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CBRN risk management in school sanitary facilities in Kinshasa: a documentary review of health risks and assessment perspectives

Lily Banzungula¹, Fiston Masikini Bombamu^{1,2,3}, Henry Jacques Bomoi Matita¹, Pierre Ensole Mbongo Pasi⁴

¹Centre of Excellence for Chemical, Biological, Radiological and Nuclear Affairs (CoE-CBRN), Ministry of Scientific Research and Technological Innovation, Democratic Republic of the Congo

²Department of Public Health, Université Méthodiste John Wesley, Kinshasa, Democratic Republic of the Congo,
masikinifiston@gmail.com

³Department of Environment and Sustainable Development, Université Chrétienne Cardinal Malula, Kinshasa, Democratic Republic of the Congo

⁴Higher Institute of Applied Techniques, Kinshasa, Democratic Republic of the Congo

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ABSTRACT

Purpose: This documentary review critically synthesises knowledge on chemical, biological, radiological, and nuclear (CBRN) risk management in school sanitary facilities in Kinshasa, and proposes assessment perspectives prior to sample collection. It reframes school sanitation deficiencies as a governance and management problem rather than a purely technical public health issue.

Methodology/Approach: A systematic documentary search was conducted in PubMed, ScienceDirect, Google Scholar, SpringerLink, and documentation from WHO, UNICEF, the World Bank, and Congolese national institutions (1980–2026). Keywords included school sanitation, WASH, CBRN risks, Kinshasa, hygiene, water quality, and health risks. A thematic analysis organised the material into five axes: state of facilities; documented health risks; potential CBRN risks; regulatory and institutional framework; and assessment perspectives.

Findings: Only 54% of Kinshasa schools have a water point (73% urban vs 23% peri-urban; $p = 0.000$). Latrine coverage is 96.88%, but only 3.6% are considered hygienic. Identified CBRN risks include chemical risks (chlorinated cleaning products, heavy metals in water and soil), biological risks (enteric pathogens, microbial proliferation, antimicrobial resistance), and potential radiological risks (natural radionuclides in groundwater). Degraded facilities act as contamination hotspots, exposing students to urogenital infections, diarrhoeal diseases, and typhoid fever.

Practical implications: The study provides a prioritisation matrix to guide resource allocation by educational and health authorities, and proposes a stepwise sampling protocol (preliminary characterisation, sample collection, analysis and interpretation) applicable to Kinshasa schools. It argues that managerial accountability and WASH budgeting are the primary levers for risk reduction.

Originality/value: This is the first review to integrate the CBRN dimension into the management analysis of school sanitary facilities in the Democratic Republic of the Congo, offering an actionable framework for decision-makers.

Keywords: school sanitary facilities, CBRN risks, Kinshasa, WASH governance, school health, risk management.

1. Introduction

1.1. General Context

Access to water, hygiene, and sanitation (WASH) in schools is a fundamental determinant of student health and educational success. According to WHO and UNICEF (2023), 2.2 billion people — 28% of the population in developing countries — lack access to basic sanitation facilities, and more than 115 million people still drink untreated surface water. Globally, an estimated 1.9 billion school days could be saved if water and sanitation targets were met (UNICEF, 2012).

In sub-Saharan Africa, only 46% of schools have access to basic water services, 44% to basic sanitation services, and 26% to basic hygiene services (Frontiers, 2025). This reality contrasts sharply with Sustainable Development Goal (SDG) 6.2, which calls for equitable access to adequate sanitation and hygiene for all by 2030.

In Kinshasa, the capital of the Democratic Republic of the Congo (DRC), school infrastructure is in a critical state. Urban and peri-urban neighbourhoods experience limited access to WASH, predisposing students to infection risks and reduced academic performance. This situation is all the more concerning as Kinshasa schools welcome millions of students in often precarious sanitary conditions.

1.2. Problem Investigated

The central question of this documentary review is: **What are the CBRN risks associated with degraded sanitary facilities in Kinshasa schools, and what are the assessment perspectives prior to sample collection?**

More specifically:

1. What is the current state of sanitary facilities (toilets, water points, handwashing devices) in Kinshasa schools?
2. What are the documented health risks for students and teaching staff?
3. What are the potential CBRN risks associated with these degraded facilities?
4. What are the gaps in CBRN risk management in Kinshasa school settings?
5. What assessment and sampling perspectives can be envisaged?

1.3. Purpose and Objectives of the Study

General objective: To conduct a critical documentary review of knowledge on CBRN risk management in school sanitary facilities in Kinshasa, highlighting associated health risks and assessment perspectives, and to draw managerial implications for educational and health authorities.

Specific objectives:

1. To synthesise available data on the state of sanitary facilities in Kinshasa schools;
2. To analyse documented health risks for students and teaching staff;
3. To characterise potential CBRN risks associated with these facilities;
4. To examine the regulatory and institutional framework for risk management in schools;
5. To propose assessment and sampling perspectives to characterize CBRN risks;
6. To formulate managerial recommendations for risk governance in the school sector.

1.4. Justification of the Study

This documentary review is of capital importance at several levels:

- **Scientifically:** It synthesises scattered knowledge on the state of sanitary facilities in Kinshasa schools and identifies research gaps regarding CBRN risks.
- **Health-wise:** It highlights risks for students and teaching staff and proposes assessment perspectives to guide interventions.
- **CBRN-wise:** It integrates the CBRN dimension into school risk analysis, an approach still rare in Congolese literature.
- **Regulatory-wise:** It provides scientific arguments to strengthen standards and controls in schools.
- **Managerially:** It reframes school sanitation as a governance issue, with clear implications for budgeting, accountability, and institutional coordination.

2. Materials and methods

2.1. Documentary Search Strategy

A systematic documentary search was conducted between January and March 2026. Databases searched included PubMed, ScienceDirect, Google Scholar, SpringerLink, and documentation from the World Health Organization (WHO), UNICEF, the World Bank, and Congolese national institutions (Ministries of Education, Health, and Environment). Keywords used, in French and English, included: school sanitary facilities, school sanitation, WASH, CBRN risks, Kinshasa, school hygiene, water quality, health risks, sanitation.

2.2. Selection Criteria

Inclusion criteria were: (a) original scientific articles, literature reviews, risk assessment reports, and theses; (b) publications in French or English; (c) publication period between 1980 and 2026; (d) studies on the state of school sanitary facilities, associated health risks, or risk management in schools. Documents not accessible in full text or not meeting the criteria were excluded.

2.3. Data Analysis

A thematic analysis was conducted to organise information into five axes: (a) state of sanitary facilities in Kinshasa schools; (b) documented health risks; (c) potential CBRN risks; (d) regulatory and institutional framework; (e) assessment and sampling perspectives.

3. Results

3.1. State of Sanitary Facilities in Kinshasa Schools

Available data paint a concerning picture. A study by Nganga et al. (2025) in the educational provinces of Mont-Amba, Lukunga, and Tshangu, involving 149 schools selected by three-stage probability sampling, is the most recent reference on the subject. Results reveal that only 54% of schools have a water point, with a marked disparity between urban (73%) and peri-urban (23%) areas ($p = 0.000$). Latrine coverage is 96.88%, but only 3.6% of these facilities are considered hygienic, with an average urinal coverage of 13.9%. Handwashing devices are almost non-existent, and only 32% of schools have a dedicated WASH budget and hygiene committee.

These quantitative data are illustrated in **Figure 1**, which highlights disparities between urban and peri-urban areas as

well as the considerable gap compared to international standards.

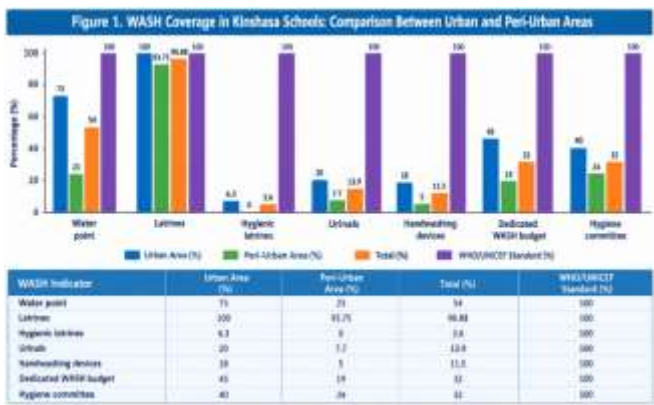


Figure 1 commentary (moved to text): This figure allows simultaneous visualisation of three critical dimensions: (i) the overall level of WASH coverage in Kinshasa schools; (ii) territorial inequalities between urban and peri-urban areas; (iii) the gap between the current situation and international standards. Interpretation reveals a fundamental paradox: while latrine coverage appears high (96.88%), the hygienic quality of these facilities is dramatically low (3.6%), meaning that almost all school latrines do not meet basic hygiene standards. This dissociation between quantity and quality of sanitary infrastructure is a key indicator of the failure of WASH policies in Kinshasa schools. Territorial disparities (73% vs 23% for water access) suggest spatial inequity in the allocation of educational resources, with peri-urban areas systematically disadvantaged. Finally, the gap compared to WHO/UNICEF standards (100%) underscores the urgency of targeted interventions and significant investments.

Field reports confirm these quantitative data. The Kabinda school complex, located in the commune of Kinshasa, has been without running water for four months, forcing students and teachers to fetch water outside with jerrycans and buckets. Similarly, at Collège Saint-Charles Lwanga, students protest against degraded learning conditions, with wastewater from neighbouring plots' sanitary facilities making the school environment unbearable.

3.2. Documented Health Risks for Students and Staff

Health risks associated with degraded sanitary facilities in Kinshasa schools are multiple and documented.

Diarrhoeal diseases and cholera: Inadequate sanitation facilities and lack of hygiene promote the transmission of diarrhoeal diseases, including cholera. The DRC has experienced cholera epidemics in recent years with more than 71,200 cases and 2,070 deaths in 2025 according to WHO

(Radio Okapi, 2026). In Kinshasa, low awareness of the disease and delays in seeking care contribute to exceptionally high case fatality rates. Schools, as gathering places, constitute potential transmission hotspots.

Urogenital infections: Lack of hygiene in school sanitary facilities promotes urogenital infections, including urinary tract infections in boys and urinary and vaginal infections in girls. Girls are particularly vulnerable, especially during menstrual periods, when the absence of adequate facilities can lead to genital infections, inflammation, or other reproductive health complications.

Typhoid fever: Typhoid fever, favoured by unclean sanitary facilities and inadequate hygiene measures, constitutes a major risk in Kinshasa schools. Contamination of water and food by faecal matter is the main mode of transmission.

Dirty hands diseases: Awareness campaigns conducted in the DRC, including one targeting 89 schools and 135,500 students, remind that access to water and soap remains the first barrier against several infectious diseases. The absence of functional handwashing devices in many Kinshasa schools compromises this essential barrier.

Impact on schooling: Beyond health effects, degraded sanitary facilities affect school attendance, particularly for girls. Lack of hygiene promotes certain infections and can affect school attendance, with girls exposed to genital infections or other reproductive health complications.

3.3. Potential CBRN Risks Associated with School Sanitary Facilities

CBRN risks in Kinshasa school sanitary facilities, although poorly documented, can be characterised from existing literature and contextual data. **Figure 2** presents the complete causal chain of these risks, from sources to health effects.



Figure 2 commentary (moved to text): This figure proposes an integrated analytical framework for understanding how deficiencies in school sanitary facilities translate into CBRN risks and concrete health effects. Step 1 (risk sources) identifies degraded facilities as the starting point of the causal chain. Step 2 (favouring factors) highlights the role of environmental conditions (humidity, heat, organic matter) and behavioural factors (lack of maintenance, low risk perception) in amplifying risks. Step 3 (exposure pathways) distinguishes five modes of contact: ingestion, skin contact, inhalation, mucosal contact, and vector bites. Step 4 (CBRN risks) breaks down three risk categories: chemical (chlorinated cleaning products, heavy metals, POPs, PAHs, VOCs), biological (enteric pathogens, bacterial resistance), and radiological/nuclear (natural radionuclides, sealed sources). Step 5 (health effects) identifies seven categories of health consequences. Each step constitutes a potential intervention point for management: prevention can target sources (facility rehabilitation), favouring factors (training, awareness), exposure pathways (protective equipment, hand hygiene), CBRN risks (surveillance, analysis), or health effects (screening, treatment).

3.3.1. Chemical Risks (C)

Chemical risks are the most documented and concerning. The use of chlorine-based cleaning products (bleach) for disinfecting school sanitary facilities can generate irritating chlorinated compounds. An incident in a school in Romania led to the evacuation of hundreds of students and teachers after CBRN measurements recorded positive values of hydrochloric acid from the cleaning solution used for room sanitisation. This type of incident, although not documented in Kinshasa, represents a potential risk in Kinshasa schools where bleach is commonly used for cleaning.

The quality of water available in Kinshasa schools is rarely monitored. Groundwater and surface water may contain heavy metals (lead, cadmium, arsenic, chromium) from local geology, industrial pollution, or pipe corrosion. A study in Limpopo Province, South Africa, assessed microbial contamination of groundwater in 20 primary schools, demonstrating the vulnerability of these sources. In Kinshasa, where potable water coverage is limited, schools often resort to alternative sources whose quality is not controlled.

Schoolyard soils and dust may contain persistent organic pollutants (POPs) from urban air pollution, waste incineration, or pesticide use. These pollutants, which accumulate in sanitary facilities and surfaces, can be resuspended and inhaled or ingested by students.

3.3.2. Biological Risks (B)

Degraded sanitary facilities, non-hygienic latrines, and the absence of handwashing devices create an environment favourable to the survival and transmission of enteric pathogens: *Escherichia coli*, *Salmonella* spp., *Vibrio cholerae*, rotavirus, norovirus, hepatitis A, *Giardia lamblia*, *Cryptosporidium*. These agents are responsible for diarrhoea, cholera, typhoid fever, and hepatitis.

Humidity, heat, and the presence of organic matter in degraded sanitary facilities promote the proliferation of microorganisms, including fungi and opportunistic bacteria. Biofilm formation in pipes and water tanks constitutes a reservoir of pathogens that is difficult to eliminate.

The presence of heavy metals and antibiotic residues in wastewater and soils can induce bacterial resistance to antibiotics. This phenomenon, documented in hospital and urban environments, could also occur in schools, exposing students to difficult-to-treat infections.

Degraded sanitary facilities and stagnant water attract vectors (flies, mosquitoes, rodents) that can carry pathogens and contribute to the spread of vector-borne diseases.

3.3.3. Radiological and Nuclear Risks (R/N)

Groundwater and soils in Kinshasa may contain natural radionuclides (uranium-238, thorium-232, potassium-40) at variable concentrations. These radionuclides may be present in water consumed by students and staff, or in dust from sanitary facilities. Gamma spectrometry is the reference method for their quantification.

Schools may use equipment containing sealed radioactive sources (smoke detectors, lightning rods, scientific equipment). Poor management or failure of these sources could lead to radioactive contamination, although this scenario is rare.

Radionuclides can accumulate in sediments, dust, and the food chain, exposing students to long-term carcinogenic risks.

3.4. Prioritisation of CBRN Risks

Figure 3. Criticality Matrix of CBRN Risks in Sanitary Facilities of Kinshasa Schools

CBRN Risk	Probability	Severity	Criticality	Priority
Diarrhoeal diseases (Shigella, Typhoid)	High	High	Critical	1
Exposure to heavy metals (Pb, Cd, Cr, As)	Medium	Very high	Critical	1
Bacterial resistance to antibiotics	Medium	Very high	Critical	1
Urogenital infections	High	Medium	High	2
Respiratory infections	High	Medium	High	2
Exposure to chlorinated cleaning products	High	Medium	High	2
Exposure to PAHs and VOCs	Medium	High	High	2
Exposure to natural radionuclides	Low	Very high	Moderate	3
Contamination by sealed sources	Very low	Very high	Moderate	3

Color scale (Probability / Severity / Criticality): Low (Very Low), Medium, High, Very high. Criticality level & Priority: Critical (C1), High (H2), Moderate (M3).

Figure 3 commentary (moved to text): This criticality matrix constitutes an essential decision-support tool for educational and health authorities. It allows moving beyond a purely descriptive approach to risks toward an analytical and prioritised approach. Interpretation reveals three levels of intervention: (i) **critical risks** (red quadrant) diarrhoeal diseases, exposure to heavy metals, bacterial resistance which combine high probability and very high severity, requiring immediate intervention; (ii) **high risks** (orange quadrant) urogenital infections, respiratory infections, exposure to chlorinated cleaning products, exposure to PAHs and VOCs which require priority intervention in the short term; (iii) **moderate risks** (yellow quadrant) exposure to natural radionuclides, contamination by sealed sources which, although of low probability, present very high severity and require enhanced surveillance. This prioritisation is particularly important in the Kinshasa context, where resources are limited and interventions must be targeted to maximise impact. It suggests that intervention priorities should focus on improving hand hygiene, rehabilitating latrines, providing potable water, and monitoring heavy metals in water and soils.

3.5. Regulatory and Institutional Framework

3.5.1. International Standards

- **WHO/UNICEF (2023):** Guidelines on water, sanitation, and hygiene in schools, recommending minimum standards for sanitary facilities.
- **SDG 6.2:** Equitable access to adequate sanitation and hygiene for all by 2030.
- **"Clean School" Approach:** Programme promoted by UNICEF and Ministries of Education, aimed at improving hygiene conditions in schools.

- **ISO 17025:** Competence of testing and calibration laboratories for sample analysis.
- **ISO 35001:** Biorisk management for laboratories and institutions.

3.5.2. National Regulatory Framework

- **Constitution of the DRC (2006):** Article 53 (right to a healthy environment), Article 54 (protection against pollution and nuisances).
- **Law No. 11/009 of 9 July 2011:** Fundamental principles relating to environmental protection.
- **Law No. 18/031 of 13 December 2018:** Public health and hygiene.
- **Ordinance No. 74-345 of 28 June 1959:** Public hygiene in urban areas.
- **National "Clean School" Programme:** Initiative of the Ministry of Education aimed at improving hygiene conditions in schools.

However, enforcement of these texts remains weak in Kinshasa schools, where controls are insufficient and WASH budgets are very limited. The absence of systematic monitoring mechanisms and sanctions for non-compliance compromises the improvement of sanitary conditions — a clear **management and governance failure**.

3.6. Assessment and Sampling Perspectives

Assessment of CBRN risks in Kinshasa school sanitary facilities requires an integrated and systematic approach. Before any sample collection, a preliminary characterisation phase is essential.

3.6.1. Preliminary Characterisation Phase

- **Facility inventory:** Comprehensive census of sanitary facilities (toilets, water points, handwashing devices) in a representative sample of Kinshasa schools, with assessment of their operational status and cleanliness.
- **Direct observation:** Use of a standardised observation grid to assess cleanliness, ventilation, lighting, presence of pests, surface condition, and waste management.

- **Staff interviews:** Semi-structured interviews with school directors, teachers, and maintenance staff to document cleaning practices, products used, maintenance frequency, and problems encountered.
- **Student questionnaires:** Survey of students to document their perceptions, hygiene practices, and health problems they associate with sanitary facilities.

3.6.2. Sample Collection Phase

- **Water samples:** Collection at points of use (taps, tanks, wells) for analysis of:
 - Physicochemical parameters: pH, temperature, conductivity, turbidity, salinity, TSS.
 - Heavy metals (Pb, Cd, Cr, As, Al, Co, Cu, Ni, Zn): by ICP-MS or ICP-OES.
 - Nutrients (NO_3^- , PO_4^{3-}): by UV spectrophotometry or ion chromatography.
 - Radionuclides (U-238, Th-232, K-40): by gamma spectrometry.
 - Microbiological analysis: by culture and molecular biology (PCR) to detect *E. coli*, *Salmonella*, *Vibrio cholerae*, rotavirus, norovirus.
- **Surface samples:** Swab sampling of sanitary facility surfaces (toilet seats, door handles, taps, floors) for microbiological and chemical analysis.
- **Dust samples:** Collection from surfaces (window sills, shelves, floors) for analysis of heavy metals, PAHs, and radionuclides.
- **Soil samples:** Collection from schoolyards and near sanitary facilities for analysis of heavy metals, PAHs, and radionuclides.
- **Cleaning product samples:** Collection and analysis of cleaning products used (bleach, detergents) to assess their composition and chemical risks.

3.6.3. Analysis and Interpretation Phase

- **Analysis in accredited laboratory (ISO 17025):** Samples must be analysed in accredited laboratories, using standardised methods (EPA, ISO) and rigorous quality controls.
- **Quantitative health risk assessment (QRA):** Calculation of hazard quotients (HQ) and excess individual risk (EIR) for chemical and radiological pollutants, using exposure scenarios adapted to students and staff.
- **Quantitative microbial risk assessment (QMRA):** Estimation of infection risks from enteric pathogens, taking into account exposure rates and infectious doses.
- **Risk mapping:** Development of CBRN risk maps by school, facility type, and exposure pathway, to guide interventions.
- **Recommendations:** Formulation of specific recommendations for each school, including immediate corrective measures (cleaning, disinfection, repair) and structural measures (facility rehabilitation, potable water supply, staff training).

4. Discussion

The results of this documentary review highlight a concerning situation: sanitary facilities in Kinshasa schools are in an advanced state of degradation, exposing students and teaching staff to multiple health risks. This situation is documented by recent data showing limited access to water (54% of schools), high latrine coverage but very low hygienic quality (3.6% hygienic latrines), and an almost generalised absence of functional handwashing devices.

Analysis of CBRN risks associated with these facilities reveals that these risks are not solely a matter of "classic" public health but are part of a global health security problem. Chemical risks (chlorinated cleaning products, heavy metals in water and soils), biological risks (enteric pathogens, microbial proliferation, bacterial resistance), and potential radiological risks (natural radionuclides in groundwater) converge to create a multi-risk exposure that remains largely unrecognised by educational and health authorities.

Several limitations characterise current knowledge:

- **Absence of local data on CBRN risks:** Very few studies have been conducted specifically on water and surface quality in Kinshasa schools, and none have integrated the CBRN dimension.
- **Variability of facilities:** Sanitary conditions vary considerably from one school to another, depending on location (urban vs peri-urban), status (public vs private), and available resources.
- **Underreporting of problems:** Schools often hesitate to report sanitary problems for fear of repercussions on their reputation or funding.
- **Low risk perception:** Students, staff, and educational authorities rarely perceive CBRN risks associated with sanitary facilities.
- **Insufficient controls:** Health and educational authorities lack the technical and financial means to ensure effective surveillance.

Assessment and sampling perspectives offer an opportunity to fill these gaps. By integrating the CBRN dimension into school surveillance programmes, it becomes possible to assess actual exposure of students and staff, identify contamination sources, and propose adapted management measures.

5. Conclusions

This documentary review confirms that sanitary facilities in Kinshasa schools constitute an unrecognised but significant source of CBRN risks. Their advanced state of degradation, limited access to potable water, and absence of functional handwashing devices create an environment favourable to the transmission of pathogens, exposure to chemical pollutants, and potentially to natural radionuclides.

Main conclusions:

1. Only 54% of Kinshasa schools have a water point, with a marked disparity between urban (73%) and peri-urban (23%) areas;
2. Latrine coverage is 96.88%, but only 3.6% are considered hygienic;
3. Documented health risks include diarrhoeal diseases, cholera, typhoid fever, urogenital infections, and dirty hands diseases;
4. Identified CBRN risks include chemical risks (chlorinated cleaning products, heavy metals), biological risks (enteric pathogens, bacterial resistance), and potential radiological risks (natural radionuclides);
5. The regulatory and institutional framework exists but its enforcement remains weak;
6. Systematic assessment including water, surface, and soil sampling is essential to characterise these risks.

6. Managerial implications and recommendations

This review carries direct implications for the management of school infrastructure and public health services in Kinshasa. The gap between latrine coverage (96.88%) and hygienic quality (3.6%) reveal a **management paradox**: infrastructure exists, but its governance does not. The following recommendations are addressed to the key institutional actors.

For educational authorities (Ministry of Education):

- Integrate the CBRN dimension into school surveillance programmes and make WASH indicators part of school performance evaluation;
- Allocate specific, ring-fenced WASH budgets in all schools, with priority to peri-urban areas;
- Train teaching and maintenance staff in good hygiene practices and risk management;
- Establish a monitoring and evaluation system for school sanitary conditions, with public reporting and accountability mechanisms.

For health authorities (Ministry of Health):

- Establish a water quality surveillance programme in schools, with regular sampling and accredited laboratory analysis;
- Conduct epidemiological studies on diseases related to school sanitary facilities;
- Raise awareness among students and staff about health risks and preventive measures.

For technical and financial partners (UNICEF, WHO, World Bank):

- Fund rehabilitation programmes for school sanitary facilities;
- Support research on CBRN risks in schools;
- Promote the "Clean School" approach in all Kinshasa schools.

For researchers:

- Conduct local studies on water, surface, and soil quality in Kinshasa schools;
- Assess student and staff exposure to chemical, biological, and radiological pollutants;
- Develop CBRN risk assessment tools adapted to the Congolese school context.

Managerial priority matrix: Based on the criticality analysis (Figure 3), managers should prioritise: (i) immediate action on critical risks (diarrhoeal diseases, heavy metals, bacterial resistance); (ii) short-term action on high risks (urogenital and respiratory infections, cleaning products, PAHs/VOCs); and (iii) sustained surveillance of moderate risks (radionuclides, sealed sources).

Conflict of interest statement

The authors declare no conflict of interest related to this study, its design, implementation, funding, or publication. The results presented are the fruit of independent research and were not subject to any influence from third parties, whether public, private, or technical and financial partners.

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