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Access to Clean Water and Human Capital Formation – Evidence from Indonesia

by

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Abstract

We estimate the causal effect of access to clean water sources on educational outcomes in Indonesia. Using the longitudinal Indonesian Family Life Survey (IFLS) panel dataset, which follows the same individuals from 1993 to 2014, and applying household fixed effects allows us to identify the causal effect of access to clean water at different childhood stages on children's educational performance. We find that lifetime and early childhood access increases strongly the likelihood of completing junior and senior secondary school; later-gained access has no discernible effect on school performance. Our results underscore the need to provide access to clean water very early on.

JEL codes: I25, O15, Q53

Keywords: Access to Tap Water, Access to Improved Water, Educational Outcomes, Indonesia

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1 Introduction

Access to clean water is crucial for individual health and well-being. It prevents water-related diseases contracted by drinking contaminated water, such as typhoid, cholera, giardia, dysentery, cancer, trachoma, and a variety of parasitic diseases caused by roundworms, hookworms, whipworms, dracunculiasis, and other parasites (Lin et al. 2022, UNESCO 2021).¹ These diseases are not only very painful and too often deadly; they also cause medical expenses that strain poor households' budgets. Water-related diseases are not a small issue at all: The WHO estimated that in 2019, 1.4 million deaths and a loss of 74 million disability-adjusted life years (DALYs) were caused by the lack of access to clean water and proper sanitation and hygiene (WASH) (UNESCO 2023, ch.6, p.88); in 2016, 829,000 people died from diarrhea alone because they lacked safe water and sanitation (Prüss-Ustün et al. 2019), many more fell ill.²

Children are particularly affected by water-related diseases as they are more vulnerable (Fink et al. 2011). In 2016, approximately 300,000 children under the age of 5 years died from diarrheal diseases related to WASH (Prüss-Ustün et al. 2019). However, deprivation of clean water affects children well beyond the immediate health effects, as measured by higher mortality and morbidity rates. It can impact the mental and social development of children (Bartlett 2003). Most importantly, it can compromise human capital formation. Children may miss school because they are sick or because parents cannot afford to send their children to school as water-related diseases drain family resources. Health expenditures rise and parents may forego income because they care for their kids. Especially young girls may have to invest more time in water-fetching at the expense of school work (Ashraf et al. 2021, Sorenson et al. 2011). This may lower school attainment, and thus compromise cognitive abilities and thereby long-term economic development of affected individuals (Almond et al. 2018).

While the effect of (lacking) access to clean water on health has been well understood,³ its effect on human capital formation has been less well researched. A central methodological challenge in the clean water–education nexus are reverse causality issues. In particular, better-educated households are more likely to have access to clean water as they tend to be richer (Hasan & Alam 2020, Yang et al. 2013); at the same time, better-educated households tend to have children who do better in school (Fleury & Gilles 2018, Liu 2018). Almost all existing studies are correlational (see below) and as such provide estimates on the “effect” of clean water access on school that are biased upwards. In addition, other confounding variables, such as attitudes and health-related behavior, are almost impossible to control for.

To address these issues we focus on the case of Indonesia and use the Indonesian Family Life

¹As a fundamental human right, access to clean water is intricately linked to the achievement of several Sustainable Development Goals (SDGs) set forth by the United Nations. Clean water access has strong effects not only at the individual level but also on the community and societal level. First and foremost, clean water is indispensable for maintaining public health, but it also affects economic prosperity and growth and the status of women (UNESCO 2021, Ray 2007). The SDG6 targets are far from the mark with an estimated 2.2 billion people who did not have access to safe drinking water in 2022 (UNESCO 2025).

²Having good quality tap water continuously available in the premises alone reduces the risk of diarrhea by three quarters (Wolf et al. 2018). Jalan & Ravallion (2003) show that children below 5 years in rural India have a much lower diarrhea prevalence if they live in households with tap water.

³E.g., Ashraf et al. (2021), Galiani et al. (2005), Gamper-Rabindran et al. (2010), Fewtrell et al. (2005), Prüss-Ustün et al. (2019).

Survey, a longitudinal household survey spanning the period 1993 to 2014 and covering more than 30,000 individuals with very low attrition rates. We employ household fixed effects, which allows us to focus on the within-household variation in access rates, thereby eliminating the confounding factors at the household level (and beyond). We compare siblings with and without access to clean water at different ages within the same non-migrating household and thus keep important confounders such as parental education, socio-economic status, genetic dispositions, ethnicity and religion, health- and education-related attitudes and a host of time-invariant regional influences constant. We control for potentially changing environmental variables by including a large array of time-varying community-level variables such as distance to school, availability of health facilities, changes in other village infrastructure etc., and by including time fixed effects.

So far, identification of causal effects in our context has been limited to exogenous variations in access rates due to large-scale interventions (Zhang & Xu 2016); these are rare and not very typical for developing essential water infrastructure, which is gradually expanded over time. Our approach allows for measuring the effect of such (gradual) investment as households are affected by it. Concretely, we analyze how access to clean water at different stages in the childhood affects the likelihood of completing primary, junior secondary, and senior secondary school.

We study the Indonesian case, because its excellent data allow for causal estimates, but it is highly interesting beyond that. Indonesia is the fourth most populous country in the world, the dominating economy in Southeast Asia, and an emerging economic power (Hill 2026); it has a diverse social and economic structure that allows to study large differences within one country and over time. In 2018, access rates to improved water sources ranged from 35 percent in West Kalimantan to 93 percent in Jakarta; average access rates have improved in our period of study from 51 percent in 1993 to 83 percent in 2014 (World Bank 2019).

Our results show that access to clean water significantly affects school completion rates – the earlier a child receives access to clean water, the better it is for educational attainment. Children who had access to clean water throughout their lives were 28 percentage points more likely to complete junior secondary school than children who had access to clean water in late childhood or never. The effect is similar for senior secondary school completion, which is 33 ppt. higher for children who had access to clean water early on. We observe more pronounced effects for children in rural areas compared to those in urban areas. If anything, boys benefit slightly more from access to clean water than girls. We find suggestive evidence that the results are driven by infections with diarrhea, both by severe infections during early childhood and by contemporaneous infections. These infections lead to an increased number of days missed at school, which is related to a lower probability of completing school levels.

Related literature Our paper speaks to several strands of the literature. Most importantly, we contribute to the literature on the role of access to clean water for school performance. Several studies have examined the link between water access and educational outcomes, yet many face methodological limitations. The main problem is that the previous studies have either been only correlational or have not been able to account for all relevant unobserved variation at the household level. The studies with only correlational analyses include Barde & Walkiewicz (2014), Dearden

et al. (2017), Dhital et al. (2022), Nauges & Strand (2017), Spears & Lamba (2016), Aggarwal et al. (2024), Koolwal & van de Walle (2013), and Florez-Garcia et al. (2025). Even though insightful, they cannot control for a range of unobservable factors such as health-related attitudes and habits, attitudes regarding school performance, or genes etc. Suppose these factors are correlated with access to clean water, for example, families more aware of health risks from contaminated water seek clean water access more strongly than others (and possibly exhibit a more careful approach to other health risks as well, or have different attitudes towards education). In that case, the factors confound the results, potentially very seriously.

A small number of studies have employed panel analyses that include fixed effects, however, these fixed effects have been limited to the village or province level only (Cameron et al. 2021, Chen et al. 2022a, Zhang & Xu 2016). These studies control for unobserved heterogeneity at the village or province level (capturing, for instance, cultural differences between provinces), but are not able to control for unobserved heterogeneity at the household level. Very similar confounding factors - differences in attitudes, habits, genes, etc. - across households (within a village or province) remain uncontrolled for, which again may significantly bias results. In contrast, we focus on the variations *within households* by including household fixed effects and thereby control for these confounders at the household level, and - as we focus on non-migrating households only - also at time-invariant confounders at the village and region level, and beyond.

Second, our study contributes to the literature on how access to clean water affects individual development. Several studies have examined the relationship between access to clean water and health using different water and health indicators. While Greenstone & Hanna (2014) find no effect of water policy in India on child mortality, most other studies agree that deteriorating water quality leads to significantly worse health outcomes (Galiani et al. 2005, Kremer et al. 2011, Ebenstein 2012, Brainerd & Menon 2014, He & Perloff 2016, Marcus 2020, Fan & He 2023, Li & Xiao 2023, Balza et al. 2025). Through its effect on health, access to clean water is likely to also affect educational outcomes.

Third, we contribute to the literature on the effects of early-life shocks on individual development. Several early-life events have been found to affect both health and education, such as natural disasters (Karbownik & Wray 2019, Gunnsteinsson et al. 2022), conflicts (Minoiu & Shemyakina 2014, Akbulut-Yuksel 2017, Unfried & Kis-Katos 2023), or rainfall shocks (Rocha & Soares 2015, Shah & Steinberg 2017). Our study provides likewise evidence on the effectiveness of early life interventions, in our case, whether children had access to clean water early in life.

The paper is organized as follows. Section two provides an overview of the current state of Indonesia's water and education systems. Section three presents the IFLS data we use. Section four details our empirical strategy. Section five presents the results including a large number of robustness checks. Section six concludes.

2 Background

2.1 Access to Clean Water Sources in Indonesia

Although the proportion of the population with access to improved water sources has increased globally, significant regional disparities persist, and some parts of the world still have very low access rates. In lower-income countries, for example, only 59 percent of the population has access to safely managed water, compared to 93 percent in high-income countries (United Nations Children’s Fund (UNICEF) & World Health Organization 2023). In recent years, technological advances have created numerous opportunities to bring clean water to a larger portion of the world’s population. However, this potential remains largely unrealized, reflecting persistent deficiencies in water management and governance. (Cosgrove & Loucks 2015).

Indonesia mirrors this picture, both in terms of overall progress and interregional divergence in access to clean water. Access to clean water has improved from an average rate of 51% in 1993 to 89% in 2014.⁴ There are large regional disparities in access rates – in Jakarta, 93.4 percent of the population has access to improved water sources, while in West Kalimantan the rate is only 34.9 percent. Figure A.2 in the appendix shows the percentage of households with access to improved water sources by region in 2018. In general, the problem of lack of access to improved water is most severe in regions with a high proportion of rural settlements. It is a severe problem overall: Approximately 33 million people in Indonesia still lack access to improved water sources.

Indonesia is the dominant country in Southeast Asia and one of the fastest-growing countries in the world. It is the third-largest democracy in the world and a very young one. Despite its remarkable growth performance – GDP has grown by an average of 5.5 percent, and poverty rates have fallen from 18.2 percent in 2002 to 11.2 percent in 2015 (World Bank 2017) – many structural problems remain in economic institutions, the political system, and in infrastructure, the environment with inadequate water infrastructure being among the most pressing concerns. 53 percent of Indonesia’s rivers are severely polluted, and access to piped water is stagnating. These problems may particularly affect women in rural areas, as they are primarily responsible for fetching water. This means they are exposed to water pollution and have less time for other activities such as studying. In addition, service interruptions are still common in Indonesia and the quality of water services for the poor remains low. Only 20 percent of the bottom 40 percent of the income distribution have a piped water connection. More importantly, a quarter of the bottom 40 percent drink from unsafe groundwater sources (World Bank 2019, 2021).

Limited access to improved water sources may generate a poverty trap. Poor households are disproportionately exposed to water-related illness (as they are less likely to have access to clean water), which lowers labor productivity, reduces savings as health expenditures crowd out small investments, and hampers human capital accumulation when children do not complete school. These mechanisms reinforce existing disadvantages and prolong poverty. Expanding access to clean water can therefore yield substantial health gains and broader development benefits, particularly for poor

⁴When we exclude bottled water from the clean water category, access rates have only increased from 45 % in 1993 to 52 % in 2014.

populations. Understanding the determinants of regional and social disparities in water access is thus essential for improving outcomes in disadvantaged areas and for designing policies that mitigate the lock-in effects described above (World Bank 2017).

2.2 Education in Indonesia

The Indonesian school system has three main stages. Children typically begin with six years of primary school between the ages of six and twelve, followed by three years each of junior and senior secondary school.

Indonesia has made substantial strides in expanding access to education since 1973, during the Suharto era. At that time, the government launched an ambitious school construction program that significantly increased the number of educational facilities. This expansion contributed to higher educational attainment (Duflo 2001), which later translated into improved labor market and marriage market outcomes (Akresh et al. 2023). Universal primary education was achieved as early as 1983. By 2007/2008, approximately 81 percent of students completed primary school, and secondary school enrollment rose from around 50 percent in 1990 to about 80 percent by 2007/2008 (Suryadarma & Jones 2013*b*).

Following the decentralization reforms in 2001, public education spending increased markedly. Between 2000 and 2016, education expenditure nearly tripled, with a strong focus on primary education (Al-Samarrai & Cerdan-Infantes 2013). This investment significantly improved school access, particularly for poorer and marginalized households. However, spending on secondary and higher education remained relatively limited. Despite decentralization, national education standards and policies continued to be set by the central government.

Local governance and fiscal policy have also influenced education outcomes. A legal mandate requires district governments to allocate at least 20 percent of their budgets to education, and this has led some districts to increase their education spending accordingly (Lewis 2023). Lewis (2021), however, suggest that this mandate has not significantly improved school participation or learning outcomes. Furthermore, the current system of fiscal transfers creates perverse incentives: many districts overspend on teacher salaries at the expense of materials and capital investments, reducing the overall efficiency of education spending. Lewis & Nguyen (2020) have found that more and better education could be delivered even without additional resources, if existing funds were used more effectively. In terms of broader educational reforms, the 1994 compulsory schooling initiative had little measurable impact on child educational attainment.

Despite these challenges, education remains central to Indonesia’s long-term economic development. The economy has returned to its pre-pandemic growth trajectory, and education continues to receive significant national funding—Rp 608 trillion was allocated in 2023 alone (Anas et al. 2022). Indonesia achieved upper-middle income status in 2020, with improvements in living standards, poverty reduction, and inequality (Hill 2021). Future goals include shifting toward higher-value production and attracting downstream industries, both of which will require a more skilled workforce. Achieving this will necessitate further reforms in how education is financed and delivered (Suryahadi & Sambodho 2013, Gupta 2023). Extending access to clean water could contribute to better

educational attainment. This is what we turn to next.

3 Data

We use five rounds of data from the Indonesian Family Life Surveys (IFLS). The IFLS data are high-quality longitudinal data available for 1993, 1997, 2000, 2007, and 2014. The data were collected by the RAND Corporation in collaboration with Universitas Indonesia, Universitas Gadjah Mada, and UCLA.

The significant advantages of the IFLS dataset include a very low attrition rate (87 percent of households included in the survey were interviewed in all five waves) and that it follows the same individuals over a long period (1993-2014). The IFLS surveys are representative of 83 percent of the Indonesian population (Strauss et al. 2016). They cover provinces with good access to clean water sources, such as DKI Jakarta, and provinces with low access rates, such as West Sulawesi. An overview of all IFLS provinces is shown in Figure A.1 in the appendix. With the sampling weights, which we use, the IFLS is representative for Indonesia as a whole.⁵ The dataset consists of several surveys on household and community characteristics. For our study, we use different household, community, and individual surveys.

We only consider households that did not migrate, thereby avoiding selection biases (Schwank 2024) and confounders from changing environments. Our analysis is furthermore restricted to households that did not lose access to clean water sources after gaining access.⁶ Unrealistic outliers are dropped from the data frame, such as individuals who were reported to have completed primary school at age 5 or 20 by restricting the data frame to individuals who completed primary school at age 12 to 14, junior secondary school at age 15 to 17 and senior secondary school at age 18 to 20. In addition, we restrict our analysis to individuals not older than 40 in our sample to avoid including individuals who left school a long time ago. This leaves us with 15,642 observations at the elementary school level, 12,433 observations at the junior secondary level, and 7,792 observations at the senior secondary level, for which we have data for our control variables.

Our dependent variables are three dummy variables for school completion; i.e., dummies for whether an individual completed elementary school, junior secondary school, and senior secondary school.

Our main independent variables indicate whether an individual had access to clean water at a certain age. We create the variables `ACCESS_TO_CLEAN_WATER_THROUGHOUT_LIFE` for children that had access to clean water in their entire life, `ACCESS_TO_CLEAN_WATER_GAINED_AGE1TO4` for children that gained access to clean water after their birth but until their fifth birthday, and `ACCESS_TO_CLEAN_WATER_GAINED_AGE5TO9` for children that gained access to clean water after

⁵Results hardly change if we do not use the sample weights.

⁶Since in 2014 these were only around five percent of all households that gained access.

their fifth birthday, but before their tenth birthday.⁷

The IFLS data detail the timelines of communities and individual households gaining access to clean water. An overview of the development of clean water sources is provided in Table A.2. The household survey states whether a household had access to clean water at the time of the survey. The village survey provides the year the village got access to a piped water system. We use these two pieces of information to compute the year the household got access. For instance, if the household survey indicated that a household had no access in the 1993 survey round, but had access in in the 1997 round and the village survey indicated that the village got connected in 1995, we use 1995 as the year the household got access. (If the household had no access in 1997, even though the village had a connection we coded the household as having no access and looked at the next survey wave.) For households that already had access to clean water in the first survey round we impute the year they got access (as we have no information on the year they gained access.) We use the year the village was connected (if they got connected before 1993) and add the average time period it took the household to get connected to the pipe system.

As control variables, we include several individual and household variables. Information on whether an individual had access to improved sanitation or was exposed to open defecation is used. We also divide households into five wealth categories measured by household consumption, with the first wealth category containing the poorest households and the fifth wealth category containing the wealthiest households. Moreover, we control for the size of the household, whether a household had access to electricity, as well as the gender of the individual and an urban/rural dummy.

As improvements in access to health and school infrastructure could bias our results, we use community information on the availability of such services. For the health infrastructure, we include dummies that indicate whether a household has a local health facility, a *puskesmas* (community health center), or a *posyandu* (integrated health post) in the community.⁸ We also include the distance to the respective school unit for each individual, which is provided in the IFLS individual survey. We thus include the distance to the primary school in the regressions with elementary school completion as the dependent variable, and the distance to nearest junior (senior) secondary school in the regression with junior (senior) secondary school completion as LHS variable. As an extension we use a number of community-level confounders that may affect either schooling outcomes directly or the effect of (lacking) water access on schooling and may be correlated with the introduction of clean water to the village such as the change to asphalt roads, new school buildings, the gained village's access to electricity, sewage system or to health facilities. These data are taken from the community survey in the IFLS.

Descriptive statistics are provided in the Appendix in Table A.1.

⁷In Indonesia, bottled water is an important source of clean water for households. As shown in Table A.2 in the appendix, 37 percent of households used bottled water as their main source of drinking water in 2014. Therefore, our definition of clean water sources encompasses both improved water sources (such as piped water, protected springs, protected wells, and rainwater) and bottled water. Burlig et al. (2025) show that households in India have a high willingness to pay for bottled water.

⁸Puskesmas serve as a primary health care service, with around 10326 facilities in Indonesia (Meliala & Rarasati 2022). Posyandu is an integrated service post that serves mothers and under-five year old children with essential health services and counseling (Yani et al. 2023).

4 Estimation Strategy

We estimate the following model:

$$Y_{ijt} = \beta_0 + \beta_1 * access_to_clean_water_age_{ijt} + X'_{1ijt} * \gamma + \mu_j + \delta_t + \epsilon_{ijt}, \quad (1)$$

where Y_{ijt} is the education or health outcome for individual i in household j born in year t . $Access_to_clean_water_{ijt}$ is the main independent variable. We include three different versions of this variable. First, we create a dummy for whether individuals have had access to clean water throughout their lives. Next, we create dummies for whether individuals did not have access to clean water at the beginning of their lives, but gained access either in the first four years of life or between the ages of five and nine. We run three separate regressions on these three dummies. As a control group, we always use the individuals who never had access to clean water and those who only had access to clean water after age 10.

X'_{1ijt} are time-varying household characteristics (wealth, access to electricity, gender of household head, education of household head, age of household head), and individual characteristics (gender, distance to school, birth order). μ_j are household fixed effects, δ_t denote year of birth fixed effects. We cluster the standard errors ϵ_{ijt} at the community level.

Our estimation strategy provides several advantages over previously used methods in the water and education literature. In the absence of a structured political program and considering the gradual evolution of water access, a household fixed effects approach stands out as the most robust method to identify a causal effect in our study.⁹ Our methodology is replicable for other situations characterized by a gradual transformation of gaining access to clean water over time, which is similar to the unfolding process of water access development in Indonesia, but it is also the most common process in other countries. Our strategy, therefore, helps to understand the effect of increasing access to clean water in many developing countries around the world and can also provide an example for similar studies in other countries where a similar data set is available.

Household fixed effects provide a huge advantage for identifying causal effects as they effectively control for observable and unobservable time-invariant characteristics at the household level that influence the probability of access to clean water or the school performance (beyond the clean water access), some of which are elusive factors very hard to measure and which, if not controlled for, could greatly confound the results. In the context of our study, these household-specific factors include socioeconomic status, genetic constitution, parental education, attitudes towards schooling, and health-related attitudes and behaviors. Since we analyze only non-migrating households, household fixed effects also capture a host of environmental factors, such as geography, availability of surface water, and cultural practices.¹⁰ By integrating household fixed effects, we essentially establish a "within-household" comparison, allowing us to disentangle the impact of changes in water

⁹In a methodologically related approach, Kammerlander & Schulze (2023) analyze the effect of local economic growth - a gradual development - on child mortality (a binary variable) using mother fixed effects, thereby controlling for a host of confounding factors.

¹⁰For instance, Bowen et al. (2012) show that the practice of handwashing at school greatly reduced student absenteeism.

access within each household. This strategy helps to mitigate potential unobserved differences across households and fortifies the internal validity of our findings.

However, it is essential to note that while the household fixed effects approach is a powerful tool for controlling for time-invariant confounding factors, it does not entirely eliminate the potential influence of time-varying confounders. Therefore, we also incorporate pertinent time-variant control variables, as described in the data section, in addition to time dummies, which control for national trends and shocks. These include in particular variables that capture ease to go to school (distance to school) and the availability of health facilities (*puskesmas*, *posyandu*).

5 Results

5.1 Main Results

Table 1, columns (1) to (3) illustrate the effect of access to clean water on primary school completion, focusing on different exposure periods. The analysis considers a specification with controls, year of birth, survey round fixed effects, and household fixed effects. Due to the high share of students who completed primary school, there is no large difference between the treatment and the control group, which leads to the insignificant results.¹¹

In columns (4) to (6), we test the effect of access to clean water on junior secondary school completion rates. We find a strong impact of access to clean water on completion rates, which decreases the later the child gained access. The effect of lifetime access to clean water is 0.28 compared to those who never had access or gained access after age 10 and reduces to 0.20 when the child gained access before turning 5. These effects are statistically highly significant and economically large! Access gained after the age of five is close to zero and no longer statistically significant.

Columns (7) to (9) estimate the effect of access to clean water on upper secondary school completion. The effect is most substantial for early access to clean water sources: an increase of 33 percentage points compared to individuals with no access or late access to clean water sources. Again, this is a very strong effect. The trend continues for senior secondary school completion, mirroring the findings observed for junior secondary schooling. As we only have few observations that could have had lifetime access to clean water and complete senior secondary school due to the length of our panel data, we only have a weak signal on the effect of lifetime access to clean water on senior secondary school completion. The weak signal explains the insignificant results here. We show the full results in the appendix in Table A.3.

¹¹We also tested our model without household fixed effects, in which we find a positive and significant effect of access to clean water throughout life on primary school completion.

Table 1: Baseline Results

	Elementary school completed			Junior secondary completed			Senior secondary completed		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Access to clean water throughout life	0.04 (0.04)			0.28*** (0.04)			0.08 (0.07)		
Access to clean water gained age 0 to 4		0.04 (0.04)			0.20*** (0.06)			0.33*** (0.07)	
Access to clean water gained age 5 to 9			-0.03 (0.03)			0.04 (0.03)			0.13*** (0.05)
Observations	15642	14010	13874	12433	10961	10925	7792	7265	7057
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Birth Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

*Note: p-values in parentheses. Standard errors clustered at the community level. Control variables include the individual's gender, an urban/rural dummy, the household size, whether the household has access to electricity, whether the household is using improved sanitation, whether the household is using open defecation, household wealth in quintiles, and the individual's distance to the respective school. *** p < 0.01, ** p < 0.05, * p < 0.1.*

5.2 Heterogeneity

5.2.1 Rural-Urban Divide

Our analysis reveals significant differences between rural and urban households, with rural households emerging as the primary drivers of the observed outcomes (Table 2). In our specifications with junior and senior secondary school completion rates as dependent variables, the effect of access to clean water is significant throughout childhood in rural areas, while we find no significant effects in urban areas. The same pattern appears: the earlier access to clean water is gained, the better it is. For rural settings also the access gained after the fifth birthday has a significant positive effect on junior high school completion rates, albeit much smaller than for earlier access.

Our results underscore the importance of considering the different environments that rural communities face compared to their urban counterparts. Our dichotomous findings could reflect differences in access to resources, infrastructure, or socioeconomic conditions. For the Indonesian case, this highlights the need for targeted interventions and policies that address the specific needs of rural populations, thereby promoting more equitable development and improving overall well-being. Our findings align with Nauges & Strand (2017), who document in Ghana that access to clean water has a larger effect in rural areas, reflecting the greater importance of water fetching time in these settings.

Table 2: Results by Urban/Rural

	Rural			Urban		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Dependent Variable: Elementary school completed						
Access to clean water throughout life	0.09 (0.06)			-0.04 (0.06)		
Access to clean water gained age 0 to 4		0.06 (0.07)			0.00 (0.08)	
Access to clean water gained age 5 to 9			-0.04 (0.04)			-0.02 (0.04)
Observations	12369	11485	11166	3273	2525	2708
Panel B: Dependent Variable: Junior high completed						
Access to clean water throughout life	0.41*** (0.07)			-0.03 (0.06)		
Access to clean water gained age 0 to 4		0.25** (0.12)			-0.10 (0.09)	
Access to clean water gained age 5 to 9			0.03* (0.05)			-0.03 (0.05)
Observations	9417	8630	8435	3016	2331	2490
Panel C: Dependent Variable: Senior high completed						
Access to clean water throughout life	0.18 (0.13)			-0.15 (0.10)		
Access to clean water gained age 0 to 4		0.29* (0.17)			0.05 (0.10)	
Access to clean water gained age 5 to 9			0.09 (0.07)			-0.003 (0.07)
Observations	5721	5379	5111	2071	1886	1946
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Birth Year	Yes	Yes	Yes	Yes	Yes	Yes
Household FE	Yes	Yes	Yes	Yes	Yes	Yes

Note: *p-values in parentheses. Standard errors clustered at the community level. Control variables include the individual's gender, the household size, whether the household has access to electricity, whether the household is using improved sanitation, whether the household is using open defecation, household wealth in quintiles, and the individual's distance to the respective school. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.*

5.2.2 Gender Differences

The analysis reveals no statistically significant differences between boys and girls (Table 3). If anything, boys appear to benefit slightly more from access to clean water. Overall, the gender-disaggregated estimates mirror the baseline results.¹²

Our results are consistent with the majority of the literature, which finds similar effects for boys and girls (Koolwal & van de Walle 2013, Zhang & Xu 2016, Chen et al. 2022*b*) . In contrast, Ao (2021), Dhital et al. (2022), Aggarwal et al. (2024) document larger effects for boys, with reductions in grade repetition and school absenteeism being more pronounced when groundwater contamination is lower.

¹²We would have liked to analyze a break down by gender *and* rural vs. urban. However, our data do not allow for this. Especially the female rural sample is too small; it would require at least two girls within one household.

Table 3: Results by Gender

	Female			Male		
	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variable: Elementary school completed						
Access to clean water throughout life	0.004 (0.06)			0.07 (0.05)		
Access to clean water gained age 0 to 4		-0.01 (0.08)			0.10 (0.07)	
Access to clean water gained age 5 to 9			-0.003 (0.04)			-0.02 (0.05)
Observations	7564	6832	6706	8078	7178	7168
Dependent Variable: Junior high completed						
Access to clean water throughout life	0.24*** (0.07)			0.21*** (0.06)		
Access to clean water gained age 0 to 4		0.20* (0.11)			0.30*** (0.10)	
Access to clean water gained age 5 to 9			0.01 (0.05)			0.11 (0.07)
Observations	6489	5691	5701	5944	5270	5224
Dependent Variable: Senior high completed						
Access to clean water throughout life	0.12 (0.10)			-0.05 (0.09)		
Access to clean water gained age 0 to 4		0.27** (0.12)			0.37*** (0.12)	
Access to clean water gained age 5 to 9			0.18*** (0.07)			0.25** (0.13)
Observations	4086	3796	3744	3706	3469	3313
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Birth Year	Yes	Yes	Yes	Yes	Yes	Yes
Household FE	Yes	Yes	Yes	Yes	Yes	Yes

Note: Standard errors clustered at the community level in parentheses. Control variables include an urban/rural dummy, the household size, whether the household has access to electricity, whether the household is using improved sanitation, whether the household is using open defecation, household wealth in quintiles, and the individual's distance to the respective school. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

5.2.3 Regional Disparities

The analysis reveals no notable differences in the results between islands (Table A.4 in the appendix), with Java showing slightly stronger results. Despite this small discrepancy, the significance levels remain comparable across these regions. This suggests that while Java may show somewhat more robust results, the underlying factors driving these results may not significantly differ from those influencing results in other regions. For junior and senior secondary school completion rates, the effects for children in Java are, on average, five percentage points higher than those in the other islands.

5.3 Village Level External Factors

The identifying assumption of our analysis is that the acquisition of clean water access in a household is not correlated with any other change that may affect school outcomes. For instance, if the access to clean water on the premises was introduced in tandem with better sewage a higher chance of school completion could be in part due to the latter change and would wrongly be attributed in full to the newly gained access of clean water. Likewise, if a school was constructed nearby around the time safe water was introduced to the household, thereby lowering the cost of school attendance, this might confound our results as well. We do control for such confounders at the household level by including distance to school, access to sanitation, availability of health posts, etc., thereby capturing any changes over time in our household panel, so that we can safely exclude confounding influences *at the household level*.

Yet, the overall environment may change beyond the changes at the household level, which may affect school outcomes at the household level. Importantly, positive external effects could materialize if the overall disease environment improved. For instance, if the village gained access to sewage – even if the household did not – the prevalence of pathogens in the environment would be reduced, the likelihood of infection would decline and school completion for children of the household would become more likely. Relatedly, if access to better and more distant health facilities such as the next hospital improved because road infrastructure was upgraded, disease duration might decline as a consequence and school completion might become more likely.¹³ If any of these improvements was correlated with households gaining access to clean water our results would be confounded.

The IFLS provides a rich set of data at the village level, which allows us to investigate such a possibility. It contains information such as whether there is an asphalt road in the village, whether the majority of households have access to electricity, whether a school was built in the last five years, whether there is a sewage system in the village and whether health facilities, i.e. *puskesmas* and *posyandu*, are close by.

In Table 4 we regress gaining different types of village level infrastructure on gaining access to clean water. We run separate regressions for each type of infrastructure. Some of the estimates turn out significant, specifically receiving asphalt roads, sewage systems, health facilities, and the majority of households having access to electricity in the village are significantly (yet not very sizably)

¹³Time-invariant environmental factors are captured by the household fixed effects as we investigate only stationary households.

correlated with households gaining access to clean water. To control for these potential confounders we therefore run our baseline model with these variables as additional control variables.

The results in Table 5 show that the estimates change only slightly and the significance levels are not affected when we include these village level infrastructure variables. The main effects of access to clean water on junior and senior high school completion rates remain virtually unchanged.¹⁴

¹⁴In the extended baseline regressions, we included all village level infrastructure variables for which we find a significant correlation in Table 4. Results remain unaffected when we also include the village level infrastructure variables for which we do not find a significant correlation in Table 4.

Table 4: External Factors on the Village Level

Dependent Variable	Effect of Gaining Clean Water Access					
	(1)	(2)	(3)	(4)	(5)	(6)
Gained Asphalt Road	0.04*** (0.005)					
School was Built		0.004 (0.005)				
Gained Majority with Electricity			0.03*** (0.006)			
Gained Sewage System				0.10*** (0.004)		
Gained Posyandu					0.06*** (0.006)	
Gained Puskesmas						0.05*** (0.006)
Observations	58024	45249	46821	57492	45262	46822
Controls	Yes	Yes	Yes	Yes	Yes	Yes

Note: Standard errors clustered at the community level in parentheses. Controls include the survey round.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 5: Extended Baseline Results

	Elementary school completed			Junior secondary completed			Senior secondary completed		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Access to clean water throughout life	0.04			0.24***			0.04		
Access to clean water gained age 0 to 4	(0.04)	0.03		(0.05)	0.16***		(0.08)	0.27***	
Access to clean water gained age 5 to 9		(0.05)	-0.04		(0.07)	0.05		(0.07)	0.09*
Observations	10146	8758	(0.03)	8096	6871	(0.04)	4822	4483	(0.05)
Baseline Controls	Yes	Yes	8888	Yes	Yes	7017	Yes	Yes	4467
Village Level Infrastructure Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Birth Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: Standard errors clustered at the community level in parenthesis. Control variables include all variables from the baseline regression and in addition village access to electricity, the availability of health posts in the village, and whether the main road in the village is an asphalt road. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

5.4 Further Robustness

We perform several additional robustness checks, which are shown in Tables 6 to 8. First, we test for non-linear effects by running a logistic regression. Results are reported in Table 6. The main result for the effect of access to clean water throughout life on the completion of junior secondary school remains highly significant.

Second, we analyze whether our results change significantly when we exclude time-variant household characteristics and only include household fixed effects and individual characteristics. Our results (Table 7) show that the water variables become more significant and larger; for primary school completion lifetime access to clean water is now significant. For senior secondary school completion also access gained after the age of five has now a significant effect.

We have shown that variation in school completion rates is closely linked to changes in access to clean water. By including household fixed effects and restricting the sample to non-migrating households, we exploit within-household changes in water access while controlling for all time-invariant household and environmental characteristics over the period 1993–2014. We further account for time-varying confounders by controlling for changes in distance to school and the availability of health facilities, which may affect school attendance and the severity of water-related illnesses. Cohort fixed effects are included to absorb nationwide shocks and development trends.

In this section we take one step further by allowing the cohort fixed effects to differ across provinces, thereby capturing potentially differing development trends (including infrastructure development) or shocks in the regions. Results are given in Table 8. They show the same pattern and magnitude as in the baseline regressions; if at all, results become more significant.¹⁵ Our results suggest that it is unlikely that our estimates are affected by time-variant environmental variables beyond the ones we control for.

Overall, our results remain robust to a number of alternative specifications and extensions.¹⁶

¹⁵For a different level of variation, we also include island times year of birth effects in the appendix in Table A.5. Again results are very similar.

¹⁶As the decision to purchase water is potentially endogenous, we also provide a robustness check with bottled water removed from the entire sample in the Appendix in Table A.6. The size and significance levels of the results remain similar.

We also weighted the observations with longitudinal household weights. The results can be seen in the Appendix in Table A.7. The results remain significant. The number of observations, however, decreases substantially as weights are missing for many observations.

Table 6: Robustness Check: Logistic Regression

	Elementary school completed			Junior secondary completed			Senior secondary completed		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Access to clean water throughout life	0.24			1.87***			-0.67		
Access to clean water gained age 0 to 4	(0.29)	0.39		(0.38)	1.45***		(0.57)	2.91**	
Access to clean water gained age 5 to 9		(0.38)	-0.29		(0.38)	0.45**		(0.60)	1.39***
Observations	12734	11433	(0.20)	9450	8627	(0.22)	5817	5452	(0.38)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Birth Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: Standard errors clustered at the community level in parentheses. Control variables include the individual's gender, an urban/rural dummy, the household size, whether the household has access to electricity, whether the household is using improved sanitation, whether the household is using open defecation, household wealth in quintiles, and the individual's distance to the respective school. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 7: Robustness Check: No time-variant household variables

	Elementary school completed			Junior secondary completed			Senior secondary completed		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Access to clean water throughout life	0.06*			0.28***			0.09		
Access to clean water gained age 0 to 4	(0.04)	0.05		(0.04)	0.21***		(0.07)	0.35***	
Access to clean water gained age 5 to 9		(0.04)	-0.02		(0.06)	0.04		(0.07)	0.14***
Observations	15642	14010	(0.02)	12433	10961	(0.03)	7792	7265	(0.05)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Birth Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: Standard errors clustered at the community level in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. The right hand side variables contain individual factors and community factors, but the variables at the household level, i.e. household size, and household wealth are dropped.

Table 8: Robustness Check: Province*Year of birth fixed effects

	Elementary school completed			Junior secondary completed			Senior secondary completed		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Access to clean water throughout life	0.04			0.29***			0.02		
Access to clean water gained age 0 to 4	(0.04)	0.04		(0.04)	0.20***		(0.08)	0.33***	
Access to clean water gained age 5 to 9		(0.04)	-0.03		(0.06)	0.04		(0.07)	0.13***
Observations	15642	14010	(0.02)	12433	10961	(0.13)	7792	7265	(0.00)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Birth Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: Standard errors clustered at the community level in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. All variables from the baseline regression are included. In addition, province* year of birth fixed effects are included as control variables.

5.5 Mechanisms

In principle, the channels through which access to clean water affects school performance are well established in the literature. Improved water quality reduces the incidence of water-borne diseases—such as diarrhea, typhoid, cholera, and parasitic infections—thereby lowering morbidity and preventing long-term developmental impairments, including cognitive delays. Reduced illness also decreases household medical expenditures and increases adult labor supply by limiting caregiving demands. Together, these mechanisms raise school attendance and learning productivity, while reducing reliance on child labor through both substitution and income effects.

Children without access to clean water are more likely to consume pathogen-contaminated sources, increasing exposure to bacteria, viruses, and parasites (Wolf et al. 2014). The resulting higher risk of diarrheal disease is particularly pronounced in settings with inadequate water and sanitation infrastructure (Komarulzaman et al. 2017, Khan et al. 2022). Access to clean water substantially mitigates these risks, both directly—by reducing consumption of contaminated water—and indirectly, by enabling improved hygiene practices such as handwashing and safer food preparation.

Recurrent diarrheal episodes during early childhood can impair physical growth and cognitive development, with lasting consequences for educational attainment (Cameron et al. 2021). Illness-related school absenteeism further disrupts learning, leading to cumulative knowledge gaps and lower academic performance. In households where multiple children fall ill, schooling may be additionally affected as siblings are kept at home to provide care or contribute to household tasks.

Persistent absenteeism increases the risk of grade repetition and school dropout, particularly when chronic illness constrains academic progression or shifts household priorities away from education. Complementary evidence highlights the importance of water access in reducing time spent fetching water (Nauges & Strand 2017, Dhital et al. 2022), lowering childhood morbidity (Chen et al. 2022*b*), and shaping health outcomes heterogeneously across age groups (Aggarwal et al. 2024).

The Indonesian Family Survey (IFLS) allows to shed light on some, but not all the pathways potentially relevant for the Indonesian case. We present suggestive evidence below, but also point out the limitations of the data.

The IFLS collects information on the incidence of selected health conditions experienced during the four weeks preceding the survey. These conditions include nausea, fever, and diarrhea, the latter being the only water-related disease captured in the dataset. Given the absence of information on other waterborne illnesses, our analysis focuses on diarrhea as the primary outcome to assess the health effects of water access. Specifically, we examine whether access to clean water is associated with a lower incidence of diarrhea among children, thereby evaluating its role as a potential mechanism linking water access to health outcomes, and using the other illnesses as placebo test.

We find a negative correlation between access to clean water and the occurrence of diarrhea in the last 4 weeks (Table 9, columns 1 and 2). This correlation is significant if the child had access throughout his/her life and negative but insignificant if the child gained access during the first five years of his/her life. In addition, the likelihood of having suffered from diarrhea in the four weeks preceding the survey is positively and significantly associated with having experienced severe diarrhea during childhood (column 3).

As a placebo test for the proposed mechanism, we examine whether access to clean water affects the incidence of non–water-related conditions, specifically fever and nausea. We find no statistically significant effect of clean water access on these outcomes, as reported in Table 10.

Table 9: Access to Clean Water, Severe Diarrhea during Childhood, and Contemporaneous Diarrhea

	Diarrhea in the last 4 weeks		
	(1)	(2)	(3)
Access to clean water throughout life	-0.04** (0.02)		
Access to clean water gained age 0 to 4		-0.01 (0.02)	
Severe diarrhea during childhood			0.03** (0.01)
Observations	4509	4509	10404
Controls	Yes	Yes	Yes
Birth Year FE	Yes	Yes	Yes

*Note: Standard errors clustered at the community level in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.*

Table 10: Placebo Test for Access to Clean Water, Fever and Nausea

	Fever		Nausea	
	(1)	(2)	(3)	(4)
Access to clean water throughout life	0.01 (0.02)		-0.001 (0.02)	
Access to clean water gained age 0 to 4		0.01 (0.02)		-0.001 (0.02)
Observations	4509	4509	4509	4509
Controls	Yes	Yes	Yes	Yes
Birth Year FE	Yes	Yes	Yes	Yes

*Note: Standard errors clustered at the community level in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.*

Table 11: Severe Diarrhea during Childhood, Contemporaneous Diarrhea and Days Missed at School

	DV: Days missed at main activity in the last 4 weeks							
	Elementary	Junior High	Senior High	All School Children	Elementary	Junior High	Senior High	All School Children
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Severe diarrhea during childhood	1.01***	1.04***	0.13	0.86***				
	(0.26)	(0.34)	(0.31)	(0.28)				
Diarrhea in the last 4 weeks					0.99***	0.92**	1.12***	0.99***
					(0.24)	(0.38)	(0.37)	(0.18)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Birth Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3974	1302	655	5931	3974	1316	682	5972

Note: Standard errors clustered at the community level in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Next, we test the effect of having been affected by diarrhea in the last 4 weeks and having experienced severe diarrhea during childhood on the number of days missed at the main activity in the last 4 weeks. We restrict the sample to school children from the age of 6 until the age of 18, so that we can see how diarrhea affects the number of school days missed. The results are shown in Table 11.¹⁷ Having experienced severe diarrhea during childhood leads to approximately one additional school days missed (in the last four weeks). The effect of contemporaneous diarrhea on days missed at school has a similar, somewhat higher size. The effect in elementary school (for 6 to 12 year olds) and in junior high school (for 13 to 15 year olds) are highly significant.¹⁸

We investigated whether the availability of health posts would mitigate the effect of diarrhea on school days missed and could not find such a significant effect. In Table A.8 in the appendix, we interact having been affected by diarrhea in the last 4 weeks with both the availability of *puskesmas* in the same community as well as the availability of *posyandu* facilities in the same community. Both the direct effect and the interacted effect of the health facilities on the number of school days missed are not significant while the effect of diarrhea in the last four weeks remains positive and significant. In addition, we looked at gender and urban-rural differences within our mechanism analysis. We did not find substantial differences in either sub-analysis.

Furthermore, we tested the effect of the distance to the respective school on school completion. We find a small negative and significant effect for the elementary school level, but no significant effects for the junior and senior high school level. As the distance to school affects school completion rates (see Table A.9 in the appendix), mostly because of the effect on elementary school children, we use it as a control variable in the main specification. The distance to the school is therefore sufficiently accounted for in our analysis.

As another possible channel we analyzed whether the distance to the water source and the location of the water source within or outside of the house had an impact on missing school. The underlying idea is that children tasked with fetching water have a tighter time budget and are therefore more likely to miss school so that not only availability of, but also distance to clean water would matter. Also, longer travel times back from the water source can increase the risk of contamination (Wright et al. 2004). In general, longer travel times between water source and point of use have been associated with significantly reduced child health (Pickering & Davis 2012).

Yet, we find that neither location of the water source, the distance to the water source nor the interaction of access to clean water and the location or the distance to the water source had a significant effect on days missed at school or school completion rates. Furthermore, neither the location nor the distance to the water source affect current or childhood diarrhea levels (results are available upon request).

The results remain insignificant when we look at gender and urban-rural divides. Therefore, we rule out the possibility of water fetching time affecting school success in our context.

¹⁷We run the regressions in Tables 9 to 11 also with the full set of village level infrastructure controls that we introduced in section 5.3, which hardly affects our results (cf. Tables A.10 to A.12 in the appendix).

¹⁸At the final stage of the analysis, we lack observations to assess whether recent school absenteeism predicts school completion, as none of the children with data on recent absence has completed the relevant schooling level yet. We are only able to assess whether having missed one's main activity in the past four weeks is correlated with not completing school. For these tests, we find significant effects.

We note that we could not assess the effect of access to clean water on water-related diseases other than diarrhea. Other water-related diseases could have likewise caused children to miss school or, if at school, to have lower learning achievements. The estimated effects of diarrhea should thus be seen as lower bounds for the overall effects of water-related diseases for school absenteeism.

6 Conclusion

Our study establishes a causal impact of the access to clean water during early childhood on human capital formation. Using a large panel data set over 22 years and including household fixed effects we are able to filter out important time-invariant confounders at the household level such as genes, parental education, culture, habits, and attitudes. Because we only consider stationary households the household fixed effects also capture time-invariant locational variables such as geographical factors conducive to or detrimental for diseases e.g., temperature, precipitation, elevation, climate etc. We control for time-varying household variables such as access to sewage or health facilities or distance to school. We also include a host of time-variant environmental factors at the community level such as health care facilities, school environment, and infrastructure and thereby control also for time-varying effects external to the household, but potentially affecting school performance either directly or through its effect on disease environment. Specifically, we test whether gaining access to clean water coincides with improved or newly acquired access to other infrastructure and find no significant changes of the results.

Our results show that lifetime access to clean water has a significantly positive and sizable causal impact on educational outcomes. We develop a comprehensive lifetime profile of access to clean water in order to examine how the timing of access during childhood affects outcomes. Access to clean water has a significantly and large positive effect on junior secondary and senior secondary completion rates with earlier access having a much larger impact. The effect is much more pronounced for children living in rural areas, and is similar for boys and girls.

Suggestive evidence points towards increased infection rates with diarrhea (and possibly other water-related diseases) during childhood as the main channel of lacking clean water access. Severe diarrhea in early childhood makes contemporaneous diarrhea more likely and leads to more school days missed. More school days missed reduce the likelihood of completing school. Our results are robust to a large number of robustness checks.

Our findings are directly policy relevant. Continuous access to clean water has a clear positive effect on educational attainment, indicating that improvements in water quality and reliability contribute to higher educational outcomes (and, of course, better health). Our results further suggest that access from early childhood is critical, underscoring the importance of ensuring clean water availability from birth. Policies that prioritize sustained investments in water infrastructure—particularly in rural areas—are therefore likely to yield long-term gains in human capital. This is a very good development policy, not only because it is very effective in fostering health and human capital formation, but also because it is a very equitable policy as it supports the poor who have lower access rates than richer households who can afford to buy bottled water at least. In the Indonesian con-

text, expanding access to uncontaminated water sources should be a central component of education, development, and infrastructure policy.

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A Appendix



Map of 13 IFLS Provinces in Indonesia

Figure A.1: IFLS provinces



Figure A.2: Access to improved water sources in Indonesian provinces in 2018

Table A.1: Descriptive statistics

Statistic	Mean	St. Dev.	Min	Max
Access to clean water throughout life	0.06	0.23	0	1
Access to clean water gained at age 1 to 4	0.03	0.18	0	1
Access to clean water gained at age 5 to 9	0.06	0.24	0	1
Elementary school completed	0.79	0.40	0	1
Junior secondary school completed	0.62	0.49	0	1
Senior secondary school completed	0.43	0.49	0	1
Male	0.50	0.50	0	1
Urban	0.30	0.46	0	1
HH size	6.13	3.30	1	40
Electricity	0.96	0.21	0	1
Wealth 1st quintile	0.25	0.43	0	1
Wealth 2nd quintile	0.23	0.42	0	1
Wealth 3rd quintile	0.21	0.41	0	1
Wealth 4th quintile	0.19	0.39	0	1
Wealth 5th quintile	0.12	0.33	0	1
Distance to elementary school in minutes	13.67	15.54	0	420
Distance to junior secondary school in minutes	18.79	15.68	1.00	600.00
Distance to senior secondary school in minutes	21.55	26.10	1.00	1,800.00
Improved sanitation	0.66	0.48	0	1
Open defecation	0.14	0.35	0	1

Table A.2: Households with access to clean water in the IFLS surveys

	1993	1997	2000	2007	2014
Piped water	0.16	0.28	0.27	0.22	0.17
Improved water	0.29	0.31	0.35	0.39	0.35
Bottled water	0.06	0.02	0.03	0.17	0.37
Other water	0.49	0.39	0.35	0.22	0.11

Table A.3: Full Results

	Elementary school completed			Junior secondary completed			Senior secondary completed		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Access to clean water throughout life	0.04 (0.04)			0.28*** (0.04)			0.08 (0.07)		
Access to clean water gained age 0 to 4		0.04 (0.04)			0.20*** (0.06)			0.33*** (0.07)	
Access to clean water gained age 5 to 9			-0.03 (0.03)			0.04 (0.03)			0.13*** (0.05)
Male	-0.00 (0.01)	-0.00 (0.01)	-0.01 (0.01)	-0.02* (0.01)	-0.02* (0.01)	-0.02* (0.01)	-0.03* (0.01)	-0.03* (0.01)	-0.03*** (0.01)
Urban	0.01 (0.02)	-0.01 (0.02)	0.02 (0.02)	0.05 (0.03)	0.06* (0.03)	0.06* (0.03)	0.03 (0.04)	0.05 (0.04)	0.06* (0.04)
Household size	-0.00** (0.001)	-0.00*** (0.001)	-0.00** (0.001)	-0.01** (0.002)	-0.004** (0.002)	-0.004** (0.002)	-0.01*** (0.002)	-0.01*** (0.002)	-0.01*** (0.002)
Electricity	0.11** (0.04)	0.12** (0.04)	0.12** (0.04)	0.12** (0.05)	0.12** (0.05)	0.14** (0.05)	-0.05 (0.08)	-0.04 (0.09)	-0.04 (0.09)
Improved sanitation	0.04*** (0.01)	0.05*** (0.01)	0.04*** (0.01)	0.05** (0.01)	0.07*** (0.01)	0.05*** (0.01)	0.04* (0.02)	0.06** (0.02)	0.04*** (0.02)
Open defecation	-0.07*** (0.02)	-0.07*** (0.02)	-0.08*** (0.02)	-0.02 (0.02)	-0.00 (0.02)	-0.01 (0.02)	-0.03 (0.04)	-0.03 (0.04)	-0.05 (0.04)
Wealth 1st quintile	0.08*** (0.01)	0.09*** (0.01)	0.07*** (0.01)	0.10*** (0.02)	0.12*** (0.02)	0.11*** (0.03)	0.02 (0.03)	0.05 (0.03)	0.06* (0.03)
Wealth 2nd quintile	0.06*** (0.01)	0.07*** (0.01)	0.06*** (0.01)	0.08*** (0.02)	0.10*** (0.02)	0.09*** (0.03)	0.04 (0.04)	0.06 (0.04)	0.06** (0.03)
Wealth 3rd quintile	0.05*** (0.02)	0.06*** (0.02)	0.05** (0.02)	0.06* (0.02)	0.07** (0.02)	0.06* (0.03)	0.02 (0.03)	0.02 (0.03)	0.05* (0.03)
Wealth 4th quintile	0.03* (0.02)	0.04* (0.02)	0.03* (0.02)	0.03 (0.03)	0.04 (0.03)	0.04 (0.03)	0.02 (0.04)	0.01 (0.04)	0.02 (0.03)
Distance to school	-0.0006* (0.0003)	-0.0007* (0.0003)	-0.0008* (0.0004)	-0.0002 (0.0005)	-0.0000 (0.0005)	-0.0004 (0.0005)	-0.0005 (0.0005)	-0.0007 (0.0006)	-0.0001 (0.0003)
Observations	15642	14010	13874	12433	10961	10925	7792	7265	7057
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Birth Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: Standard errors clustered at the community level in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A.4: Results by Java/Off-Java

	Java			Off-Java		
	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variable: Elementary school completed						
Access to clean water throughout life	0.05 (0.05)			0.03 (0.04)		
Access to clean water gained age 0 to 4		0.00 (0.06)			0.12** (0.05)	
Access to clean water gained age 5 to 9			-0.05 (0.03)			0.01 (0.03)
Observations	8865	7737	7579	6777	6273	6295
Dependent Variable: Junior high completed						
Access to clean water throughout life	0.35*** (0.06)			0.20*** (0.05)		
Access to clean water gained age 0 to 4		0.22** (0.09)			0.23*** (0.09)	
Access to clean water gained age 5 to 9			0.14** (0.06)			-0.02 (0.04)
Observations	7007	5969	5920	5426	4992	5005
Dependent Variable: Senior high completed						
Access to clean water throughout life	0.14 (0.12)			0.02 (0.08)		
Access to clean water gained age 0 to 4		0.43*** (0.10)			0.21*** (0.10)	
Access to clean water gained age 5 to 9			0.12*** (0.00)			0.12* (0.07)
Observations	4344	3964	3794	3448	3301	3263
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Birth Year	Yes	Yes	Yes	Yes	Yes	Yes
Household FE	Yes	Yes	Yes	Yes	Yes	Yes

Note: Standard errors clustered at the community level in parentheses. Control variables include the individual's gender, an urban/rural dummy, the household size, whether the household has access to electricity, whether the household is using improved sanitation, whether the household is using open defecation, household wealth in quintiles, and the individual's distance to the respective school. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A.5: Robustness Check: Island*Year of birth fixed effects

	Elementary school completed			Junior secondary completed			Senior secondary completed		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Access to clean water throughout life	0.05			0.28***			0.07		
Access to clean water gained age 0 to 4	(0.04)	0.04		(0.04)	0.20***		(0.08)	0.33***	
Access to clean water gained age 5 to 9		(0.04)	-0.03		(0.06)	0.04		(0.07)	0.13***
Observations	10147	8820	(0.53)	8336	7144	(0.36)	5167	4824	(0.00)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Birth Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: Standard errors clustered at the community level in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A.6: Treatment Group Without Bottled Water

	Elementary school completed			Junior secondary completed			Senior secondary completed		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Access to clean water throughout life	0.04 (0.04)			0.13*** (0.05)			-0.11 (0.12)		
Access to clean water gained age 0 to 4		0.03 (0.04)			0.06 (0.06)			0.22** (0.09)	
Access to clean water gained age 5 to 9			-0.03 (0.03)			0.05 (0.04)			0.06 (0.06)
Observations	14711	13219	13082	9937	9132	8880	5419	5418	7057
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Birth Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

*Note: Purchased water was removed from the treatment group. The control group is unchanged. p-values in parentheses. Standard errors clustered at the community level. Control variables include the individual's gender, an urban/rural dummy, the household size, whether the household has access to electricity, whether the household is using improved sanitation, whether the household is using open defecation, household wealth in quintiles, and the individual's distance to the respective school. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.*

Table A.7: Regressions with Longitudinal Household Weights

	Elementary school completed			Junior secondary completed			Senior secondary completed		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Access to clean water throughout life	0.12** (0.05)			0.35*** (0.05)			0.12 (0.10)		
Access to clean water gained age 0 to 4		0.11 (0.07)			0.31*** (0.09)			0.47*** (0.14)	
Access to clean water gained age 5 to 9			-0.01 (0.03)			0.02 (0.04)			0.12** (0.06)
Observations	11755	10431	10373	9358	8168	8181	5831	5475	5323
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Birth Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

*Note: Observations are weighted with longitudinal household weights. Standard errors clustered at the community level. Control variables include the individual's gender, an urban/rural dummy, the household size, whether the household has access to electricity, whether the household is using improved sanitation, whether the household is using open defecation, household wealth in quintiles, and the individual's distance to the respective school. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.*

Table A.8: Contemporaneous Diarrhea, Access to Health Care, and School Days Missed

	DV: Days missed at main activity in the last 4 weeks			
	Elementary	Junior High	Senior High	All School Children
	(1)	(2)	(3)	(4)
Diarrhea in the last 4 weeks	0.72*** (0.19)	1.24** (0.56)	1.77*** (0.47)	0.97*** (0.20)
Puskesmas	0.09 (0.11)	0.22 (0.18)	0.36 (0.25)	0.16* (0.10)
Posyandu	0.20 (0.32)	0.08 (0.46)	1.47 (1.15)	0.27 (0.31)
Diarrhea in the last 4 weeks * puskesmas	0.76 (0.58)	-0.99 (0.76)	-1.25* (0.71)	0.03 (0.40)
Diarrhea in the last 4 weeks* posyandu	-0.02 (1.07)	1.49 (3.27)	-3.60*** (1.25)	0.27 (1.25)
Controls	Yes	Yes	Yes	Yes
Birth Year FE	Yes	Yes	Yes	Yes
Observations	3974	1316	682	5972

Note: Standard errors clustered at the community level in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A.9: Distance to School and School Completion

	DV: School completion		
	Elementary (1)	Junior High (2)	Senior High (3)
Distance to school in minutes	-0.0004*** (0.0001)	0.0002 (0.0003)	0.0003 (0.0004)
Controls	Yes	Yes	Yes
Birth Year FE	Yes	Yes	Yes
Observations	15834	9994	5447

*Note: Standard errors clustered at the community level in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.*

Table A.10: Mechanism Analysis with all village level controls

	(1)	(2)	(3)
Diarrhea in the last 4 weeks			
Access to clean water throughout life	-0.04** (0.02)		
Access to clean water gained age 0 to 4		-0.01 (0.02)	
Severe diarrhea during childhood			0.03** (0.01)
Observations	4509	4509	10284
Baseline Controls	Yes	Yes	Yes
Village Level Infrastructure Controls	Yes	Yes	Yes
Birth Year FE	Yes	Yes	Yes

*Note: Standard errors clustered at the community level in parentheses. Control variables include all individual controls, household characteristics and village level controls. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.*

Table A.11: Placebo Test for Access to Clean Water, Fever and Nausea with all village level controls

	Fever		Nausea	
	(1)	(2)	(3)	(4)
Access to clean water throughout life	0.01 (0.02)		-0.003 (0.02)	
Access to clean water gained age 0 to 4		0.01 (0.02)		-0.00 (0.02)
Observations	4509	4509	4509	4509
Baseline Controls	Yes	Yes	Yes	Yes
Village Level Infrastructure Controls	Yes	Yes	Yes	Yes
Birth Year FE	Yes	Yes	Yes	Yes

*Note: Standard errors clustered at the community level in parentheses. Control variables include all individual controls, household characteristics and village level controls. * * * $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.*

Table A.12: Mechanism with all village level controls

	Elementary	Junior High	Senior High	All School Children	Elementary	Junior High	Senior High	All School Children	Elementary	Junior High	Senior High	All School Children
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)				
Severe diarrhea during childhood	1.02***	1.05***	0.11	0.87***								
	(0.26)	(0.34)	(0.29)	(0.18)								
Diarrhea in the last 4 weeks					1.00***	0.92**	1.09***	0.99***				
					(0.24)	(0.38)	(0.38)	(0.18)				
Baseline Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes				
Village Level Infrastructure	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes				
Controls												
Birth Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes				
Observations	3974	1302	655	5931	3974	1316	682	5972				

Note: Standard errors clustered at the community level in parentheses. Control variables include all individual controls, household characteristics and village level controls. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.