to the short-term morbidity in the last thirty days, (10) school fees, whether the child gets free uniform (binary), costs of books, (11) Whether the household head considers the child's class teacher to be fair, parents' PTA participation (binary), child's teacher's gender, whether the child's admission to school was difficulty, frequency of child's teacher being absent at school. Lastly, district-level average short-term morbidity, state fixed effects, and survey month controls are also included to estimate each result.

Table S.12: The Effect of District-level Mean faecal Coliform Instrumented by Mean faecal Coliform in the Immediate Upstream District

| **All Districts** | (1) Reading Score | (2) Maths Score | (3) Writing Score | (4) Reading Score | (5) Maths Score | (6) Writing Score |
|---|---|---|---|---|---|---|
| Model | RE | RE | RE | RE-IV | RE-IV | RE-IV |
| Mean FCOLI | -0.0991 | -0.0722 | 0.0308 | -0.321 | 0.0445 | 0.0855 |
| | (0.0505) | (0.0377) | (0.0256) | (0.147) | (0.0976) | (0.0791) |
| Mean NIT | -0.384 | -0.276 | -0.368 | -0.352 | -0.293 | -0.376 |
| | (0.277) | (0.221) | (0.138) | (0.390) | (0.180) | (0.135) |
| *N* | 871 | 871 | 871 | 871 | 871 | 871 |
| **River Districts** | (7) Reading Score | (8) Maths Score | (9) Writing Score | (10) Reading Score | (11) Maths Score | (12) Writing Score |
| Model | RE | RE | RE | RE-IV | RE-IV | RE-IV |
| Mean FCOLI | -0.00365 | -0.000807 | -0.000521 | -0.000751 | -0.0000480 | 0.000206 |
| | (0.000735) | (0.000862) | (0.000904) | (0.000199) | (0.000224) | (0.000284) |
| Mean NIT | -1.681 | -0.549 | -0.483 | -1.602 | -0.604 | -0.460 |
| | (0.269) | (0.316) | (0.317) | (0.233) | (0.266) | (0.276) |
| *N* | 460 | 460 | 460 | 460 | 460 | 460 |
| **Tributary Districts** | (13) Reading Score | (14) Maths Score | (15) Writing Score | (16) Reading Score | (17) Maths Score | (18) Writing Score |
| Model | RE | RE | RE | RE-IV | RE-IV | RE-IV |
| Mean FCOLI | -0.716 | -0.819 | -0.0919 | -0.717 | -0.819 | -0.0919 |
| | (0.362) | (0.446) | (0.402) | (0.362) | (0.446) | (0.402) |
| Mean NIT | 0.249 | 0.668 | -0.296 | 0.249 | 0.668 | -0.296 |
| | (0.444) | (0.429) | (0.441) | (0.444) | (0.429) | (0.441) |
| *N* | 567 | 567 | 567 | 567 | 567 | 567 |

- Robust standard errors clustered at district level in parentheses. MeanFCOL = district-average faecal coliform MPN/100 ml, in millions. MeanNIT = district-average Nitrate-N + Nitrite-N mg/l. The results in columns labeled "RE-IV" utilize the district-average faecal coliform amount, which is instrumented by the average level of faecal coliform from its upstream neighbouring district.
- MeanFCOL>2500 MPN per 100 ml is the safety limit for faecal coliform. Mean NITRATE- N+ NITRITE-N are measured in miligrams per litre of water. The regression specifications corresponding the results in columns 1 to 18 include all explanatory variables used for results in Tables 3, 4, and 5 with additional controls for (1) whether respondent child receives scholarship for education, (2) year-round water availability (1=adequate, 0=inadequate), (3) drinking water storage vessel (1=the household has storage vessel, 0=none), (4) Whether the HH boils water to purify water (1=does, 0=does not), (5) frequency of washing hands after defecation, (6) child's years of schooling, (7) binary: Whether household has mobile phones, (8) binary: Whether household has computer, (9) Short-term morbidity controls - the number of days the child was disabled in the last thirty days, the number of days the child showed certain symptoms like fever and coughing, and the amount of medical cost due to the short-term morbidity in the last thirty days, (10) school fees, whether the child gets free uniform (binary), costs of books, (11) Whether the household head considers the child's class teacher to be fair, (12) whether parents participate in PTA meetings (binary), (13) child's teacher's gender, (14) binary: whether the child's admission to school was difficulty, (15) frequency of child's teacher being absent at school.

Table S.13: Differential Effect of Water Pollution on Girls

| | (1) Reading Score | (2) Maths Score | (3) Writing Score | (4) Reading Score | (5) Maths Score | (6) Writing Score |
|---|---|---|---|---|---|---|
| Female | -0.00831 | -0.124 | 0.0511 | 0.0716 | -0.0269 | -0.0163 |
| | (0.0684) | (0.0987) | (0.0810) | (0.0844) | (0.0640) | (0.0758) |
| (1) $1[\overline{FCOLI} > limit]$ | -0.231 | -0.222 | -0.197 | -0.107 | -0.0804 | -0.547 |
| | (0.0907) | (0.139) | (0.177) | (0.194) | (0.201) | (0.239) |
| Female × (1) | -0.0223 | 0.0465 | -0.0283 | -0.0919 | -0.0658 | 0.0457 |
| | (0.0806) | (0.128) | (0.109) | (0.112) | (0.101) | (0.103) |
| $1[\overline{NIT} > limit]$ | 0.0498 | -0.0353 | -0.133 | 0.0948 | 0.00750 | -0.109 |
| | (0.0744) | (0.0751) | (0.0872) | (0.260) | (0.131) | (0.228) |
| Observations | 1147 | 1147 | 1147 | 576 | 576 | 576 |
| Sample | All | All | All | River | River | River |

| | (7) Reading Score | (8) Maths Score | (9) Writing Score | (10) Reading Score | (11) Maths Score | (12) Writing Score |
|---|---|---|---|---|---|---|
| Female | 0.0274 | -0.0458 | 0.0100 | 0.0631 | 0.0112 | 0.0343 |
| | (0.0517) | (0.0497) | (0.0497) | (0.0928) | (0.102) | (0.0747) |
| (2) Cost of Books, Uniform | 0.103 | 0.0665 | 0.0163 | 0.0940 | 0.0799 | -0.0134 |
| in 1000 Rupees. | (0.0291) | (0.0377) | (0.0363) | (0.0494) | (0.0543) | (0.0360) |
| Female × (2) | -0.0630 | -0.0555 | 0.0257 | -0.0806 | -0.109 | -0.0138 |
| | (0.0293) | (0.0355) | (0.0330) | (0.0466) | (0.0490) | (0.0356) |
| $1[\overline{FCOLI} > limit]$ | -0.243 | -0.199 | -0.211 | -0.169 | -0.133 | -0.526 |
| | (0.0833) | (0.101) | (0.155) | (0.169) | (0.168) | (0.223) |
| $1[\overline{NIT} > limit]$ | 0.0415 | -0.0426 | -0.130 | 0.0699 | -0.0295 | -0.117 |
| | (0.0745) | (0.0756) | (0.0870) | (0.267) | (0.144) | (0.231) |
| Observations | 1147 | 1147 | 1147 | 576 | 576 | 576 |
| Sample | All | All | All | River | River | River |

| | (13) Reading Score | (14) Maths Score | (15) Writing Score | (16) Reading Score | (17) Maths Score | (18) Writing Score |
|---|---|---|---|---|---|---|
| Female | -0.0317 | -0.0907 | 0.0247 | -0.0193 | -0.0838 | -0.00166 |
| | (0.0401) | (0.0479) | (0.0442) | (0.0650) | (0.0836) | (0.0626) |
| (3) HH has indoor piped water | 0.0939 | 0.0292 | 0.134 | 0.252 | 0.0666 | 0.0534 |
| | (0.115) | (0.0872) | (0.136) | (0.125) | (0.129) | (0.149) |
| Female × (3) | 0.0593 | -0.00682 | 0.0434 | 0.0222 | -0.00904 | 0.143 |
| | (0.0930) | (0.103) | (0.165) | (0.119) | (0.169) | (0.200) |
| $1[\overline{FCOLI} > limit]$ | -0.244 | -0.199 | -0.213 | -0.149 | -0.113 | -0.526 |
| | (0.0821) | (0.101) | (0.155) | (0.154) | (0.163) | (0.214) |
| $1[\overline{NIT} > limit]$ | 0.0549 | -0.0348 | -0.128 | 0.160 | 0.0238 | -0.0689 |
| | (0.0730) | (0.0755) | (0.0850) | (0.232) | (0.122) | (0.214) |
| Observations | 1147 | 1147 | 1147 | 576 | 576 | 576 |
| Sample | All | All | All | River | River | River |

- Robust standard errors clustered at district level in parentheses. FCOLI = Faecal Coliform and NIT = Nitrate-N + Nitrite
- The regression specifications corresponding the results in columns 1 to 18 include all explanatory variables used for results in Tables 3, 4, and 5 with additional controls for (1) whether respondent child receives scholarship for education, (2) year-round water availability (1=adequate, 0=inadequate), (3) drinking water storage vessel (1=the household has storage vessel, 0=none), (4) HH boils water to purify water (1=does, 0=does not), (5) frequency of washing hands after defecation, (6) completed years of education, (7) Binary: Whether household has mobile phones, (8) Binary: whether household has computer, (9) short-term morbidity controls - the number of days the child was disabled in the last thirty days, the number of days the child showed certain symptoms like fever and coughing, and the amount of medical cost due to the short-term morbidity in the last thirty days, (10) school fees, whether the child gets free uniform (binary), costs of books, (11) Whether the household head considers the child's class teacher to be fair, parents' PTA participation (binary), child's teacher's gender, whether the child's admission to school was hard, frequency of child's teacher being absent at school. Lastly, district-level average short-term morbidity, state fixed effects, and survey month controls are also included to estimate each result.

Table S.14: Differential Effect of Water Pollution on Girls (continued...)

| | (1) Reading Score | (2) Maths Score | (3) Writing Score | (4) Reading Score | (5) Maths Score | (6) Writing Score |
|---|---|---|---|---|---|---|
| Female | 0.0114 | -0.141 | -0.181 | 0.331 | -0.493 | -0.225 |
| | (0.183) | (0.303) | (0.361) | (0.337) | (0.346) | (0.278) |
| (1) Water availability normal the whole year = 1 | -0.165 | -0.0181 | -0.0279 | 0.0272 | 0.124 | -0.0852 |
| | (0.157) | (0.149) | (0.187) | (0.276) | (0.292) | (0.285) |
| Female × (1) | -0.0366 | 0.0511 | 0.219 | -0.343 | 0.417 | 0.252 |
| | (0.190) | (0.308) | (0.360) | (0.344) | (0.333) | (0.257) |
| $1[\overline{FCOLI} > limit]$ | -0.242 | -0.199 | -0.212 | -0.155 | -0.115 | -0.524 |
| | (0.0834) | (0.100) | (0.157) | (0.164) | (0.164) | (0.224) |
| Nitrate/Nitrite unsafe levels | 0.0496 | -0.0350 | -0.132 | 0.0968 | 0.0147 | -0.109 |
| | (0.0746) | (0.0749) | (0.0875) | (0.262) | (0.130) | (0.227) |
| Observations | 1147 | 1147 | 1147 | 576 | 576 | 576 |
| Sample | All | All | All | River | River | River |

| | (7) Reading Score | (8) Maths Score | (9) Writing Score | (10) Reading Score | (11) Maths Score | (12) Writing Score |
|---|---|---|---|---|---|---|
| Female | -0.107 | -0.189 | 0.0986 | 0.00506 | 0.240 | 0.368 |
| | (0.0705) | (0.164) | (0.209) | (0.211) | (0.425) | (0.265) |
| (2) Water availability normal during summer | 0.0909 | 0.106 | -0.0727 | -0.0132 | -0.331 | -0.362 |
| | (0.0873) | (0.158) | (0.211) | (0.236) | (0.417) | (0.304) |
| Female × (2) | -0.0630 | -0.0555 | 0.0257 | -0.0806 | -0.109 | -0.0138 |
| | (0.0293) | (0.0355) | (0.0330) | (0.0466) | (0.0490) | (0.0356) |
| $1[\overline{FCOLI} > limit]$ | -0.228 | -0.187 | -0.192 | -0.118 | -0.0948 | -0.515 |
| | (0.0840) | (0.103) | (0.157) | (0.159) | (0.163) | (0.215) |
| Nitrate/Nitrite unsafe levels | 0.0487 | -0.0356 | -0.137 | 0.0725 | 0.00707 | -0.114 |
| | (0.0747) | (0.0757) | (0.0849) | (0.259) | (0.121) | (0.226) |
| Observations | 1147 | 1147 | 1147 | 576 | 576 | 576 |
| Sample | All | All | All | River | River | River |

| | (13) Reading Score | (14) Maths Score | (15) Writing Score | (16) Reading Score | (17) Maths Score | (18) Writing Score |
|---|---|---|---|---|---|---|
| Female | -0.107 | -0.189 | 0.0986 | 0.00506 | 0.240 | 0.368 |
| | (0.0705) | (0.164) | (0.209) | (0.211) | (0.425) | (0.265) |
| (3) HH purifies water before drinking | -0.0478 | -0.0304 | 0.274 | 0.000347 | 0.461 | 0.296 |
| | (0.111) | (0.157) | (0.194) | (0.217) | (0.302) | (0.346) |
| Female × (3) | 0.0593 | -0.00682 | 0.0434 | 0.0222 | -0.00904 | 0.143 |
| | (0.0930) | (0.103) | (0.165) | (0.119) | (0.169) | (0.200) |
| $1[\overline{FCOLI} > limit]$ | -0.228 | -0.187 | -0.192 | -0.118 | -0.0948 | -0.515 |
| | (0.0840) | (0.103) | (0.157) | (0.159) | (0.163) | (0.215) |
| $1[\overline{NIT} > limit]$ | 0.0487 | -0.0356 | -0.137 | 0.0725 | 0.00707 | -0.114 |
| | (0.0747) | (0.0757) | (0.0849) | (0.259) | (0.121) | (0.226) |
| Observations | 1143 | 1143 | 1143 | 573 | 573 | 573 |
| Sample | All | All | All | River | River | River |

- Robust standard errors clustered at district level in parentheses. FCOLI = Faecal Coliform and NIT = Nitrate-N + Nitrite
- The regression specifications corresponding the results in columns 1 to 18 include all explanatory variables used for results in Tables 3, 4, and 5 with additional controls for (1) whether respondent child receives scholarship for education, (2) year-round water availability (1=adequate, 0=inadequate), (3) drinking water storage vessel (1=the household has storage vessel, 0=none), (4) Whether the HH boils water to purify water (1=does, 0=does not), (5) frequency of washing hands after defecation, (6) completed years of education, (7) Binary: Whether household has mobile phones, (8) Binary: Whether household has computer, (9) Short-term morbidity controls - the number of days the child was disabled in the last thirty days, the number of days the child showed certain symptoms like fever and coughing, and the amount of medical cost due to the short-term morbidity in the last thirty days, (10) school fees, whether the child gets free uniform (binary), costs of books, (11) Whether the household head considers the child's class teacher to be fair, parents' PTA participation (binary), child's teacher's gender, whether the child's admission to school was difficulty, frequency of child's teacher being absent at school. Lastly, district-level average short-term morbidity, state fixed effects, and survey month controls are also included to estimate each result.

Table S.15: Interaction between Indoor Piped Water Supply and Exposure to faecal Coliform above Safety Level

| Test | (1) Reading Score | (2) Maths Score | (3) Writing Score | (4) Reading Score | (5) Maths Score | (6) Writing Score | (7) Reading Score | (8) Maths Score | (9) Writing Score |
|---|---|---|---|---|---|---|---|---|---|
| Female | -0.0255 | -0.0920 | 0.0306 | -0.0175 | -0.0866 | 0.0204 | -0.0261 | -0.0568 | 0.0778 |
| | (0.0377) | (0.0495) | (0.0440) | (0.0577) | (0.0823) | (0.0682) | (0.0409) | (0.0598) | (0.0513) |
| (1) Household has Indoor Piped Water Supply | 0.130 | -0.328 | 0.894 | 0.0447 | -0.267 | 0.818 | 0.216 | -0.296 | 0.819 |
| | (0.486) | (0.406) | (0.163) | (0.391) | (0.344) | (0.190) | (0.533) | (0.412) | (0.191) |
| $1[\overline{FCOLI} > limit]$ | -0.244 | -0.210 | -0.189 | -0.173 | -0.150 | -0.444 | -0.482 | -0.323 | -0.0411 |
| | (0.0837) | (0.105) | (0.148) | (0.160) | (0.173) | (0.192) | (0.122) | (0.142) | (0.184) |
| $(1) \times 1[\overline{FCOLI} > limit]$ | -0.00651 | 0.389 | -0.812 | 0.259 | 0.387 | -0.803 | -0.0373 | 0.546 | -0.630 |
| | (0.466) | (0.405) | (0.167) | (0.380) | (0.397) | (0.211) | (0.492) | (0.438) | (0.236) |
| $1[\overline{NIT} > limit]$ | 0.0529 | -0.0347 | -0.129 | 0.171 | 0.0441 | -0.122 | 0.0254 | -0.00812 | -0.230 |
| | (0.0732) | (0.0756) | (0.0835) | (0.231) | (0.129) | (0.215) | (0.0689) | (0.0886) | (0.107) |
| Observations | 1147 | 1147 | 1147 | 576 | 576 | 576 | 738 | 738 | 738 |

Robust standard errors clustered at district level in parentheses. FCOLI = Faecal Coliform and NIT = Nitrate-N + Nitrite

- The regression specifications corresponding the results in columns 1 to 9 include all explanatory variables used for results in Tables 3, 4, and 5 with additional controls for (1) whether respondent child receives scholarship for education, (2) year-round water availability (1=adequate, 0=inadequate), (3) drinking water storage vessel (1=the household has storage vessel, 0=none), (4) Whether the HH boils water to purify water (1=does, 0=does not), (5) frequency of washing hands after defecation, (6) completed years of education, (7) Binary: Whether household has mobile phones, (8) Binary: Whether household has computer, (9) Short-term morbidity controls - the number of days the child was disabled in the last thirty days, the number of days the child showed certain symptoms like fever and coughing, and the amount of medical cost due to the short-term morbidity in the last thirty days, (10) school fees, whether the child gets free uniform (binary), costs of books, (11) Whether the household head considers the child's class teacher to be fair, parents' PTA participation (binary), child's teacher's gender, whether the child's admission to school was difficulty, frequency of child's teacher being absent at school. Lastly, district-level average short-term morbidity, state fixed effects, and survey month controls are also included to estimate each result.