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Comparative analysis of drinking water standards between China and Nigeria.

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Abstract- *Drinking water quality standards are essential for ensuring safe and sustainable water supplies worldwide. However, significant differences exist between countries in their regulatory frameworks, parameter limits, and enforcement mechanisms. This review provides a comparative analysis of drinking water standards between China and Nigeria, focusing on the national frameworks, parameter limits, and institutional architectures that govern drinking water quality. China's GB 5749-2022 standard reflects the country's rapid urbanization, technological advancement, and growing concerns about emerging contaminants. In contrast, Nigeria's NSDWQ (NIS 554:2015), based on WHO guidelines, faces challenges due to fragmented regulatory frameworks, inconsistent enforcement, and limited monitoring capacity. This review examines these differences, identifies gaps in both countries' compliance with global norms, and recommends strategies to improve water quality governance. Main recommendations include strengthening institutional coordination, updating standards to address emerging contaminants, and enhancing digital compliance systems for better monitoring and enforcement. The analysis emphasizes the importance of adapting global standards to local contexts while addressing emerging water quality risks to ensure equitable access to safe drinking water.*

Keywords: Drinking water standards, China, Nigeria, Water quality, comparative analysis.

1. Introduction.

Robust national water quality standards translate health risk science into enforceable regulatory limits for drinking and ambient waters, underpinning surveillance systems, treatment design, and public reporting required for achieving SDG 6. The World Health Organization's 2022 Guidelines for Drinking Water Quality (GDWQ) remain the global reference framework, emphasizing health based targets, water safety plans, and risk based surveillance calibrated to local contamination profiles and institutional capacity (Tsaridou and Karabelas 2021;Han et al. 2023). These guidelines have increasingly shaped national regulatory reforms worldwide as countries respond to intensifying anthropogenic pressures, emerging contaminants, and evolving scientific evidence.

China's recently revised GB 5749-2022 standard, effective from April 2023, represents one of the most comprehensive national updates to drinking water regulation in Asia. The revision expands parameter coverage, updates analytical methods, and strengthens hygiene requirements for centralized and secondary water supplies. Implementation is coordinated through a vertically integrated regulatory architecture involving the National Health Commission, market surveillance agencies, and environmental authorities, and is complemented by the surface water quality framework defined under GB 3838-2002. The update reflects China's response to increasingly complex pollution pressures linked to rapid urbanization, industrial discharges, and broader ecological challenges that necessitate frequent recalibration of microbiological, chemical, and disinfection-by-product (DBP) controls [3].

In Nigeria, the Nigerian Standard for Drinking Water Quality (NSDWQ; NIS 554:2015) remains the primary regulatory benchmark, specifying maximum allowable concentrations for microbiological, physical, and chemical contaminants, with limits largely adapted from WHO guideline values. [4] However, empirical studies consistently show that actual water quality particularly in small towns, per-urban areas, and rural settlements frequently fails to meet these regulatory thresholds, with recurrent exceed dances in microbial indicators, turbidity, and selected metals. [5]. Microbial contamination of packaged and

distributed water also persists despite the existence of Nigerian Industrial Standards for bottled and sachet water [6]. Highlighting the ongoing disconnection between formal regulation and effective implementation.

Globally, rising concern over Emerging contaminants residues is driving regulators toward ultra-low, parts-per-trillion thresholds.(Leslie et al. 2025; de Sadeleer 2025). Both China and Nigeria will need to integrate these evolving risk criteria and analytical performance standards in their next revision cycles.

The main aims of this study is to compare the regulatory frameworks, implementation capacity, and alignment of national drinking water quality standards in China and Nigeria with the World Health Organization (WHO, 2022) Guidelines for Drinking Water Quality. The analysis identifies three major findings**,** China maintains a vertically integrated and technology driven monitoring system; Nigeria's framework is fragmented and inconsistently enforced, and both countries face gaps regarding emerging contaminants and transparency. Accordingly, three actions are recommended regular standard revision, expansion of accredited laboratory networks, and development of digital compliance tracking platforms to strengthen governance and ensure equitable access to safe drinking water.

2. Regulatory Frameworks and Institutional Architecture.

When considered beyond their legal texts, the regulatory architectures of China and Nigeria reveal two systems addressing the same public health mandate through markedly different institutional strategies. China's drinking water standard GB 5749-2022, in force since April 2023, functions as a comprehensive "source-to-tap" regulatory blueprint. Rather than merely prescribing numerical limits, it delineates responsibilities across utilities, secondary water supply managers, and sanitary inspectors, specifies which materials and products may come into contact with drinking water, and defines the analytical methods required for compliance verification[9]. As Li et al. (2024) emphasize, ensuring safe tap water in China depends not only on treatment-plant performance but also on the integrity of building level distribution systems the critical "last mile" where stagnation, microbial regrowth and plumbing deterioration can compromise water quality. These concerns have driven recommendations for enhanced secondary disinfection, systematic flushing, and more rigorous maintenance of internal plumbing systems.

This broad regulatory scope reflects China's rapid urbanization and the expansion of dense, interconnected water supply networks, where lapses at any point can propagate across districts[10]. Implementation is intentionally multi pillar, the National Health Commission (NHC) oversees sanitary supervision, the State Administration for Market Regulation (SAMR) governs conformity of products, materials and monitoring devices, and the Ministry of Ecology and Environment (MEE) links drinking-water quality to ambient water protection through basin-wide ecological management [11]. Importantly, GB 5749 operates in tandem with the Environmental Quality Standard for Surface Water (GB 3838-2002), which classifies water bodies (Classes I–V) and establishes ecological and chemical objectives that underpin both source-water protection and enforcement strategies. Recent public health and regulatory analyses highlight that the combined framework now encompasses over 100 indices and is steadily shifting toward risk based verification aligned with WHO guidance [2].

In Nigeria, the principal regulatory instrument is the Nigerian Standard for Drinking Water Quality (NSDWQ; NIS 554:2015) promulgated by the Standards Organization of Nigeria (SON) [12]. This standard establishes maximum allowable concentrations for a broad suite of physical, chemical and microbiological parameters, largely derived from the WHO Guidelines for Drinking Water Quality.

It covers drinking water supplied by public utilities, community systems and packaged water (with separate standards for mineral and sachet water. In practice, however, implementation authority is distributed across the Standards Organization of Nigeria (SON)**,** NESREA**,** the Federal Ministry of Water Resources**,** and state level water agencies [13]. This multi-level arrangement increases institutional reach but also introduces challenges: accreditation, equipment maintenance and sampling frequency vary substantially among states, leading to uneven regulatory performance [14]. Government assessments and peer reviewed studies consistently identify the same priorities updating NSDWQ to reflect modern toxicology and analytical methodologies, expanding accredited laboratory networks and proficiency testing, and strengthening inter-agency coordination to ensure that non-compliance triggers timely corrective action[15].

Placed side by side, the institutional contrast becomes clear. China's vertical, centrally coordinated model integrates public-health supervision, market regulation and basin level ecological management under standards that explicitly reference

test methods, thereby promoting predictable enforcement across provinces [16] Nigeria's federal plus state model is well suited to local diversity but requires regular standard revision, interoperable data systems and sustained funding to avoid disparities in consumer protection [17]. Recent scholarship argues that neither architecture is inherently superior; rather, the level of procedural detail, stability of funding, and strength of institutional capacity determine regulatory outcomes. In China, explicit method references, defined inspection frequencies and expanded public reporting have driven measurable improvements in both river quality and treated water compliance. Nigeria's ongoing SDG-6 reviews and policy reforms similarly highlight opportunities to achieve greater consistency through updated norms, improved NESREA, SON coordination and more systematic basin level disclosure.[18].

Table 1. Comparative Summary of Regulatory Frameworks and Institutional Architecture in China and Nigeria.

Dimension	China	Nigeria	References
Legal Standard and Scope	GB 5749-2022 (97 mandatory indicators, includes PFAS)	NIS 554 (NSDWQ), WHO-derived microbial and chemical limits	[2]
Emerging Contaminants Management	Sets PFOS and PFOA limits (80 ng/L, 40 ng/L)	Regulatory gap for many emerging pollutants	[19]. [20]
Institutional Structure	Centralized: NHC, MEE, SAMR coordinate regulation, water safety & materials	Distributed: SON, NESREA, Federal & State water agencies share regulation	[21] [22]
Monitoring & Compliance	National radioactivity monitoring, 11,000 samples (2012–2024), within GB 5749 limits	Monitoring uneven; large regional gaps, especially in the North	[23]
Emergency and Risk Flexibility	Allows temporary relaxation of some chemical and aesthetic limits in emergencies (per GB 5749-2022)	Emergency provisions exist but enforcement is inconsistent	[24]
Regulatory Challenges	Managing disinfection by-products, plumbing regrowth, PFAS residues	Weak lab capacity, irregular sampling, fragmented enforcement	[25])

3. Comparative Parameter Benchmarks and WHO Configuration

3.1. Microbiological parameters.

The WHO (2022) Drinking Water Quality Guidelines establish absolute zero tolerance (0 CFU/100 mL) for ***E. coli*** as the universal benchmark for microbial safety, anchoring a risk-based framework in which verification, sanitary risk assessment, and operational monitoring function as coordinated safeguards [26] [27]. China's GB 5749-2022 not only adopts this zero-E. coli requirement but integrates it within a highly institutionalized Water Safety Plan (WSP) model**,** mandating routine sanitary inspections, tiered monitoring frequencies based on system size, and compulsory documentation of corrective actions. Municipal utilities are required to conduct daily or near-daily microbial checks**,** while provincial and national agencies implement an additional layer of oversight through audit inspections, online reporting platforms, and regulatory enforcement mechanisms. [28] This multilayered verification structure ensures that deviations are rapidly identified and addressed, thereby reducing outbreak risks and stabilizing compliance across urban service areas.

In contrast, Nigeria's NSDWQ likewise stipulates 0 CFU/100 mL *E. coli*, but the translation of this requirement into consistent practice remains challenged by resource constraints, fragmented institutional arrangements, and uneven enforcement capacity. Many state water agencies lack routine access to functional microbiological laboratories, resulting in infrequent or ad-hoc microbial testing, often limited to periodic surveillance by state ministries of health or externally funded programs.[29] Sanitary inspections are not systematically documented, corrective action pathways are inconsistently applied, and real-time monitoring systems are largely absent [30]. Besides, rural and peri-urban water providers frequently operate outside formal regulatory oversight, leaving verification largely dependent on emergency-response sampling rather than preventive risk management.

As a result, while both countries align normatively with WHO's zero-tolerance standard, China achieves a higher degree of operational fidelity through structured monitoring schedules, digital compliance reporting, and enforceable accountability mechanisms. Nigeria's compliance remains aspirational but inconsistent, shaped by infrastructural limitations, weak surveillance continuity, and variability in subnational governance capacity. [31]This divergence emphasizes the importance of institutional maturity, monitoring frequency, and regulatory enforcement in determining the real-world effectiveness of microbial standards, even when nominal limits are identical.

3.2. Physicochemical and inorganic chemical parameters.

The revised GB 5749-2022 standard of Ministry of Health of the People's Republic of China (effective April 2023) expands and refines the operational and health-based drinking-water requirements, covering an updated set of 97 water-quality indicators including physical, chemical, and toxicological parameters among them pH, turbidity, TDS, nitrate, fluoride, and major ions thereby aligning with but often tightening thresholds compared to prior editions.[32] Recent empirical evaluations confirm these tighter controls, for example, a 2024 water-quality assessment in Xinjiang reported that treated tap water under compliance schemes consistently met GB 5749-2022 physicochemical limits, demonstrating the standard's practical enforceability.[33] Meanwhile, Chinese regulators have complemented the drinking-water standard with source-water quality controls (e.g., via classification under surface-water standards), thereby indirectly shaping treatment requirements for parameters such as organic load and certain chemical indices a holistic regulatory architecture that links ecological water quality with drinking-water treatability.[2] By contrast, Nigeria's NSDWQ (Nigerian Standard for Drinking Water Quality) (via Standards Organization of Nigeria, and related potable water regulations) nominally mirrors the physical and chemical limit values set by the World Health Organization (WHO), maintaining pH, TDS and EC, nitrate, fluoride, chloride among its core parameters. [15] Nevertheless, recent field based reviews reveal substantial and persistent deviations in water sources and supplies. A 2024 nationwide assessment found a significant proportion of groundwater and surface water sources in northern Nigeria classified as "unfit for consumption," with more than half failing portability criteria for chemical or physicochemical indices. [22] Also, as of 2024 survey of water quality across Nigerian states reported that up to 15 % of samples exceeded WHO and NSDWQ nitrate limits, 10 % exceeded chloride thresholds, and many also recorded elevated TDS and conductivity, with concurrent contamination by heavy metals and other inorganic constituents in some areas. [34] These findings suggest that despite the presence of sound numeric limits on paper, actual compliance in Nigeria remains uneven largely due to weak institutional capacity, inconsistent monitoring, and insufficient treatment or water-source protection, rather than the absence of standards per se.

Thus, compared to Nigeria, China's physicochemical regime under GB 5749-2022 demonstrates a stronger alignment with WHO's health-based and operational targets, stricter control of water-quality indices, and integrated source-to-tap regulatory architecture, supported by empirical evidence of high compliance in treated supplies. In Nigeria, the same core parameters are regulated but implementation gaps including irregular monitoring, inadequate treatment infrastructure, and variable source-water quality mean that physicochemical compliance remains inconsistent, underscoring that the effectiveness of water quality standards depends as much on governance and capacity as on the limit values themselves [35].

3.3. Heavy Metals.

For priority metals (Pb, As, Cd, Cr and Hg), China's GB 5749-2022 and Nigeria's NSDWQ (NIS 554:2015) both adopt maximum allowable concentrations that are essentially harmo nised with WHO guideline values, so the *numerical* limits for these toxic elements are broadly convergent in the two systems. However, GB 5749-2022 embeds these limits within a more prescriptive, risk-based framework, the standard classifies indices as regular and expanded, specifies water-quality examination methods and detection requirements, and couples limit values with process-wide management obligations for utilities and laboratories, including unified testing and surveillance arrangements. [32] Recent monitoring of tap water in Wuhan, for example, found that concentrations of ten metals including Cd, Cr and Pb were almost uniformly below GB 5749-2022 limits, with hazard indices <1 and total carcinogenic risk within internationally acceptable ranges, illustrating what consistent enforcement of the standard can achieve in large urban systems.[36] By difference, Nigeria's NSDWQ sets metal limits comparable to WHO but is primarily a parameter and values document, a national review highlights that, although the standard exists, understanding and implementation among producers and subnational regulators remain uneven, and practical enforcement mechanisms are weak. [37] Empirical case-studies show the consequences of this gap, borehole water in Minna, Niger State contained Pb, Cd, Hg and Ni far above both NSDWQ and WHO limits in all sampled wells,[38] and groundwater near municipal dumpsites in Benin City exhibited cumulative cancer risks from Pb, Cr and Ni that exceeded internationally accepted risk thresholds despite

the formal existence of NSDWQ aligned limits. [39] Taken together, these findings suggest that while China and Nigeria nominally converge on health-based metal standards, China's more detailed specification of analytical methods, surveillance and Quality Assurance and Quality Control under GB 5749-2022 has translated into more consistent compliance in treated municipal supplies, whereas Nigeria's weaker enforcement, fragmented laboratory capacity and locally contaminated groundwater sources continue to expose many communities to metal-related health risks.

3.4. Disinfection by-products (DBPs) and disinfectant residuals.

For disinfection by-products (DBPs) and disinfectant residuals, both China and Nigeria nominally regulate similar indicator families, but the depth of control and monitoring differs sharply. Under GB 5749-2022, China specifies allowable ranges for free residual chlorine at the treatment works and consumer taps and sets binding limits for several DBP classes (e.g. total THMs, HAAs, bromate, chlorite), reflecting its reliance on large chlorinated networks and a risk-based management approach.[40] Recent Chinese studies show why this regulation matters: multi-province monitoring and risk assessments confirm that THMs and HAAs are the dominant regulated DBPs, with thousands of tap-water samples in central China generally meeting GB 5749-2022 limits, but with localized episodes where total Trihalomethane (TTHM) and Haloacetic Acids (HAA) levels approach cancer-risk thresholds (10^{-6}–10^{-4}), highlighting the need for continuous control of residual chlorine and precursors. [41] Source water investigations around Wuhan similarly identify trichloromethane (TCM) and trichloroacetic acid (TCAA) as main DBPs formed from chlorine residues, again aligning with the regulatory focus on THMs and HAAs. [42] In response, Chinese utilities increasingly deploy integrated advanced trains such as pre-ozonation followed by biological activated carbon (O_3–BAC) and downstream Nano filtration and UF which recent pilot and full-scale work shows can markedly suppress DBP formation by stripping natural organic matter and specific DBP precursors before final chlorination; combined O_3–BAC + NF configurations on Taihu Lake water, for example, substantially reduced both regulated and toxic emerging DBPs compared with conventional sand filtration chlorination alone. [43] This trajectory is consistent with global reviews that identify ozone BAC, granular activated carbon and membrane barriers as among the most effective strategies for DBP mitigation when coordinated with optimized disinfection. [44]

Nigeria's NSDWQ (NIS 554) also contains a dedicated table for "disinfectants and their by-products, requiring a free residual chlorine band of 0.2–0.25 mg/L at consumers' taps and setting a very stringent limit of 0.001 mg/L (1 µg/L) for total THMs in chlorinated supplies, alongside values for a few individual organic by-products such as 2,4,6-trichlorophenol. [5] On paper this is stricter than WHO's commonly used TTHM guideline, but recent reviews of the Nigerian standard emphasis that systematic DBP monitoring is rare, awareness of DBP requirements among operators is limited, and enforcement provisions are weak. [37] Empirical data from treatment plants in Lagos and Ogun States show the practical outcome: measured TTHM concentrations in treated water reached up to 950 µg/L, with average levels at primary and secondary disinfection points exceeding both WHO and NSDWQ limits and producing elevated lifetime cancer risks via ingestion.[45] A global assessment of THM regulation and monitoring further classifies Nigeria as a country with only partial THM data and no nationwide routine monitoring, whereas countries like China, although not yet providing full national coverage, have denser regional datasets and more systematic surveillance. [46] Taken together, recent evidence indicates that China couples its DBP limits to detailed specifications for residual disinfectant control, extensive monitoring networks and investment in O_3–BAC–membrane trains that actively manage DBP precursors, while Nigeria's framework converges numerically on residual chlorine and THM limits but lacks comparable measurement frequency, process integration and enforcement, so that DBP exposure is governed more by local treatment capacity and operational practice than by the written standard.

Table 2. Comparison of Selected Drinking Water Quality Standards.

Parameter	Unit	WHO (2022)	China GB 5749-2022	Nigeria NSDWQ (2007)	Significance
pH	–	6.5 – 8.5	6.5 – 8.5	6.5 – 8.5	Acceptable aesthetic and operational range
Turbidity	NTU	5	5	5	Indicator of filter performance
Total Dissolved Solids (TDS)	mg L^{-1}	1000	1000	1000	Taste and acceptability threshold
Electrical Conductivity (EC)	µS cm^{-1}	1500	1500	1500	Proxy for salinity, ionic load
Total Hardness (as	mg L^{-1}	500	450	500	Scaling potential, non-health

$CaCO_3$)					parameter
Nitrate (NO_3^-)	mg L^{-1}	50	50	50	Infant methaemoglobinaemia risk
Fluoride (F^-)	mg L^{-1}	1.5	1.0	1.5	Balance dental benefit and fluorosis risk
Chloride (Cl^-)	mg L^{-1}	250	250	250	Taste and corrosion criterion
Sulphate (SO_4^{2-})	mg L^{-1}	250	250	100	Laxative taste threshold
Iron (Fe)	mg L^{-1}	0.3	0.3	0.3	Aesthetic, staining indicator
Lead (Pb)	mg L^{-1}	0.01	0.01	0.01	Neurotoxicity, priority heavy metal
Arsenic (As)	mg L^{-1}	0.01	0.01	0.01	Carcinogenic; chronic toxicity
Cadmium (Cd)	mg L^{-1}	0.003	0.003	0.003	Kidney damage threshold
Chromium (Cr total)	mg L^{-1}	0.05	0.05	0.05	Toxic metal control
Mercury (Hg)	mg L^{-1}	0.006	0.001	0.001	Tightest limit for neurotoxicity
Free Residual Chlorine	mg L^{-1}	0.2 – 0.5	0.3 – 0.5	0.2 – 0.5	Disinfection assurance
Trihalomethanes (TTHMs)	mg L^{-1}	0.1	0.1	0.1	DBP control from chlorination
E. coli	CFU 100 mL^{-1}	0	0	0	Fundamental microbial safety criterion
Total Coliforms	CFU 100 mL^{-1}	0	3 (100mL)	10 (100 mL)	Operational indicator; stricter in China
Permanganate Index	mg L^{-1} O_2	5	3	–	Proxy for organic load (China specific)
Turbidity post-treatment	NTU	1	1	5	Treatment-process control

4. Monitoring, Compliance, and Enforcement

In China, the regulatory architecture for drinking water and ambient water monitoring has progressed from a historically fragmented inspection regime to a coordinated, risk based governance model. [47] The adoption of GB 5749-2022 formalized comprehensive sampling plans that mandate routine monitoring and sanitary inspections not only for centralized utilities but also for secondary supply systems such as institutional buildings and dormitories. The standard incorporates explicit references to accredited analytical methods and delineates responsibilities across main agencies, including the National Health Commission and the State Administration for Market Regulation (SAMR). Furthermore, integration with the GB 3838-2002 ambient water classification system ensures that basin level functional zoning directly informs monitoring, permitting and transparency measures [48].

China has also expanded its national monitoring infrastructure at an unprecedented scale. According to recent analysis, the number of surface water monitoring stations increased from 972 in 2015 to 3,646 under the 14th Five-Year Plan (2021–2025), enhancing the frequency of violation detection and aligning national practice with water-safety-planning principles.[49]. The operational value of this expanded network is demonstrated by Li et al. (2025), who used a multi-model framework to pinpoint heavy-metal sources in surface and groundwater, illustrating how systematic surveillance enables more targeted interventions. [50]. Complementary developments including standardized analytical methods, linkage of discharge permits to ambient classifications, and nationwide disclosure platforms such as the Blue Map portal further strengthen accountability. Collectively, these reforms reflect a shift from nominal compliance toward continuous verification, transparency and adaptive management.

In Nigeria, by contrast, regulatory enforcement remains uneven despite the presence of established numerical limits within NIS 554:2007 (NSDWQ) for drinking water and the National Environmental (Surface and Groundwater Quality Control) Regulations (2011) for ambient waters. Environmental variability further complicates implementation: Nnaemeka Okeke and Okeke (2024) demonstrate that seasonal precipitation coupled with coal weathering pressures significantly influences groundwater quality in Enugu, where only 1% of sampled wells met “excellent” criteria and the majority ranged from good to very poor categories. [51]. Institutional responsibilities are distributed across the Standards Organization of Nigeria (SON), NESREA, the Federal Ministry of Water Resources and numerous state-level water boards, creating a multi-layered but fragmented structure. Recent assessments highlight inconsistent monitoring coverage, limited laboratory accreditation, weak QA and QC practices and minimal public disclosure of compliance data [52]. Enforcement is often ineffective, one

comprehensive review characterized the situation as "grave," citing frequent guideline violations with minimal consequences [53]. Field studies reinforce these concerns only 13% of drinking-water sources in northern Nigeria satisfied safe-water definitions, with more than half deemed unfit for consumption, and Lagos based investigations reveal systemic inspection failures and poor equipment maintenance. In Aba, Ijioma et al. (2025) documented extensive bacteriological contamination linked to dysfunctional waterworks, unregulated urban activity and dependence on sachet water, underscoring persistent institutional and infrastructural weaknesses. [4].

Comparatively, the divergence between China and Nigeria lies less in the written standards than in the capacity to monitor, verify and enforce them. China's method-linked accreditation systems, nationwide monitoring networks, basin integrated disclosure mechanisms and structured sanction architecture collectively confer a strong operational advantage. Nigeria's persistent constraints agency fragmentation, under-resourced analytical infrastructure and weak transparency limit effective implementation[54]. Addressing these gaps will require strategic investment in accredited laboratories, improved inter-agency coordination, digital reporting platforms and risk based monitoring frameworks measures that mirror China's evolving model and offer transferable lessons for strengthening Nigeria's water safety governance.

Table 3: Comparative Monitoring, Compliance, and Enforcement Framework for Water Quality in China and Nigeria

Dimension	China .	Nigeria.	Reference
Regulatory framework	GB 5749-2022 integrates routine monitoring, accredited methods, and watershed oversight	NIS 554 and related rules are in place, yet enforcement is poorly coordinated."	[40]. [15]
Monitoring network capacity	Monitoring capacity grew sharply under recent national plans, improving early detection.	Monitoring is uneven, with major spatial gaps and infrequent sampling.	[55] . [56].
Analytical methods & lab accreditation	Mandatory QA/QC strengthens reliability of monitoring results.	Lab accreditation and QA/QC are inconsistent across states.	. [57] [58]
Data transparency & public disclosure	Monitoring data are increasingly published online, boosting accountability.	Public disclosure is limited, with few platforms sharing routine compliance data.	[59]. [60]
Enforcement & sanctions	Greater focus on checking compliance and applying penalties for violations.	Weak enforcement allows many violations to go unpenalized.	[61]. [62]
Empirical case studies and examples	Multi-model source identification aids pinpointing pollution origins.	Few water sources meet "excellent" quality standards.	[55] [63]
Main bottlenecks and strengths	Standardization (GB 5749-2022) ensures consistent water quality measures.	Improvements need accreditation, digital disclosure, and inter-agency coordination. .	[64] [65]

5. Emerging Contaminants, Treatment Technologies, and Future Needs

5.1. Emerging Contaminants.

The increasing prevalence of emerging contaminants such as per- and poly fluoroalkyl substances (PFAS), pharmaceutical residues, and pesticides has become a major global concern, prompting regulators to update water quality standards to address these compounds' health risks and environmental persistence [66]. China has been proactive in revising its GB 5749-2022 drinking water quality standard to include stricter limits on PFAS, pharmaceuticals, and disinfection by-products (DBPs), integrating these emerging risks into its regulatory framework. This shift reflects the country's rapid industrialization and the increased detection of these pollutants in surface and drinking water sources [67]. In contrast, Nigeria's regulatory focus remains largely on conventional water quality parameters, such as microbial contamination, turbidity, and heavy metals, with limited provisions for managing emerging pollutants. This gap highlights the need for future updates to Nigeria's NSDWQ (NIS 554:2015) to incorporate new contaminants that are increasingly detected in water supplies due to industrial and agricultural practices, with significant potential for adverse public health outcomes [68].

5.2. Treatment Technologies and Challenges

In response to these emerging challenges, China has made significant strides in implementing advanced treatment technologies designed to remove a broader spectrum of contaminants. These include zonation, ultraviolet (UV) disinfection, and membrane filtration systems, which have been shown to be highly effective in reducing not only traditional microbial contaminants but also chemical pollutants and disinfection by-products. Studies have demonstrated that these advanced technologies, when combined with real time monitoring and automated treatment control systems, significantly enhance water treatment efficiency and compliance with updated standards [69]. In contrast, Nigeria's water treatment infrastructure is primarily based on chlorination and sedimentation, methods that are effective for traditional contaminants but less capable of addressing the complex array of chemical pollutants and emerging contaminants [70]. The reliance on basic technologies, combined with challenges in operational consistency and maintenance, hampers the country's ability to meet the increasingly stringent water-quality standards, particularly in light of modern chemical threats (Fadare, 2022). Therefore, Nigeria's water-treatment systems must modernize to incorporate advanced treatment technologies and emerging contaminant monitoring to safeguard public health.

6. Lessons, Policy Insights, and Harmonization Pathways

A comparative assessment of WHO guidelines, China's GB 5749-2022, and Nigeria's NSDWQ demonstrates that the most significant gains in drinking-water safety arise not from numeric limits alone but from the institutional architecture that ensures their implementation. WHO's Framework for Safe Drinking Water and the Water Safety Plan (WSP) approach establish a preventive, risk-based model that integrates system assessment, operational monitoring, and independent surveillance across the entire catchment to consumer chain.[71] China's 2022 revision represents one of the most advanced national applications of these principles, it expands the scope of regulated contaminants, mandates explicit analytical methods and minimum detection limits, strengthens Quality assurance and Quality Control obligations for laboratories, and embeds routine surveillance within a vertically integrated digital reporting and enforcement system [72]. Recent studies show that these features combined with investments in multi-barrier treatment trains such as ozonation BAC and UF/NF have significantly reduced microbial risks, inorganic contaminants, and disinfection by-product loads in major Chinese cities [73]. By compare, Nigeria's regulatory challenges stem from implementation gaps, inconsistent monitoring frequencies, heterogeneous laboratory protocols, weak enforcement, and limited risk-based operational control, particularly in small and state-managed utilities. [74]

Therefore, Nigeria can improve drinking-water quality by systematically adopting WHO's risk based Water Safety Plan model and integrating China's GB 5749-2022 advancements such as expanded indicator coverage, mandatory quality assurance and quality control, digital surveillance, and multi-barrier treatment optimization into its national regulatory framework.

These different experiences emphasize a critical policy insight, achieving safe drinking-water requires governance capacity, institutional unity, and methodological rigor not just regulatory text. Consequently, for Nigeria to translate its nominal alignment with WHO and NSDWQ limits into safe water for all, policymakers should adopt a harmonization pathway modeled after China's experience and WHO guidance. This would require institutionalizing Water Safety Plans across utilities to enable proactive risk assessment and hazard control, Modernizing NSDWQ to include explicit analytical methods, Quality Assurance and Quality Control protocols and detection limit standards, investing in accredited, well-equipped laboratories complemented by digital compliance reporting platforms, and Integrating basin-scale source water protection, surveillance, and cross agency coordination. Through these interventions, Nigeria could evolve from a standards-on-paper regime toward a resilient, transparent and evidence-driven regulatory system, thereby significantly improving water safety and public health while aligning with global best practices.

7. Conclusion

This review demonstrates that while both China and Nigeria anchor their drinking-water regulatory frameworks in the principles of the WHO Guidelines for Drinking Water Quality, their levels of alignment, enforcement capacity, and technological preparedness differ markedly. China's GB 5749-2022 reflects a mature, vertically integrated regulatory ecosystem supported by advanced treatment technologies, real time monitoring, and coordinated multi-agency oversight. These components collectively enable consistent compliance and rapid incorporation of emerging contaminants into regulatory updates. Conversely, Nigeria's NSDWQ (NIS 554:2015) provides a solid normative foundation but is constrained by

fragmented institutional responsibilities, limited laboratory capacity, inconsistent enforcement, and infrastructural deficits that hinder effective implementation, particularly in rural and peri-urban settings.

Despite these contrasts, the experiences of both countries highlight important cross-cutting priorities for improving drinking water safety. Strengthening source water protection, modernizing treatment processes, institutionalizing risk based surveillance, and increasing investments in laboratory accreditation and digital reporting systems are essential pathways for enhancing regulatory effectiveness. Furthermore, the growing global attention to PFAS, pharmaceuticals, and other emerging contaminants highlights the urgency of regular standard revision and adaptive risk governance.

Eventually, achieving equitable access to safe drinking water requires regulatory systems that are both scientifically rigorous and contextually responsive. China's progress illustrates the benefits of coordinated national oversight and technological innovation, while Nigeria's challenges emphasize the need for targeted capacity building, harmonized enforcement protocols, and sustained infrastructure investments. Together, these findings reinforce that harmonizing national water quality standards with global best practices is not merely a technical exercise but a broader governance imperative one that demands continual learning, institutional coherence, and long term political commitment to safeguarding public health.

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