ANALYZING THE CAUSAL EFFECT OF EXPOSURE TO NON-FUNCTIONAL WATER POINTS ON CHILD HEALTH OUTCOMES

MUSA Usman[1] & SALIHU Muhammad-Kabir[2]
[1,2]Department of Economics, Ahmadu Bello University, Zaria
Corresponding Author: usman4musa@gmail.com (08069592121)

ABSTRACT

This study investigates the causal pathways through which exposure to non-functional water points affect child health outcomes in Nigeria. Using a nationally representative sample, integrating household-level health data (DHS) with georeferenced water point functionality information (WPDx), the study applies Average Causal Mediation Effects (ACME) and Controlled Direct Effects (CDE) estimation techniques to disentangle the indirect effects of water access from direct health outcomes. Findings reveal that maternal education significantly mediates the relationship between non-functioning water source and child outcomes such as diarrhoea, stunting, and under-five mortality. Specifically, mothers with secondary education or higher are more likely to mitigate health risks associated with water scarcity through improved caregiving practices. These results suggest that interventions aimed at improving child health must address both infrastructure deficits and socio-behavioral capabilities, especially among women in low-income settings.

Keywords: Water points, Child health, Causal mediation, Maternal education, Nigeria.

JEL Codes: I12, I15, Q25, C21

1. Introduction

Access to safe water is a fundamental human right and a critical determinant of child health and survival. Despite global progress, over 2.1 billion people still lack access to safely managed drinking water (WHO/UNICEF, 2021). In Sub-Saharan Africa, where infrastructural deficits are widespread, the burden of water-related diseases remains disproportionately high. In Nigeria, frequent water point breakdowns exacerbate this challenge, undermining the achievement of Sustainable Development Goal (SDG) 6 on clean water and sanitation. Recent Nigeria WASHNORM survey revealed that approximately 67% of rural water points were non-functional in 2021, with rural households most affected (Federal Ministry of Water Resources, 2021).

A body of literature has highlighted the association between access to safe drinking water and improved child health outcomes (Fink , Günther, & Hill , 2011) (Headey & Palloni, 2019). Moreso, recent studies reaffirm that poor water and sanitation services continue to drive high rates of diarrhoeal diseases, stunting, and under-five mortality in Sub-Saharan Africa (Amadu, Seidu, Agyemang, & Arthur-Holmes, 2023; Geere & Hunter, 2020). In Nigeria, (Azeez , Henderson-Mitchell, LaFevor , & Gregg, 2023) found that limited access to functional water infrastructure significantly increased the risk of childhood illness, while (Azuh, et al., 2022) identified socio-demographic and environmental determinants of child mortality in rural communities. These studies provide compelling evidence of the key role of water infrastructure in child health.

Beyond water sources, maternal education has been consistently linked with improved child health outcomes. Educated mothers are more likely to adopt safe hygiene practices, utilize preventive healthcare services, and respond appropriately to early symptoms of illness (Cumming & Cairncross, 2016; Skoufias & Vinha, 2021). (Yorke, Wahab, & Turkson, 2023), using data from West African countries, found that maternal education significantly reduced malnutrition prevalence. Similarly, (Okafor, Akinyemi, Wika-Kobani, Olubodun, & Eze, 2022) showed that maternal knowledge and hygiene practices played a crucial role in preventing childhood diarrhoea in Nigeria. These findings demonstrate that maternal education not only improves child well-being directly but also mediates the effectiveness of infrastructural interventions.

Does maternal education control the effects of health outcomes on children exposed to non-functioning water points? While earlier studies have established strong associations between water access, maternal education, and child health, few have employed causal mediation analysis to disentangle the direct and indirect effects of infrastructural failures. This is particularly relevant for Nigeria, where non-functional water points are widespread and maternal education levels vary significantly across regions. Addressing this gap, this study contributes by applying a causal mediation framework to estimate both the direct effects of non-functional water points on child health and the indirect effects mediated through maternal education.

2. Literature Review

2.1 Conceptual Clarification

Water, sanitation, and hygiene (WASH) are widely recognized as foundational determinants of health and well-being. Non-functional water points is defined as public or private water sources that have broken down or failed to provide reliable water for more than three consecutive days in a month which can pose a significant challenge to household water security (WHO/UNICEF, 2021). The failure forces households to rely on unimproved sources such as

streams or open wells, increasing the risks of diarrhoeal diseases, parasitic infections, and malnutrition (Amadu, Seidu, Agyemang, & Arthur-Holmes, 2023).

Child health outcomes in this study refer to measurable indicators such as diarrhoea prevalence, stunting, and under-five mortality. These outcomes are influenced not only by environmental exposures but also by socio-economic and demographic variables. Among these, maternal education is a critical determinant, as it shapes hygiene behavior, health knowledge, and utilization of health services (Yorke, Wahab, & Turkson, 2023). The conceptual link examined here is therefore a dual pathway: (1) direct effects of non-functional water points on child health, and (2) indirect effects mediated through maternal education.

2.2 Theoretical Review

Several theories explain the relationship between maternal education, WASH, and child health. Among them few are reviewed as follows:

2.2.1 Mosley and Chen (1984) child survival framework

This theory is adopted as the theoretical framework for this study. Because, it identifies proximate determinants of child survival which includes: environmental contamination, nutrient intake, and maternal health-seeking behavior, shaped by socio-economic factors. Maternal education is in this study, positioned as a key socio-economic determinant that influences these proximate variables.

2.2.2 Health knowledge and empowerment perspective

The model suggests that maternal education enhances women's autonomy, improves their capacity to interpret health information, and increases their ability to adopt preventive health practices. For instance, educated mothers are more likely to ensure hygienic storage of drinking water, timely treatment of diarrhoea with oral rehydration solutions, and use of antenatal and child immunization services (Cumming & Cairncross, 2016; Okafor, Akinyemi, Wika-Kobani, Olubodun, & Eze, 2022).

2.2.3 WASH-Health Nexus model

The model emphasizes the interaction between environmental infrastructure and social characteristics. Within this framework, water access and sanitation infrastructure interact with maternal knowledge and practices to influence disease transmission pathways (Geere & Hunter, 2020). Thus, maternal education can act as a mediator, strengthening household resilience to infrastructural deficits such as non-functional water points.

2.3 Empirical Review

Empirical studies consistently show strong relationships between water access, maternal education, and child health, though the pathways differ.

(Fink , Günther, & Hill , 2011) demonstrated that access to improved water and sanitation significantly reduced childhood morbidity across multiple countries, including Nigeria. (Isukuru, Opha, Isaiah, Orovwighose, & Emmanuel, 2024) provided Nigeria-specific evidence, showing that limited access to safe drinking water increased child illness risk. (Azuh, et al., 2022) further identified socio-demographic and environmental determinants, with maternal education emerging as a critical protective factor. (Skoufias & Vinha, 2021) confirmed that maternal education improves early childhood development outcomes in Nigeria by reducing stunting and enhancing child stature. Okafor et al. (2022) found that maternal hygiene knowledge substantially reduced diarrhoea incidence among children, underscoring the preventive role of education.

Amadu et al. (2023) reported that the joint effect of poor sanitation and unsafe water significantly increased diarrhoeal disease prevalence across Sub-Saharan Africa, highlighting the compounded risks of infrastructure deficits. (Adeyinka, Muhajarine, Petrucka, & Isaac , 2020) observed inequities in child survival in Nigeria during the SDG era, strongly associated with maternal education levels. Yorke et al. (2023), analyzing DHS data from West Africa, confirmed that maternal education significantly lowers malnutrition prevalence.

Headey and Palloni (2019) provided global evidence showing that sanitation and water infrastructure are strongly correlated with reductions in child morbidity. Geere and Hunter (2020) highlighted that households where women spend significant time fetching water face higher child health risks, with maternal burden compounding vulnerability. (Vikram & Vanneman, 2019), while focusing on India, offered transferable insights: maternal education improves multiple health outcomes, including nutrition, morbidity, and immunization coverage.

2.4 Synthesis of the literature

Overall, the empirical literature demonstrates that both water infrastructure and maternal education are crucial for improving child health. However, most studies emphasize correlations and regression-based associations, with limited attention to causal mediation. Few have explicitly decomposed the direct and indirect effects of non-functional water points, particularly within the Nigerian context. This study therefore contributes by applying causal mediation analysis to quantify the extent to which maternal education mediates the relationship between water infrastructure reliability and child health outcomes.

3. Methodology

3.1 Data Sources

This study utilized the Nigeria Demographic and Health Survey (NDHS) 2018 dataset (DHS, 2019), which provides nationally representative information on household demographics,

health outcomes, and maternal characteristics. The survey employed a stratified two-stage cluster sampling design, ensuring representativeness across urban and rural areas.

To measure exposure to water infrastructure, the NDHS 2018 was merged with the Water Point Data Exchange (WPDx) records. The WPDx database contains georeference information on public water points, including functionality status. Households were merged to nearby water points using geospatial coordinates, enabling the analysis of exposure to non-functional water sources.

3.2 Variables and Constructs

This study specified the model based on the theoretical framework adopted from (Mosley & Chen, 1984) seminal work on child survival in developing countries. This is assumed that child health is a function of maternal factor, environmental factor, nutrition deficiency, and socio-economic conditions. In this study, child health outcomes were proxies by child diarrhoea, child stunting, and child mortality.

$$CH_{ij} = \beta_0 + \beta_1 Wat_j + \beta_2 San_j + \chi X_{ij} + \delta_j H_j + \varepsilon_{ij} \quad \ldots\ldots\ldots\

3.3.2 Average Direct Effect (ADE): The direct effect of exposure on child health not mediated by maternal education.

3.3.3 Total Effect (TE): The sum of the direct and mediated effects.

Estimation was performed using logistic regression models for binary outcomes and bootstrapping for confidence intervals.

3.4 Addressing Endogeneity

In order to reduce the potential endogeneity that might exist, we account for: Region and cluster fixed effects were included to control for unobservable environmental or infrastructural conditions. And stratified analysis was conducted by urban vs. rural location to account for spatial heterogeneity in both exposure and access to education.

4. Results and Discussion

4.1 Descriptive Insights

Among the 6,130 children in the analytic sample, 58.9% resided in rural areas, and 41.1% in urban areas. About 53.6% of the households were linked to non-functional water points. The prevalence of diarrhoea, stunting, and mortality was notably higher among children whose mothers had no formal education and who were exposed to non-functional water points.

S/N	Health Outcome	No education	Education(Secondary +)
	Diarrhoea	28.4%	12.9%
	Stunting	42.1%	18.7%
	Mortality rate	99 per 1000	54 per1000

4.2 Causal Mediation Analysis

The mediation model estimates are summarized below for each outcome. Bootstrapped 95% confidence intervals (CI) are reported.

4.2.1 Diarrhoea

ACME	ADE	Total Effect	Proportion Mediated
0.061 (0.038, 0.092)	0.089 (0.058, 0.123)	0.150 (0.118, 0.184)	40.7%

Roughly 41% of the total effect of exposure to non-functional water points on diarrhoea operates through maternal education.

4.2.2 Stunting

ACME	ADE	Total Effect	Proportion Mediated
0.073 (0.050, 0.101)	0.085 (0.055, 0.114)	0.158 (0.129, 0.191)	46.2%

Nearly half of the effect of water source reliability on stunting is mediated by the mother's education level.

4.2.3 Under-five Mortality

ACME	ADE	Total Effect	Proportion Mediated
0.057 (0.032, 0.082)	0.069 (0.045, 0.097)	0.126 (0.096, 0.160)	45.2%

Maternal education mediates nearly 45% of the mortality impact attributable to water source failure.

In rural areas, mediation through maternal education was stronger than in urban areas: for diarrhoea mediation effect is 47.8%, for stunting mediation effect is 52.1%, and for mortality mediation effect is 49.6%. But of urban mediation effects were present but lower, suggesting that alternative pathways (e.g., infrastructure alternatives or private supply) may compensate for water point failures in cities.

4.3 Discussion

This study offers important insights into how and why exposure to non-functional water points affects child health outcomes in Nigeria. By using a causal mediation framework, we uncover that a substantial share of the effect is mediated by maternal education, particularly in rural settings. These findings extend the literature on water access and child health by emphasizing not just the structural failures, but also the social and behavioral mechanisms that shape how those failures translate into health risks.

Across all three health outcomes such as diarrhoea, stunting, and under-five mortality, maternal education accounted for 40% to 46% of the total effect of exposure to non-functional water points. This suggests that educated mothers possess knowledge, behaviors, and coping strategies that mitigate the health risks posed by poor water access.

These findings are in line with (Vikram & Vanneman, 2019), who emphasized that maternal education improves child feeding practices, hygiene behaviors, and health-seeking habits. Similarly, Fink et al. (2011) found that maternal literacy significantly improves the likelihood of water purification and handwashing, which directly reduces diarrhoea prevalence.

Moreover, maternal education enhances a mother's ability to interpret health information, adhere to medical advice, and navigate public services, especially critical when children fall ill due to water-related illnesses. As shown by Headey and Palloni (2019), educated caregivers are more likely to immunize children and seek timely medical treatment, further reducing mortality risk.

The urban–rural disaggregation shows that maternal education has greater protective power in rural settings, where infrastructure alternatives are limited. In these environments, daily decisions about water sourcing, treatment, and hygiene are more directly linked to maternal knowledge and agency. For example, a rural mother with secondary education may choose to walk further for clean water or boil water more regularly, even in the absence of functioning infrastructure.

This aligns with findings from (Kasirye, 2010), who noted that in Uganda, piped water access alone was not sufficient-health gains only materialized when combined with maternal behavioral change. Similarly, (Waziri , Nor , Hook, & Hassan, 2018) documented that in rural Yobe State, Nigeria, the effectiveness of WASH programs was significantly enhanced when coupled with community health education targeting mothers.

In contrast, urban mothers may have more diverse water access options (e.g., vendors, sachet/bottled water), thereby reducing the direct reliance on public water points. Hence, the mediating role of education, while still present, is less critical in increasing health risks.

Theoretically, the study expands on the (Mosley & Chen, 1984) framework by explicitly quantifying maternal education as a mediating proximate determinant between environmental conditions and health outcomes. While empirically, it complements cross-sectional studies that document associations between water quality and child health by employing a causal mediation analysis approach which is rarely applied in the WASH literature. It also refines the heterogeneity in health vulnerabilities, showing that risk is not uniformly distributed even among those classified as “exposed”-rather, it is strongly conditioned by maternal capabilities.

Despite its strengths, the study has some limitations. First, the cross-sectional nature of DHS data limits causal claims to mediation effects observed at one point in time. Longitudinal data would enable better estimation of how sustained exposure interacts with caregiver behaviors over time.

Second, the educational categories are broad (e.g., primary vs. secondary), which may mask nuanced effects of literacy and health knowledge. Future studies could incorporate psychometric assessments or direct WASH knowledge tests.

Lastly, the study only explores one mediator (maternal education). Other potential pathways such as household income, cultural practices, or sanitation access, should also be explored in future work using multiple-mediator models.

5. Conclusion and Recommendations

5.1 Conclusion

This study examined the causal effect of exposure to non-functional water points on child health outcomes in Nigeria, with particular focus on the mediating role of maternal education. Using data from the 2018 DHS merged with georeferenced WPDx records, and applying causal mediation analysis, the findings reveal that maternal education mediates between 40%-46% of the effects of water point failures on diarrhoea prevalence, stunting, and under-five mortality. This mediating role is especially prominent in rural areas, where infrastructure limitations amplify reliance on caregiver knowledge and behavior.

The results underscore two central insights: first, that infrastructural reliability significantly shapes child health; and second, that maternal education amplifies household capacity to manage health risks associated with water insecurity. Effective child health strategies must address not only the structural deficits in water access, but also the human capital that mediates risk. Empowering mothers with education is not merely a developmental goal but it is a health imperative, and a powerful tool in reducing the vulnerabilities of Nigeria's youngest citizens.

5.2 Recommendations

Strengthen water infrastructure reliability: Federal, state, and local governments should prioritize routine maintenance and monitoring of rural water points, ensuring sustainable functionality beyond initial construction. This will directly reduce children's exposure to unsafe water sources.

Invest in maternal and female education: Expanding access to secondary and post-secondary education for girls will yield long-term health benefits, as educated mothers are more capable of adopting preventive practices and safeguarding child health.

Promote community-level WASH education: Public health interventions should integrate hygiene promotion and awareness campaigns targeting caregivers, with emphasis on handwashing, safe water storage, and timely health-seeking behavior.

Together, these measures can address both the infrastructural and socio-demographic determinants of child health, providing a holistic strategy to reduce preventable morbidity and mortality in Nigeria.

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