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Rural Water Supply Challenges, Public Health Implications, and Purification Strategies in Nigeria

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***Abstract* — Nigeria is paradoxically endowed with substantial freshwater resources—an estimated 215 cubic kilometres of renewable surface water annually, complemented by extensive groundwater reserves—yet a large proportion of its population, particularly in rural areas, lacks reliable access to safe drinking water. This review synthesises historical, institutional, and public health evidence to characterise the scope and drivers of Nigeria's rural water crisis. It traces the evolution of public water supply from the colonial era through the establishment of River Basin Development Authorities and State Water Corporations, and examines the 2010 United Nations Resolution 64/292 affirming water as a fundamental human right. The review then documents the traditional water sources on which rural communities depend—rainwater harvesting, springs, streams, ponds, and hand-dug wells—and the microbiological and chemical hazards associated with each. Current national statistics are presented, including estimates that approximately 60 million Nigerians lack access to basic drinking water and that 77.3% of household drinking water contains bacterial contamination, most notably Escherichia coli. Finally, the review evaluates three widely used water purification technologies—activated charcoal filtration, reverse osmosis, and granular activated carbon—assessing their respective mechanisms, benefits, and limitations for household and community-scale application. The review concludes that closing Nigeria's rural water access gap will require coordinated investment in infrastructure, strengthened institutional capacity, genuine community participation, and sustained international partnership, alongside continued reliance on appropriate low-cost purification technologies where centralised infrastructure remains unavailable.**

***Keywords* — rural water supply; Nigeria; water quality; waterborne disease; activated charcoal; reverse osmosis; granular activated carbon; Sustainable Development Goals.**

I. INTRODUCTION

Access to safe, sufficient, and affordable water is a foundational requirement for human health, dignity, and development.

Yet in Nigeria—a country whose very geography is defined by major rivers, and after which several states are named, including Benue, Niger, Kaduna, Rivers, and Cross River—a substantial share of the population continues to rely on unsafe, seasonal, or contaminated water sources. This paradox of abundance amid scarcity is most acute in rural communities, where less than two-thirds of households have access to even a basic water supply and where women and children routinely walk long distances to fetch water from streams, ponds, and unprotected wells.

This review examines the persistent challenge of rural water accessibility in Nigeria from three complementary angles. First, it traces the historical and institutional evolution of public water supply, from the earliest colonial-era schemes through the establishment of River Basin Development Authorities and, more recently, the National Water Supply and Sanitation Policy. Second, it situates the discussion within the global human-rights framework established by United Nations Resolution 64/292 and examines the traditional water sources on which rural Nigerians depend, together with the health hazards each entails. Third, it evaluates the traditional and modern purification technologies—activated charcoal filtration, reverse osmosis, and granular activated carbon—that rural and peri-urban households increasingly rely upon in the continued absence of comprehensive piped infrastructure.

The purpose of this review is twofold: to consolidate dispersed historical, statistical, and technical evidence into a single coherent account of Nigeria's rural water crisis, and to argue that meaningful progress will require simultaneous attention to institutional reform, infrastructure investment, and continued support for the low-cost purification technologies that already serve millions of households in the absence of centralised alternatives.

II. LITERATURE REVIEW

A. Historical Development of Water Supply in Nigeria

Organised public water supply in Nigeria dates to the early twentieth century, when a small number of urban centres received the country's first formal water schemes (Federal Republic of Nigeria, 2000).

Responsibility for these systems was initially placed at the lowest administrative level, with cities such as Lagos, Calabar, Kano, Ibadan, Abeokuta, Ijebu Ode, and Enugu among the earliest beneficiaries. These early schemes were financed chiefly through revenue from water sales and received little or no direct operational subsidy from government authorities. Figure 1 shows the approximate locations of these pioneer urban centres.

Figure 1. Map of Nigeria indicating early beneficiaries of organised public water supply.

Following the creation of regional governments in the early 1950s, responsibility for financing, planning, and expanding water infrastructure shifted to the regional administrations, which also assigned supervisory personnel to oversee operations and maintenance. Despite these expanded responsibilities, regional governments were slow to establish autonomous water agencies. It was not until 1966 that the first Water Corporation was established, in the Western Region, inheriting the assets, liabilities, and personnel of existing schemes and absorbing staff previously attached to the Water Division of the Ministry of Works.

Federal participation in water resources management began in 1976 with the creation of the Federal Ministry of Water Resources alongside eleven River Basin Development Authorities (RBDAs) (Ishaku et al., 2011). The RBDAs were mandated primarily to supply bulk water for dry-season irrigation in selected agricultural—largely rural—communities; domestic water supply fell outside their remit. Today, public water supply is administered by Water Corporations or Public Utility Boards across all thirty-six states and the Federal Capital Territory, complemented by local government provision for smaller communities.

The adoption of the National Water Supply and Sanitation Policy in January 2000 reaffirmed that responsibility for water services should be shared among the Federal, State, and Local Governments.

Despite these successive policy initiatives, the public sector continues to satisfy only a fraction of national demand. Fewer than half of the approximately 85 million people residing in urban and semi-urban areas have reliable access to safe water, forcing many low-income households to depend on private vendors who charge substantially more than public utilities. In rural areas, manually operated boreholes and hand-dug wells have provided partial relief, but many have deteriorated due to mechanical failure and declining groundwater levels; during the dry season, numerous boreholes and wells produce little water or fail entirely. Where infrastructure does exist, service is often unreliable and of poor quality, reflecting weak management, inadequate operation and maintenance, inappropriate pricing, and an inability to recover operating costs—factors that have collectively driven the deterioration of much of the nation's water supply infrastructure.

United Nations Resolution 64/292 affirms that "the human right to water entitles everyone to sufficient, safe, acceptable, physically accessible and affordable water for personal and domestic uses" (Saheed et al., 2014). This landmark declaration recognises access to clean, safe, and affordable water as a fundamental human right to be guaranteed without discrimination. As a signatory to the United Nations Charter and its associated conventions, Nigeria is formally committed to upholding this obligation.

In practice, however, universal access to potable water remains an elusive goal for the vast rural population, and even many urban centres continue to experience inadequate, unreliable, and unaffordable drinking water supplies. It is against this backdrop that the present review examines the persistent challenge of water accessibility in Nigeria and considers practical pathways toward sustainable availability of this indispensable resource.

The cultural and symbolic significance of water is also reflected in the Christian scriptural tradition, in which the separation of the waters from the land created habitable space for humanity (Genesis 1:9–10). Before this act, water is described as covering the entire earth—an image of abundance and universal availability. Read against this backdrop, the contemporary scarcity of potable water appears less a natural inevitability than the consequence of human activity, ineffective management, and environmental degradation, underscoring the urgency of restorative intervention.

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B. The Water Challenge of the Present Millennium

According to Ahmed et al. (2011), one of the defining challenges of the present millennium is meeting the continuously rising demand for safe water supply and adequate sanitation. The centrality of water to survival is well established: the human body requires approximately 3–10 litres of water daily for normal physiological function, and as Nnamani (2019) observes, while humans can survive several weeks without food, they can live only a few days without water.

Several interlocking factors have been identified as responsible for poor access to potable water in rural Nigeria, including inadequate coordination among relevant agencies, weak maintenance culture, limited institutional and technical capacity, and excessive bureaucratic control by supervising ministries. Obeta and Nwankwo (2015) catalogue a wider set of contributing factors: the seasonal nature of available water sources, insufficient infrastructure, long distances to streams and springs, inadequate protection of existing sources, limited community participation, weak political commitment, politicisation of water projects, inadequate funding, ageing infrastructure, and misappropriation of allocated funds. They further highlight topographical constraints, cultural and traditional practices, rapid urbanisation, vandalism, geological limitations, and unresolved questions of infrastructure ownership. Taken together, these findings point to environmental, infrastructural, socioeconomic, geographical, and institutional bottlenecks as the principal barriers to effective rural water delivery.

According to World Bank estimates, approximately 98 million Nigerians resided in rural communities as of 2019—nearly half the national population. Although these communities produce a substantial share of the food consumed in urban areas, they continue to experience severe infrastructural deficiencies, among which the limited availability of safe water for drinking and domestic use is among the most pressing. In many rural settlements, residents travel several kilometres daily to fetch water from streams, rivers, ponds, and springs; where communities depend on shallow wells, shortages intensify sharply during the Harmattan season as groundwater levels fall.

In other areas, rural households rely on stagnant ponds as their principal water source. These ponds are frequently shared by humans and animals alike, creating conditions favourable to numerous infectious diseases (Agbadike, 2010). More troubling still is the widespread practice, documented in some rural communities, of urinating directly into rivers and streams (Babalola, 2019), and in many riverine communities of southern Nigeria, open defecation into rivers remains common.

Kalu et al. (2019) report that Cross River, Akwa Ibom, Delta, and Bayelsa States continue to experience significant challenges associated with open defecation.

A particularly striking illustration occurred in 2017, when a member of the Bayelsa State House of Assembly commissioned a so-called “floating toilet” for residents of the Okor Ama and Oweideo Ama communities in Amassoma Local Government Area, Southern Ijaw Constituency (The Cable, 2017). Constructed directly above a river, the facility effectively institutionalised open defecation into the water body it overhung—an episode that starkly illustrates the depth of the sanitation and water-management challenges confronting many rural Nigerian communities.

C. Traditional Water Sources in Rural Nigeria and Their Associated Risks

Rural Nigerian communities have traditionally relied on two principal sources of domestic water: the direct collection of rainwater using pots, gourds, buckets, and other locally available containers, and the extraction of water from natural springs, streams, ponds, rivers, and hand-dug wells. Although these sources have sustained rural livelihoods for generations, most are seasonal and become unreliable during the dry season, making water scarcity a recurring challenge. The United Nations (2018) has emphasised that achieving the Sustainable Development Goals requires universal access to safe drinking water and adequate sanitation by 2030, as a foundation for good health, well-being, and gender equality.

I. Springs: Springs constitute one of the most important natural sources of freshwater and continue to support millions of people worldwide, particularly in developing countries such as Nigeria (Bhat et al., 2020, 2022). A spring forms where groundwater naturally emerges at the earth's surface, marking a critical stage of the hydrological cycle in which underground water flows upward before discharging into streams or rivers (Water Science School, 2018; Chukwu, 1999). Springs often develop in recharge zones characterised by karst topography, where surface water infiltrates the soil, mixes with groundwater, and later resurfaces after passing through impermeable geological formations. This underground passage subjects water to natural filtration, generally improving quality by removing many disease-causing microorganisms while enriching the water with dissolved minerals such as calcium, magnesium, and iron (FAO, 2002).

Despite these natural purification processes, spring water quality remains vulnerable to both natural and anthropogenic contamination.

Geochemical reactions, agricultural activity, saline water intrusion, improper waste disposal, urbanisation, and other human influences can significantly degrade groundwater quality (Alum et al., 2021; Akhtar et al., 2014), making regular monitoring essential for safeguarding public health in communities that depend on springs as a principal drinking-water source. According to Jones et al. (2014), groundwater monitoring techniques serve not only to establish the current status of water resources but also to identify long-term environmental trends, enabling authorities to evaluate health risks and implement preventive measures. Groundwater chemistry is, in turn, continually reshaped by rapid urbanisation, industrial development, mining, radioactive emissions, domestic wastewater discharge, agricultural practice, volcanic activity, rock weathering, and evaporation (Dippong et al., 2018, 2020; Roșca et al., 2020), underscoring Biswas and Tortajada's (2010) observation that water-quality management strategies must be tailored to local and regional conditions rather than applied uniformly.

Although Sub-Saharan Africa has made considerable progress in expanding access to improved water sources—now reaching approximately 43% of the population—these supplies are predominantly drawn from privately owned boreholes that are rarely subjected to systematic quality monitoring (WHO/UNICEF, 2015). Nigeria, with an estimated population exceeding 205 million (Worldometer, 2020), faces enormous challenges in providing safe drinking water to its rapidly growing population. In the near-absence of functional piped systems across much of the country, households increasingly depend on alternative groundwater sources such as springs, boreholes, and wells (Owamah et al., 2013; Dahunsi et al., 2014); because these sources are often poorly monitored, millions of people remain exposed to significant, and largely preventable, health risks.

II. Streams, Ponds, and Hand-Dug Wells: The concerns associated with spring water apply equally to other traditional sources such as streams, ponds, and hand-dug wells. Streams are largely seasonal, flowing abundantly during the rainy season but often disappearing entirely during prolonged dry periods. Human activity—including road construction and other infrastructural development—frequently alters or obstructs their natural flow, while sediments, organic waste, and other pollutants collected along their course make streams a major source of waterborne disease.

Ponds present even greater public health concerns, consisting of stagnant water with little or no natural circulation.

These water bodies provide ideal breeding grounds for pathogenic microorganisms, parasites, and disease vectors; successive rainy seasons replenish and multiply existing contaminants, increasing the risk of disease outbreaks. Women and children, who are typically responsible for fetching water, remain the most vulnerable to these hazards.

Hand-dug wells present a still more critical challenge. Many are shallow, poorly protected, and easily contaminated by surface runoff, sewage infiltration, and other environmental pollutants, with water quality often deteriorating markedly during both the rainy and dry seasons. Taken together, the conditions confronting many rural Nigerian communities are deeply concerning and demand urgent national and international intervention. Strengthened collaboration among governments, development partners, humanitarian organisations, researchers, and local communities is essential to complement existing local efforts, improve access to safe drinking water, enhance public health outcomes, and ultimately raise the quality of life for millions of rural Nigerians.

D. Current Statistics on Water Access and Quality in Nigeria

In 2018, the Federal Government of Nigeria officially declared the Water, Sanitation and Hygiene (WASH) sector to be in a state of emergency, reflecting the magnitude of the country's water and sanitation challenges. Despite various interventions, the situation remained alarming in 2019: a combination of inadequate infrastructure, shortage of skilled human resources, insufficient investment, and an ineffective regulatory framework left approximately 60 million Nigerians without access to basic drinking water, 80 million without access to improved sanitation, and 167 million without access to basic handwashing facilities.

The situation is more severe still in rural communities, where approximately 39% of households lack access to even a basic water supply, only about half have access to improved sanitation, and nearly 29% continue to practise open defecation—a proportion that has changed only marginally since 1990, indicating slow progress despite decades of policy intervention.

Nigeria is naturally endowed with abundant water resources, possessing approximately 215 cubic kilometres of renewable surface water annually in addition to substantial groundwater reserves. Nevertheless, these resources have not translated into universal access to safe drinking water: although roughly 70% of Nigerians reportedly have access to a basic water source, only a small percentage have access to water that is consistently safe for drinking.

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In rural areas specifically, nearly 39% of households remain without access to even a basic supply, and average daily per-person water consumption is approximately 9 litres—well below the nationally recommended minimum of 12–16 litres per day.

The most common domestic water sources nationally are tube wells, boreholes, and hand-dug wells. Pipe-borne water now accounts for only 9.5% of household supply, a dramatic decline from 61.6% in 1995, while boreholes presently supply approximately 21.5% of household tap water. Water quality remains a further major concern: approximately 86% of Nigerian households consume water without any form of treatment prior to use, and studies indicate that 77.3% of household drinking water contains bacterial contamination, particularly Escherichia coli (E. coli), exposing millions of people to serious health risks. Unsafe drinking water contributes to approximately 7.34% of recorded deaths in Nigeria, with cholera, typhoid fever, hepatitis, and dracunculiasis (Guinea worm disease) among the most prevalent waterborne illnesses.

Nigeria's public water distribution infrastructure has also deteriorated considerably: most major supply pipelines were installed during the 1970s, with little significant replacement or expansion since. This ageing infrastructure has become a major constraint on efficient nationwide distribution, and the resulting demand for alternative sources has stimulated growth in the water-treatment industry—Nigeria currently accounts for approximately 15% of the Sub-Saharan African market for water filtration products, ranking behind South Africa (43%) and Ethiopia (18%). Although Nigeria faces a relatively low risk of prolonged drought (a drought index score of 1.2 out of 5), access to safe drinking water remains constrained primarily by infrastructure deficiencies rather than by water scarcity itself.

Bottled and sachet water have become widely consumed alternatives—popular brands include Eva Water, Nestlé Pure Life, Aquafina, Cascade, Redeemed Water, and Bigi Table Water—yet concerns persist regarding their quality. Studies indicate that approximately 30% of bottled and sachet water products contain bacterial contamination, and nearly 58% of commercially available sachet water fails to meet World Health Organization standards for potable water, despite costing up to twenty times more than the equivalent volume of public tap water. Children remain among the most affected: approximately 29% (about 26.5 million) of Nigerian children lack sufficient access to water to meet their daily domestic and hygiene requirements.

Table 1 presents the historical trend in the proportion of Nigeria's population with access to clean water between 2000 and 2020, illustrating a slow but consistent upward trajectory that nonetheless leaves the majority of the population without reliably safe supply.

TABLE 1
ACCESS TO CLEAN WATER IN NIGERIA, 2000–2020 (HISTORICAL TREND)

Year	% of Population with Access	Annual Change
2020	21.67%	0.35%
2019	21.32%	0.36%
2018	20.96%	0.36%
2017	20.60%	0.37%
2016	20.23%	0.37%
2015	19.86%	0.38%
2014	19.49%	0.38%
2013	19.11%	0.39%
2012	18.72%	0.39%
2011	18.33%	0.40%
2010	17.93%	0.40%
2009	17.53%	0.41%
2008	17.12%	0.41%
2007	16.71%	0.41%
2006	16.30%	0.42%
2005	15.88%	0.42%
2004	15.46%	0.43%
2003	15.03%	0.43%
2002	14.60%	0.43%
2001	14.17%	0.45%
2000	13.72%	0.45%

E. Traditional and Modern Water Purification Technologies

Faced with persistent gaps between policy aspiration and actual service delivery, rural Nigerian communities have developed practical, affordable methods for improving the quality of the water available to them. Conventional purification methods that remain widely practised include boiling, filtration, sedimentation, prolonged storage, solar disinfection, chemical treatment, and irradiation. This section examines three technologies of particular importance in the Nigerian context—activated charcoal filtration, reverse osmosis, and granular activated carbon—assessing the underlying mechanism, principal benefits, and limitations of each.

I. Activated Charcoal Filtration: Activated charcoal filtration is one of the oldest and most effective indigenous methods for improving drinking-water quality.

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The activated charcoal used in water purification should be distinguished from ordinary charcoal briquettes used for cooking; water-filtration systems instead use activated charcoal supplied as loose granules or compressed carbon blocks. Production involves heating carbon-rich materials above 1000°F in an oxygen-free environment, followed by a second stage involving oxygen and steam that creates a highly porous internal structure; the resulting material is subsequently treated chemically with gases such as argon and nitrogen. This porosity is the principal characteristic responsible for the material's exceptional filtration efficiency.

The purification mechanism is based on adsorption rather than absorption: dissolved substances and gases adhere chemically to the solid surface of the charcoal, rather than penetrating into the material itself. Because activated charcoal possesses an enormous internal surface area—reaching approximately 2,000 square metres per gram—it provides countless microscopic sites to which contaminants can bond. As contaminated water passes through the filter, organic compounds are attracted to and retained on the charcoal surface, effectively removing chlorine, volatile organic compounds (VOCs), unpleasant odours, and various organic pollutants, while largely preserving beneficial dissolved minerals.

Not all contaminants are removed: substances that, depending on molecular size, polarity, or chemical properties, are not attracted to the carbon surface will pass through the filter. Over time, adsorption sites become saturated with trapped contaminants, reducing filter effectiveness and necessitating periodic replacement. Nonetheless, activated charcoal filters remain relatively inexpensive, easy to maintain, and widely accessible, making them particularly well suited to rural communities with limited financial resources.

Figure 2. Activated charcoal used for household water purification.

II. Benefits of Activated Charcoal Water Filters: Activated charcoal filtration offers several advantages that make it one of the preferred methods of household water purification.

i. Preservation of essential minerals. Whereas many conventional filtration systems remove both harmful contaminants and beneficial minerals, activated charcoal selectively adsorbs harmful organic contaminants while allowing many essential minerals to remain in the treated water—though it does not eliminate all microorganisms, and is therefore often combined with complementary purification methods.
ii. Improvement of nutritional quality. By preserving or allowing the reintroduction of minerals such as calcium, magnesium, and iron, activated charcoal filtration contributes to the nutritional value of treated water.
iii. Enhancement of taste and odour. Activated charcoal effectively adsorbs chlorine, organic chemicals, and other odour-producing compounds—commonly responsible for the metallic taste or objectionable smell of municipally treated tap water—resulting in more palatable drinking water, which in turn encourages consumption and reduces reliance on commercially bottled water.
iv. Cost-effectiveness. Compared with more sophisticated household treatment systems, activated charcoal filters are inexpensive to manufacture and install, making them economically viable for low-income rural households.
v. Ease of maintenance. Charcoal filtration systems require minimal upkeep. Filter cartridges should typically be replaced approximately every six months, or sooner if water quality, taste, odour, or flow rate noticeably deteriorate.

III. Reverse Osmosis (RO): Reverse osmosis is a highly effective water purification technology in which pressure is applied to force water molecules through a semipermeable membrane, separating dissolved contaminants from clean water. Unlike natural osmosis, in which water moves spontaneously from a region of low solute concentration toward one of higher concentration, reverse osmosis reverses this process by applying external pressure to the more concentrated side of the membrane. Among modern water treatment technologies, RO is recognised as one of the most efficient and cost-effective methods for removing a broad spectrum of impurities: the membrane retains dissolved salts, suspended particles, microorganisms, and other contaminants, which are then flushed away as concentrate (reject water), while purified water passes through for collection.

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High-pressure pumps generate sufficient pressure to overcome the natural osmotic pressure of the feed water, enabling systems to retain approximately 95–99% of dissolved salts and impurities on the concentrate side.

IV Principles of Reverse Osmosis: The operation of reverse osmosis rests on the scientific principle of osmosis, under which water containing dissolved salts naturally moves across a semipermeable membrane toward a region of higher solute concentration until equilibrium is reached—a process fundamental to numerous biological systems, from nutrient uptake in plant roots to fluid regulation in the kidneys. Reverse osmosis deliberately reverses this phenomenon: external pressure, typically generated by a high-pressure pump, is applied to the feed water, exceeding the natural osmotic pressure and forcing water molecules through a highly selective membrane while preventing the passage of dissolved salts, microorganisms, and numerous chemical contaminants. The resulting permeate possesses extremely high purity, suitable for drinking and numerous industrial applications.

Rejected substances concentrate on the feed side of the membrane and are continuously removed, either directed to drainage or recycled through further treatment. Commercial and industrial RO systems typically recover approximately 75% of incoming feed water as purified product; in applications where conservation is particularly important, recovery efficiencies may rise to approximately 85%, although excessively high recovery rates must be balanced against membrane performance and contaminant removal efficiency. An important operational feature is cross-flow filtration, in which purified water flows through the membrane in one direction while contaminants are continuously carried away in another, minimising fouling, maintaining membrane cleanliness, and prolonging system lifespan.

V. Advantages of Reverse Osmosis

i. Effective reduction of Total Dissolved Solids (TDS). Very few water treatment technologies achieve comparably high levels of dissolved-contaminant removal, making RO the technology of choice wherever high-purity water is required.

ii. Cost-effectiveness in industrial applications. RO enables efficient large-scale water purification at relatively low operating cost, allowing industries to treat substantial volumes of water within acceptable financial limits.

iii. Environmentally friendly operation. Because separation occurs primarily through applied pressure rather than heat, RO consumes significantly less energy than thermal distillation, reducing operating costs, greenhouse gas emissions, and overall carbon footprint.

iv. Removal of water hardness. By eliminating carbonate, calcium, and magnesium ions, RO improves water quality for domestic consumption, industrial processes, and household appliances.

VI. Limitations of Reverse Osmosis

a) High water consumption. RO systems generate considerable reject water; domestic units in particular often discharge larger volumes of wastewater relative to the purified water produced, though industrial systems can achieve better recovery through advanced pressure control and recycling.

b) Removal of beneficial minerals. Because RO membranes remove contaminants indiscriminately, beneficial minerals such as calcium and magnesium are also lost; many modern systems therefore incorporate remineralisation stages to restore nutritional quality, improve taste, and reduce the corrosive tendency of highly purified water within pipeline systems.

c) Management of concentrated waste streams. The reject water generated during RO treatment contains elevated concentrations of dissolved contaminants and must be disposed of responsibly, requiring industrial facilities to implement environmentally compliant disposal methods to prevent secondary pollution.

Reverse osmosis remains one of the most reliable and scientifically proven technologies for producing high-quality drinking water. When properly designed, operated, and maintained, it offers exceptional purification efficiency and remains an indispensable component of modern water treatment systems.

VII. Granular Activated Carbon (GAC): Granular Activated Carbon (GAC) is another widely adopted water purification technology used to improve drinking-water quality. GAC is produced from carbon-rich raw materials such as coal, coconut shells, and wood, heated in the absence of oxygen to activate the carbon and substantially increase its internal surface area—a process that also gives rise to the common designation “charcoal filters.” Activated carbon used in water treatment exists principally in two forms, Granular Activated Carbon (GAC) and Powdered Activated Carbon (PAC), distinguished chiefly by particle size and manufacturing process: GAC consists of relatively larger granules, whereas PAC comprises much finer particles, with consequent differences in manufacturing cost and operational characteristics even where raw materials and activation methods are identical.

Owing to its exceptional adsorption properties, activated carbon filtration can remove up to 99% of suspended solids, volatile organic compounds, silt, heavy metals, chloramines, chlorine, and numerous other common drinking-water contaminants.

VIII. GAC Filter Characteristics: Before entering service, a GAC filter is normally backwashed to remove fine particles and properly arrange the carbon granules within the filter bed; following backwashing, the smallest granules settle toward the upper portion of the bed while larger particles occupy the lower section. Two parameters are commonly used to describe the particle-size characteristics of GAC media: effective size and uniformity coefficient. Effective size, expressed in millimetres, represents the diameter corresponding to the smallest 10% of the carbon granules and significantly influences both filtration efficiency and hydraulic performance—smaller particles provide greater surface area for adsorption, increasing filtration efficiency, but also produce a higher pressure drop as water encounters greater resistance.

The Uniformity Coefficient (UC) is a dimensionless parameter indicating how uniformly the carbon particles are distributed within the filter bed; a value of 1 represents perfectly uniform particle size, with larger values indicating increasing size variation. Per AWWA Standard B604-96, the Uniformity Coefficient is defined as the ratio of the sieve opening that passes 60% of a representative sample of filter material to the sieve opening that passes 10% of the same sample—a parameter that assists engineers in evaluating the hydraulic characteristics and expected filtration performance of activated carbon media.

GAC filtration has proven highly effective for removing numerous contaminants responsible for undesirable taste, odour, and colour, and is equally efficient at eliminating chlorine and hydrogen sulfide, both associated with objectionable tastes and odours, including the characteristic smell of rotten eggs. Despite these advantages, activated carbon filtration has notable limitations: it is generally ineffective at removing nitrates, fluoride, dissolved salts, most microorganisms, and water-hardening minerals. Consequently, activated carbon is frequently incorporated into multi-stage treatment systems, where it complements other technologies such as reverse osmosis, ultraviolet disinfection, or membrane filtration.

III. Discussion

The evidence reviewed here points to a rural water crisis that is fundamentally institutional and infrastructural rather than resource-driven.

Nigeria's renewable freshwater endowment is substantial, and the country's major rivers lend their names to several of its states; the persistence of widespread water insecurity is therefore best explained not by physical scarcity but by decades of fragmented governance, underinvestment in maintenance, weak cost-recovery mechanisms, and limited community involvement in the planning and stewardship of local water infrastructure. This conclusion is consistent with the historical trajectory traced in Section 2, in which successive transfers of responsibility—from regional governments to River Basin Development Authorities to State Water Corporations—have rarely been matched by the institutional capacity or sustained funding needed to keep pace with population growth.

The public health implications of this institutional gap are considerable. With 77.3% of household drinking water estimated to contain bacterial contamination and unsafe water contributing to a meaningful share of national mortality, the traditional water sources documented in Section 5—springs, streams, ponds, and hand-dug wells—cannot on their own meet the safety standard that Resolution 64/292 establishes as a matter of human right. At the same time, the purification technologies reviewed in Section 7 illustrate that meaningful, affordable improvements in water quality are achievable at the household level even where centralised infrastructure remains unavailable. Activated charcoal and granular activated carbon filtration in particular offer a favourable balance of cost, accessibility, and effectiveness for organic contaminants, chlorine, and unpleasant taste or odour, even though neither technology reliably removes dissolved salts, nitrates, fluoride, or the full range of microorganisms responsible for waterborne disease. Reverse osmosis addresses many of these residual risks but does so at a materially higher cost in both equipment and water consumption, limiting its accessibility for the lowest-income rural households without external subsidy or support.

Taken together, these findings suggest that no single technology or policy instrument is likely to close Nigeria's rural water access gap on its own. Rather, progress will depend on a layered approach: continued and expanded use of low-cost household purification technologies as an immediate protective measure, alongside sustained investment in piped and borehole infrastructure, strengthened regulatory oversight of water quality, and governance reforms that give rural communities a genuine stake in the planning, financing, and maintenance of the systems that serve them.

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IV. Conclusion And Recommendations

The lack of reliable and timely access to safe drinking water remains one of the most pressing developmental challenges confronting rural communities in Nigeria (Marks et al., 2013). The evidence presented throughout this review indicates that persistent deficiencies in rural water supply stem largely from weaknesses in policy implementation, institutional arrangements, and infrastructure development, rather than from any underlying scarcity of the resource itself. The sustainability of Rural Water Supply Schemes has been undermined by inadequate institutional capacity, ineffective management of publicly owned facilities, insufficient financial and technical resources, and the geographical dispersion of many rural settlements—factors that collectively hinder efficient planning, operation, maintenance, and long-term sustainability.

Beneficiary communities are, moreover, rarely involved meaningfully in either the planning or maintenance of rural water supply systems. Because most schemes remain under centralised state control, local communities often have limited opportunity to contribute to decision-making or routine maintenance, weakening both ownership and sustainability. The resulting inadequacy of potable water access carries profound implications for rural livelihoods, adversely affecting health, productivity, education, and overall quality of life, while disproportionately burdening women and children, who often travel long distances to obtain water for household use.

Based on the evidence synthesised in this review, the following recommendations are proposed:

a) Strengthen institutional frameworks governing Rural Water Supply Schemes, with clearer delineation of Federal, State, and Local Government responsibilities and stronger accountability mechanisms for operations and maintenance.
b) Expand genuine community participation in the planning, financing, and stewardship of local water infrastructure, moving beyond consultation toward shared ownership and management.
c) Increase sustainable funding for infrastructure rehabilitation and expansion, including realistic cost-recovery mechanisms that do not place undue burden on low-income households.
d) Promote continued access to low-cost household purification technologies—particularly activated charcoal and granular activated carbon filtration—as an interim protective measure in communities lacking centralised infrastructure, supported by public education on appropriate filter maintenance and replacement schedules.
e) Establish regular, systematic water-quality monitoring for springs, boreholes, and wells, particularly in areas at elevated risk of contamination, to inform timely public health interventions.
f) Strengthen international collaboration, particularly with the United Nations and development partners, to mobilise the technical and financial support needed to accelerate progress toward Sustainable Development Goal 6.

Achieving these objectives will require coordinated efforts involving the Federal, State, and Local Governments, development partners, non-governmental organisations, researchers, private sector stakeholders, and the beneficiary communities themselves. Ensuring universal access to clean water is not merely an infrastructural obligation—it is a fundamental human right and an indispensable prerequisite for achieving sustainable development.

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