

Borehole Failure and Groundwater Contamination in Nigeria: Public Health Implications of Substandard Water Infrastructure

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Dr Kelvin Meyeyin-Bala

Action Health International Institute, Lagos, Nigeria

 **MK** [0009-0000-3033-1765](https://orcid.org/0009-0000-3033-1765)

Correspondence: Dr Kelvin Meyeyin-Bala, kelvinmeyeyin@gmail.com

Abstract

Groundwater abstracted by boreholes is the principal source of drinking-water for the vast majority of Nigerian households, yet an increasing proportion of the country's water points are non-functional, poorly sited, or structurally damaged, thus exposing populations to a direct or indirect disease pathway. This paper systematically reviews the causes of borehole failure in Nigeria and collates associated health impacts. A systematic review was conducted in accordance with Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) 2020 guidelines. Two electronic databases (Pub Med, Scopus), and three free-access publisher/grey-literature sources (Google Scholar, African Journals Online, UN & related agency repositories) were systematically searched for records in English published 01/2020-09/2026 using keyword combinations of 'borehole' OR 'groundwater' AND 'water infrastructure failure' OR 'water quality' OR 'waterborne disease' OR 'cholera' AND 'Nigeria'. Eligible records presented primary data, secondary evidence or systematic evidence on borehole quality, groundwater contamination, or cholera, typhoid or diarrhoeal disease in Nigeria. Screening, eligibility assessment, and thematic synthesis were performed in accordance with PRISMA guidance. Results Evidence synthesis converged on the conclusion that an estimated one-third- to one-half of Nigeria's improved water sources, boreholes especially, are permanently non-functional or deliver contaminated water at any given time, by a confluence of operational, financial, environmental, political, institutional and technical failures. These failure modes are associated with waterborne faecal coliforms, microplastics and heavy metals (especially lead, chromium and aluminium) in many states. Borehole failure must be understood and addressed as a population health issue, not only an engineering or infrastructure challenge. Key interventions include enforcing well siting and construction standards, establishing routine groundwater quality monitoring systems, establishing community-based borehole operation and maintenance systems, and integrating WASH and other water-related public health indicators into public health policy.

Keywords: Borehole Failure, Groundwater Contamination, Water, Sanitation and Hygiene (Wash), Waterborne Disease, Cholera, Nigeria, Systematic Review, Public Health

1. INTRODUCTION

Groundwater abstracted through boreholes is the dominant source of household drinking water across Nigeria, constituting a vital asset where the piped-water supply system remains underfunded and mostly non-functioning. National estimates on basic drinking-water coverage, citing UN/WHO Joint Monitoring Programme (WHO/UNICEF JMP, 2025), stands at about two thirds of the population, with only a few per cent enjoying the higher "safely managed" standard (WHO/UNICEF JMP, 2025). And clean, safely managed water access has been estimated at less than 30 per cent nationally in recent years (Macrotrends, 2025). In areas where piped-water supply does not reach and surface water bodies are contaminated or rely on seasonal flow, households, health facilities, schools, and IDP camps depend on government and private boreholes, drilled by non-governmental organisations, religious groups, and contractors with a wide range of skills. This dependence would not pose a public health concern if boreholes were reliably located, designed, and built such that the aquifers are protected. Data from Nigeria, however, documents a large and increasing number of boreholes either breaking down soon after being drilled or continuing in operation while delivering chemically or microbiologically contaminated water (Adeoti et al., 2024; 2025). The failure of boreholes turns a "safe" alternative to surface water into a conduit for disease. The public health implications are well known, but rarely considered in the context of the engineering and governance literature explaining the reasons for borehole failure. Nigeria has experienced among the largest cholera outbreaks in Africa over the past five years (Eneh et al., 2024; Gulumbe et al., 2023), with tens of thousands of cases in 2021 and 2022 alone in states where water infrastructure is most fragile (Eneh et al., 2024; Gulumbe et al., 2023). Heavy-metal, microbial and, increasingly, microplastic, contamination of borehole waters has been documented through independent studies in Lagos, Kebbi and other states (Yahaya et al., 2023, 2024). This paper joins these two strands of evidence.

1.1 Rationale and Objectives

Why this review A simple premise for this review is the following: Policy responses to the Nigerian water crisis are often made without sufficient regard to the functionality and water-quality assurance and downstream health impacts of interventions (number of boreholes drilled, amount of capital work spent) Given the importance of borehole failure to the efficacy of water interventions, there is the urgent need for systematic synthesis of (i) the reasons for borehole failure, and (ii) the known health impacts of borehole failure and consequent water quality deterioration. We will therefore aim to: Systematically identify and categorise the technical, environmental, financial, social, political, and institutional determinants of borehole failure in the peer-reviewed and grey literature published between 2020 and 2026.

Synthesize the public health impacts of borehole failure and groundwater contamination (including waterborne infection and chemical /physical contaminants) Identify the demographics most vulnerable to borehole failure (such as children, conflict-affected groups, flood-affected groups, and rural dwellers). Develop evidence-based policy, regulation, and practice recommendations.

2. METHODOLOGY

This review was performed as a systematic review of the peer-reviewed and grey literature per the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) statement (Page et al., 2021).

2.1 Search strategy

Electronic searches were performed on Pub Med/MEDLINE, Scopus, Google Scholar, African Journals Online (AJOL), and medRxiv. Targeted searches of institutional and grey-literature sources were conducted, including the WHO/UNICEF Joint Monitoring Programme for Water Supply, Sanitation and Hygiene (JMP), UNICEF Nigeria, the Nigeria Centre for Disease Control (NCDC), and the Standards Organisation of Nigeria (Nigerian Code of Practice for Water Well Construction, NCP 027:2010). Search terms combined the concept of borehole/groundwater infrastructure with the concept of failure or contamination and the concept of health outcome using Boolean strings like ("borehole" OR "tube well" OR "groundwater") AND ("failure" OR "functionality" OR "contamination" OR "water quality") AND ("Nigeria") AND ("public health" OR "waterborne disease" OR "cholera" OR "diarrhoea" OR "heavy metal"). Searches were limited to records published from 1 January 2020 to 11 September 2026 (date of the review).

2.2 Eligibility criteria

Records were eligible for inclusion if they (i) contained original data, systematic review evidence, or authoritative surveillance data of borehole or groundwater functionality, quality, or construction quality in Nigeria; (ii) included or allowed inference of an associated public health outcome (infectious or chemical); (iii) were published in English between 2020 and 2026; and (iv) were peer-reviewed journal articles, peer-reviewed preprints with accessible methodology, or authoritative institutional reports. Records were ineligible if they addressed water infrastructure outside Nigeria without Nigerian-disaggregated data, focused solely on urban piped-water supply systems with no groundwater component, or were opinion pieces without available evidence.

2.3 Study selection and data extraction

Titles and abstracts identified during the search were assessed for relevance, followed by assessment of entire articles using the same eligibility criteria. Data extracted from each article included: location within Nigeria, study design, data source (dataset size), identified causes of groundwater or water infrastructure failure, water-quality parameters, and health outcomes reported or implied by the study. Findings were synthesised narratively and thematically, categorising causes of infrastructure failure into technical, financial, environmental, social, political, and institutional domains, as has been previously applied by Adeoti et al. (2025) in a systematic review of Nigerian water infrastructure sustainability.

2.4 Quality appraisal

Studies were appraised according to use of clearly defined sampling and analytical methodologies, explicitly stated laboratory and statistical standards (e.g., WHO drinking-water guideline values, recognised standard procedures for microbiological and heavy-metal analysis), and acknowledgement of study limitations. Studies passing this quality and eligibility appraisal process were included in the narrative synthesis; no quantitative meta-analysis was conducted due to variation of outcomes (functionality rate, level of contamination, incidence of waterborne disease) amongst the series of included studies.

2.5 PRISMA study flow

The search, screening and inclusion of records across the five selected databases produced an initial evidence series from which duplicate entries were first removed. Title and abstract screening then followed, with full text review of remaining records, prior to final inclusion of eligible articles. The majority of evidence informing this review was from published systematic reviews of Nigeria's water and sanitation infrastructure (Adeoti et al., 2024; 2025), state- and city-level water quality surveys (Yahaya et

al., 2023; 2024), cholera national surveillance and outbreak investigations (Eneh et al., 2024; Gulumbe et al., 2023; Abba et al., 2026) and survey analyses of household WASH behaviour (Mobolaji & Akinwumiju, 2025), in addition to data from JMP/UNICEF, the Nigeria Centre for Disease Control (NCDC), and the Nigeria Standards Organisation of Nigeria (2010) Code of Practice for Water Well Construction.

3. RESULTS

3.1 Functionality of Borehole and Groundwater Infrastructure

Across all the studies under review, the consistent picture emerges that a significant proportion of Nigeria's borehole stock simply does not work (functionality rate of around 65 percent per findings from 15 studies) or provides an un-safe or unreliable supply (Adeoti et al. (2025)). Likewise, a systematic review of literature tracking Nigeria's water infrastructure performance, Adeoti et al. (2025) notes that just over 2 in 3 persons are served basic water services, and nearly half of the entire population's improved water points are non-functioning at any one time. A parallel field study carried out across 1,696 communities found that nearly half of all communities had not water supply at all, and observed high rates of water source failure along with water-related disuse driven by 'poverty' and low 'community ownership' (Adeoti et al., 2024). Findings from Nigeria's 2025 JMP (WHO/UNICEF, 2025) likewise reveal that large parts of Nigeria's population remain unserved by any basic drinking-water services and that smaller segments are served by safely managed, on-premises, and contamination-free water supplies (Macrotrends, 2025). Geospatial household-level analysis published by Mobolaji and Akinwumiji (2025) also shows that approximately 1-in-4 Nigerians still used unimproved drinking-water sources, with rural and socioeconomic disparities clearly mapped out.

3.2 Causes of Borehole Failure

In all of the studies, borehole failure can be categorized into six interrelated domains, namely: technical, financial, environmental, social, political and institutional (See Table 1 for a summary of the key processes identified in each domain).

Table 1. Domains and mechanisms of borehole/water-infrastructure failure in Nigeria

Domain	Representative Failure Mechanisms	Illustrative Source(s)
Technical	Poor siting without hydrogeological/geophysical investigation; substandard drilling and casing; inadequate borehole development; wrong pump selection; deterioration of ageing infrastructure with no preventive maintenance	Adeoti et al. (2024, 2025)
Financial	Insufficient capital and maintenance budgets; absence of user-fee collection systems; households unable to afford repairs or treatment; inefficient use of donor/government funds	Adeoti et al. (2025)

Domain	Representative Failure Mechanisms	Illustrative Source(s)
Environmental	Unfavourable hydrogeology; declining groundwater tables; proximity to landfills, latrines, or industrial effluent; flooding and climate variability; naturally occurring geogenic contaminants	Adeoti et al. (2025); Yahaya et al. (2023, 2024)
Social	Weak community ownership and management; low willingness or ability to pay; population growth outpacing water-point capacity; vandalism and theft of components	Adeoti et al. (2025); Mobolaji & Akinwumiju (2025)
Political / Institutional	Weak enforcement of the Nigerian Code of Practice for Water Well Construction (NCP 027:2010); fragmented regulatory oversight; corruption and non-compliance; poor monitoring and quality control; conflict-related destruction and displacement	Adeoti et al. (2025); Gulumbe et al. (2023)

According to Adeoti et al. (2025), technical causes-most notably infrastructure failure, construction problems, and poor operation and maintenance-are responsible for the largest proportion of well failure documented; closely behind are institutional causes, such as planning, monitoring, and quality assurance. Nigeria's Code of Practice for Water Well Construction (NCP 027:2010), published by the Standards Organisation of Nigeria, lays out requirements for siting, construction, completion, and abandonment to avoid these failure modes, but these are inconsistently implemented by states and contractors (Standards Organisation of Nigeria, 2010; WASHNigeria, 2022).

3.3 Groundwater Contamination and Chemical Hazards

In locations where boreholes continue to be used despite poor siting or construction, there are numerous independent water-quality studies indicating contamination above WHO guideline values, sometimes by large margins. In Oshodi/Isolo, Lagos, a toxicological evaluation of borehole water reported high concentrations of heavy metals including lead, exceeding WHO maximum allowable concentrations at most sampling locations, and modelled non-carcinogenic and carcinogenic health-risk estimates supported that ingestion and dermal absorption would present significant health risks (Yahaya et al., 2023). Another assessment of groundwater in Birnin Kebbi singled out microplastic contamination of borehole water as an emerging threat which was likely related to poor source protection, as well as relative proximity of the boreholes to waste-disposal sites (Yahaya et al., 2024). These chemical and physical dangers co-occur with microbiological risks in poorly constructed boreholes, as unsealed or misaligned casings provide ready access for surface contamination including faecal, industrial or leachate to reach the aquifer.

3.4 Waterborne Infectious Disease

The public health impact of unsafe water infrastructure is perhaps most starkly exemplified by Nigeria's persistent cholera outbreaks. Gulumbe et al. (2023) report that Nigeria's 2021 epidemic was its most serious in a decade, with the NCDC recording more than 100,000 suspected cases and over 3,600 deaths by the end of 2021, primarily in water-scarce, conflict-prone northern states of Borno, Yobe, Katsina,

Gombe, Taraba and Kano. Eneh et al. (2024) contextualizes this trend with national cholera surveillance records over the last two decades, revealing a pattern of recurrent large outbreaks in 2010, 2018, 2021 and 2022 associated with deficient WASH infrastructure and calling for more robust case surveillance along with case-area targeted interventions to achieve the Global Task Force on Cholera Control's target of 90% reduction in cholera deaths by 2030.

In an active outbreak in Zamfara, molecular surveillance detected toxigenic *V. cholerae* in water sources including boreholes, wells and rivers and sachet water, emphasising the point that boreholes are not necessarily safe once source protection infrastructure or standards are undermined (Abba et al., 2026). Beyond cholera, data at national and sub-national levels mentioned across the literature reviewed here link insecure drinking water with heavy paediatric diarrhoeal disease mortality and ongoing transmission of typhoid and other bacillary dysentery and diarrhoeal diseases, with children under five years of age bearing a disproportionate burden (UNICEF Nigeria, 2020; JMP, 2025).

3.5 Populations Disproportionately Affected

Evidence examined suggests three populations should be prioritised. First, rural populations, in which most non-functional water points are located, and where household income limits both the capacity to pay for repairs and the capacity to pay for treated options (Adeoti et al., 2024, 2025). Second, populations affected by conflict and displacement, especially in the North-East and North-West regions, where non-state insurgent-led destruction of infrastructure, displacing populations into overcrowded IDP camps and disrupted supply chains for water treatment chemicals perpetuate cholera transmission (Gulumbe et al., 2023). Third, under-fives, who are disproportionately affected by and account for most of the cholera mortality nation-wide (UNICEF Nigeria, 2020).

4. DISCUSSION

This review synthesises evidence that has mostly been produced and published in separate literatures, water-infrastructure engineering and management on one side, and public health surveillance and toxicology on the other, to make explicit a causal chain that is only implicit in any individual study: poorly sited, constructed and maintained boreholes induce failure and continued use of contaminated sources; this in turn causes measurable waterborne infectious disease and chemical exposures. Three points of synthesis merit highlighting. First, failure of a borehole should not be read solely as mechanical breakdown leading to dry, abandoned or nonfunctioning well; a functioning borehole that still provides water may still be a public health threat if it was poorly sited or constructed, a distinction that matters for surveillance systems that tend to measure functionality rates without tracking water quality (Adeoti et al., 2024; Yahaya et al., 2023).

Second, the technology and institutional problems identified in the water-infrastructure literature (poor siting, enforcement of NCP 027:2010, post-construction monitoring) appear directly connected to the contamination pathways measured in the water-quality and disease-surveillance literature, suggesting that improvement of construction quality and regulation enforcement would generate measurable downstream gains. Third, the load of failure borne by low-income, rural and conflict-affected populations is not proportional, instead being delivered to them the hardest; they have the fewest alternative water sources, and the least ability to treat water at the point of use.

4.1 Gaps in the Evidence

Several notable gaps restrict the degree of causal inference that can be ascertained from the existing literature: few studies have demonstrated a link between borehole-level data on the provision of water (construction, etc.) or water quality at a particular site and individual- or household-level health data; most

of the associations observed are at the community- and state- and national-level; long-term prospective monitoring that integrates borehole asset condition, water-quality data, and clinical outcome data is still infrequent; delineating the scope of water-quality data coverage by region (south versus north), and water quality information (more from the south than from the north), remain challenges for the literature despite the cholera burden residing in the north; and the scope of microplastic and emerging-contaminants exposure at the national level through borehole water remains under-characterised outside a handful of state-level studies (Yahaya et al., 2024).

5. POLICY AND PRACTICE RECOMMENDATION

Building on the evidence synthesised, we recommend the following actions to policy makers, regulators, development partners and public health actors:

1. To make any borehole siting contingent on adherence to the Nigerian Code of Practice for Water Well Construction (NCP 027:2010) requiring independent inspection at all stages of siting construction and completion as a condition for borehole procurement licensing of drillers or government or donor-funded projects.
2. To institutionalise post-construction water-quality surveillance including microbiological and heavy-metal testing of boreholes as an incorporated performance element of the mandate of state Rural Water Supply and Sanitation Agencies (RUWASSAs) and to link test results to a national borehole asset-management database.
3. To incorporate WASH infrastructure indicators into disease surveillance data with cholera typhoid and diarrhoeal disease reporting by Nigeria Centre for Disease Control routinely crosschecked against borehole water quality and functionality indicators at the local government level.
4. To prioritise investment and support for low-income and conflict-affected communities especially those requiring community-based operation-and-maintenance (Village-Level Operation and Maintenance) financing and in humanitarian contexts to include a rapid-repair provision for water points.
5. To strengthen geological and hydrogeological siting practice by expanding the use of desk-based geological review and geophysical survey prior to drilling especially in locations with geogenic contaminant potential or proximity to waste-disposal sites.
6. To expand household- and point-of-use water-treatment promotion (chlorination filtration) in the interim where borehole functionality needs restoring cannot be expected in the short term.
7. To build up the evidence base linking borehole quality and construction data directly to household health outcomes with larger-scale geographic coverage in northern states and in conflict-affected areas.

6. LIMITATIONS OF THE REVIEW

There are a number of limitations associated with this review that are common to the methods used in narrative systematic reviews of a heterogeneous evidence base. Because the evidence base represents a wide range of study designs, outcome measures, and sample sizes, a formal meta-analysis was not possible. The English language restriction may have excluded evidence published in French from neighbouring Sahelian countries or in other languages. Grey literature and non-published government and donor reports in the public domain are likely under-represented. Finally, because most of the evidence base is composed of observational studies, the associations described between borehole failure and disease outcomes should be considered associations consistent with, but not necessarily proof of, causality.

7. CONCLUSION

The problem of failed boreholes in Nigeria is as much an infrastructure and engineering problem as it is a public health problem. Based on the evidence from this review, we conclude that a failure in the technical, financial, environmental, social, political, and institutional aspects of borehole governance has left Nigeria with millions of unsafe and non-functional boreholes, and that dependence on contaminated water sources measurably increases the burden of cholera, diarrhoea, and typhoid disease while also exposing individuals to harmful metals and other contaminants. Populations living in rural, low-income, conflict-affected areas,

and children under the age of five, bear the brunt of this problem. Bridging the gap between water-infrastructure policy and public health policy, through mandatory construction standards, monitoring of water quality, and integrated disease-infrastructure surveillance offers a tangible, evidence-based solution to preventable ill health and death from diarrhoea, cholera, and typhoid.

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