



# A Study of Expired Laboratory Chemicals Stockpiles, Storage Facilities and Their Disposal Patterns in Zanzibar's Secondary Schools

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**Abstract:** *The prolonged storage of expired laboratory chemicals in Zanzibar's secondary schools presents a largely undocumented environmental and public health risk. In many institutions, inventory audits reveal chemicals that expired decades ago remain in storage, where prolonged aging blended with the poorly ventilated and inadequate laboratory conditions have resulted in significant and severe chemical degradation and deterioration of storage containers, thereby increasing occupational and environmental risks. In the absence of clear national policies, standardized disposal guidelines, and functional sewage or waste-treatment systems, schools have accumulated substantial quantities of obsolete reagents. Limited teacher awareness of chemical hazards, coupled with inadequate institutional oversight and resource constraints, has further exacerbated the problem. Using field observations, chemical inventory audits, and semi-structured interviews with chemistry teachers and school administrators, this study documents average percentage of expired and highly degraded chemicals, their physical transformations over time and state of storage conditions, possible health hazard to students and related staff, and possible environmental effects where improper disposal occasionally occurs. The findings reveal significant governance gaps, infrastructural deficiencies, and critical knowledge deficits in chemical waste management. The paper proposes an actionable framework for laboratory infrastructure, safe disposal, emergency risk mitigation, and long-term policy development tailored to resource-constrained educational settings. Addressing these legacy chemicals is essential for safeguarding public health, improving laboratory safety, and aligning Zanzibar's education system with contemporary environmental standards.*

**Keywords:** *Expired laboratory chemicals, Chemical waste management, School laboratory safety, Environmental health risks, Policy gaps*

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## 1. Introduction

Effective management of laboratory chemicals is essential for maintaining safe learning environments and preventing environmental contamination. Yet many low-income

education systems lack clear chemical-safety regulations and laboratory frameworks including disposal, resulting in the accumulation of obsolete reagents in school laboratories (UNEP, 2019; UNESCO, 2021). In Zanzibar, secondary schools operate without specific guidelines for

handling, storage, or disposal of expired chemicals, as neither the national education policies nor environmental management regulations adequately address school-based hazardous waste (MOEVT, 2016; ZEMA, 2020). Weak enforcement mechanisms, limited institutional oversight, and low teacher awareness further contribute to inconsistent chemical-handling practices, increasing risks of exposure to students and staff (WHO, 2020). Despite these concerns, no systematic assessment has been conducted to document the extent or condition of legacy chemicals in Zanzibar's schools. This study examines the physical states, risk pathways of expired chemical stockpiles, storage conditions and disposal sites in selected secondary schools with possible associated health hazards. The findings aim to support evidence-based recommendations for improved school laboratory governance, disposal units and the development of context-appropriate policies for good chemical storage practices in resource-constrained educational settings.

## 2. Literature Review

The safe management of laboratory chemicals is a critical component of environmental health protection, occupational safety, and quality science education. In many low- and middle-income countries (LMICs), schools lack adequate chemical storage, inventory control including disposal systems, leading to the accumulation of expired or degraded substances. Although research in East and Southern Africa has addressed laboratory hazards in higher education institutions (kwarteng et al, 2023; Fu et al, 2023), the situation in basic and secondary schools remains under-investigated. Zanzibar presents an acute case with many school laboratories hold chemicals that had expired more than 20 years ago and often stored without security, or school laboratory protocols and environmental safeguards.

Research indicates that expired or degraded chemicals commonly kept in secondary schools release hazardous fumes that expose teachers and learners to respiratory irritation, skin burns, and accidental poisoning (Mkumbo & Kavishe, 2021; Mkindi, 2019). Improperly stored flammable and reactive substances also elevate the risk of fires and explosions, particularly in laboratories lacking ventilation and appropriate containment facilities (UNEP, 2019). Environmental concerns arise where leaking acids and solvents contaminate indoor air, drainage systems, and even surrounding soil, adding to the burden of hazardous waste already reported in Tanzanian educational institutions (NEMC, 2020). These safety weaknesses directly affect teaching quality, as many teachers limit or avoid practical sessions when laboratory conditions are unsafe, thereby undermining hands-on learning and effective implementation of the chemistry curriculum

(Lema & Mwalongo, 2018) hence gives rise to pedagogical implications.

Effective chemical storage requires compliance with international standards such as Globally Harmonized System (GHS) guidelines, segregation of incompatible substances, and routine inspection for expiry or deterioration (UNEP, 2019). However, in resource-constrained school settings, such systems are rarely present. Many countries rely on old colonial-era laboratory safety manuals or photocopied guidance without enforcement mechanisms (Aliyo & Edin, 2023). Studies show that secondary school laboratories often lack dedicated storage rooms, proper shelving, ventilation, and temperature control (Muzammal & Hashmi, 2025). Chemical containers become brittle or corroded with age, causing leaks and the formation of crystalline residues ("chemical rocks") due to evaporation reactions, photo-degradation, or polymerization. For example, old nitric acid can form nitrogen dioxide fumes, while outdated metal salts may hydrate, oxidize, or solidify (National Research Council, 2008). These transformations increase toxicity and create unpredictable hazards. In well-resourced systems, chemicals are monitored through inventory software, barcodes, and periodic auditing (Talib, 2022). Expired chemicals such as ether, picric acid, peroxide-forming compounds, and highly reactive salts have been documented as explosion risks after long periods of dormancy (EHS, 2022). In schools where these substances are left unattended for decades, the risks rise significantly. Studies have emphasized that degraded chemicals cannot be assumed safe simply because they are no longer usable for experiments, they often become more dangerous over time (NRC, 2011).

Globally, hazardous waste generation has increased due to industrialization, urbanization, and educational expansion. While developed countries have detailed laws governing chemical disposal (Wijethilake et al, 2024; Mariani, 2024), LMICs face persistent structural gaps (Verma & Verma, 2025). Common challenges include lack of national hazardous waste legislation, absence of treatment facilities, weak institutional coordination, limited public awareness and insufficient funding for chemical waste transport and disposal (Adman et al, 2025). Large portions of hazardous waste in African countries are mismanaged, with estimates showing more than 70–80% of chemical waste ending in open dumpsites or unlined pits (UNEP, 2021). Schools contribute to the problem but are rarely addressed in national policies. A study in Kenya found that most secondary schools dispose of laboratory chemicals through sinks, open burning, or burying methods that contaminate soil and groundwater (Susan et al, 2024). Zanzibar shares similar constraints: limited waste-treatment infrastructure, under-resourced environmental authorities, and reliance on rudimentary sewage systems. Without proper disposal

protocols, expired chemicals accumulate for decades in storage cupboards and laboratory benches. Literature on small-island developing states (SIDS) notes that isolation, high costs of transport, limited land availability, and inadequate regulatory frameworks exacerbate hazardous waste management problems (Periathamby & Sunil, 2014). This may contextualize Zanzibar's challenges within a broader global pattern.

Expired chemicals can release toxic vapors, corrode containers, or form unstable compounds. Exposure pathways include inhalation, dermal absorption, accidental ingestion, and chemical burns. Schoolchildren are particularly vulnerable due to developing physiology and lack of hazard awareness (Toska et al, 2024). Chemical incidents in schools reported internationally include acute respiratory irritations from acid fumes, burns from spilled corrosives, and long-term exposure to mercury residues (Anderson et al, 2017). Long-stored chemicals increase the chances of volatility changes, pressure buildup in sealed containers, carcinogenic degradation by-products, fire and explosion risks. Reports also show that some chemicals have solidified, corroded caps, or decomposed into unknown compounds (Fu et al, 2023). Without analytical testing capacity, schools cannot determine the toxicity of these altered substances (Kumar, 2020). These risks are magnified in poorly ventilated, overcrowded laboratories and lack of fume extraction which are common in Zanzibar school systems. Improper disposal or leakage of laboratory chemicals threatens soil quality, aquatic ecosystems, and biodiversity. Heavy metals, halogenated solvents, and persistent organic pollutants (POPs) can bioaccumulate, posing long-term contamination risks (Wang et al, 2025).

Given Zanzibar's fragile coastal ecosystems and porous coral-rag geology, groundwater contamination from laboratory waste is a serious concern. Literature on island ecosystems emphasizes that even small quantities of hazardous substances can cause disproportionate harm due to restricted land area and limited dilution capacity (Mohammadi, 2021). The absence of clear policies in Zanzibar mirrors broader patterns in East African science education systems, where chemical safety guidelines are often poorly implemented or outdated. Environmental literacy is studied but not taken seriously hence low among science teachers in many African schools Zanzibar. Without awareness of the dangers of expired chemicals, schools either retain obsolete substances indefinitely or dispose of them unsafely (Kwarteng et al, 2023). Teachers also fear handling "old dangerous chemicals," preferring to leave them untouched, contributing to long-term accumulation.

In Zanzibar, there are no specific guidelines for inventory tracking, safe disposal, or emergency response in

secondary schools (MOEVT, 2016; ZEMA, 2020). Limited enforcement of general environmental regulations and inadequate teacher training create a governance vacuum, leaving schools to develop ad hoc practices that may compromise safety (UNESCO, 2021). Despite clear hazards, empirical studies documenting the prevalence, condition, and risk pathways of expired laboratory chemicals in Zanzibar are scarce. Most existing research focuses on industrial or hospital settings, leaving educational institutions under-studied. This gap limits evidence-based policy development and hampers interventions for laboratory safety and chemical waste management in schools (Akhdiyat et al., 2025).

In Tanzania and Zanzibar, science curricula have undergone changes, but legacy stocks from older syllabi remain in storerooms since most chemicals are supplied by government through the ministry of education. Despite the growing importance of science education in Zanzibar, school laboratories continue to store large quantities of chemicals that expired as far back as the 2000s, many of which have degraded into unknown or hazardous forms. In the absence of disposal policies, functional waste-management systems, or trained personnel, these chemicals have accumulated unchecked for decades. This situation poses significant health risks to students and staff, threatens surrounding environments, and undermines laboratory safety standards. Yet, no systematic assessment has been conducted to document the extent of the accumulation, the conditions of storage, or the risks involved. The lack of empirical evidence and regulatory guidance leaves schools without practical solutions, making this a critical and urgent problem for both education and environmental governance in Zanzibar.

The reviewed literature demonstrates that expired chemical stockpiles result from a combination of policy gaps, institutional weaknesses, and limited awareness. Building on this evidence, the present study investigates the types, storage conditions, and potential exposure risks of obsolete chemicals in Zanzibar's secondary schools. Findings aim to inform targeted interventions, safe storage, disposal practices, and policy development tailored to resource-constrained educational settings

## 3. Methodology

### 3.1 Research Design

This study employed a mixed-methods descriptive research design to document the extent, condition and management practices associated with expired chemicals stored in secondary school laboratories in Zanzibar. A mixed approach was appropriate because the problem involves

both quantifiable aspects, that is number of expired chemicals and storage conditions; and qualitative insights which is composed of teacher knowledge, disposal practices, and institutional challenges.

## **3.2 Study Area**

The research was conducted in selected secondary schools across Unguja and Pemba Islands, Zanzibar. The region is characterized by limited laboratory infrastructure, inconsistent supply chains for science materials, and absence of formal chemical-waste disposal facilities. Laboratories in many schools have retained chemical stocks for over two decades, making Zanzibar an appropriate setting for investigating chemical accumulation and associated safety risks.

### **3.2.1 Target Population**

The target population comprised, Laboratory technicians and Science teachers, Heads of science departments and School administrators responsible for laboratory management. This population was chosen because they are directly responsible for or affected by chemical storage practices in schools.

## **3.3 Sampling Procedures**

### **3.3.1 Sampling Technique**

A purposive sampling strategy was used to select schools with established science laboratories and known histories of accumulated expired chemicals. Schools were selected to represent Urban and rural settings, large, medium, and small institutions, government and private schools. Within each school, criterion sampling were laboratory technician if available, chemistry teacher, science head and the administrator as the respondent.

### **3.3.2 Sample Size**

The sample included 10 secondary schools across Zanzibar, 20 respondents, including laboratory technicians, chemistry teachers, and administrators. The school sample size is consistent with exploratory environmental-safety studies in low-resource contexts, where purposive selection is required to capture high-risk sites.

## **3.4 Data Collection Methods**

### **3.4.1 Laboratory Inventory Audit**

A structured inventory checklist was used to document; Types and quantities of expired chemicals; Date of expiry and origin (purchased/donated); Physical condition (liquid, solidified, crystallized, corroded, leaking); Storage environment (ventilation, segregation, security, temperature) and Presence of safety equipment (PPE, fume hoods, spill kits). This tool provided quantifiable data on chemical stockpiles and their conditions.

### **3.4.2 Field Observation**

Non-participant observation was conducted using an observation guide to capture Laboratory layout and housekeeping; Storage practices; Environmental hazards (leaks, odors, corrosion, unstable containers) and Waste disposal behaviors (sink disposal, open burning, storage accumulation)

### **3.4.3 Semi-Structured Interviews**

Semi-structured interviews were conducted with laboratory technicians, chemistry teachers, and school administrators to explore Knowledge of chemical hazards, Awareness of disposal procedures, Experiences with expired chemicals, Challenges in chemical management' Perceived risks to students and staff, Institutional or policy constraints. Each interview lasted 20–40 minutes.

### **3.4.4 Document Review**

School-level documents were examined, including laboratory stock books, safety guidelines, timetables for practical sessions and any available policy documents or circulars related to laboratory safety. This review allowed cross-checking of inventory data and insights into administrative practices.

### **3.4.5 Research Instruments**

Data were collected using inventory checklist (structured quantitative tool), observation guide (qualitative environmental assessment tool), interview guide (semi-structured questions) and document review form. All tools were developed based on international laboratory safety standards (WHO, GHS, OSHA) and were adapted to the Zanzibar context.

## **3.5 Data Analysis**

### **3.5.1 Quantitative Data**

Inventory data and numerical observations were coded and analyzed using descriptive statistics which includes frequencies and percentages of expired chemicals,

proportions of chemicals in harmful or degraded states, frequency of safety equipment and storage deficiencies. These analyses provided clear patterns of chemical accumulation and risk.

### 3.5.2 Qualitative Data

Interview transcripts and observation notes were analyzed using thematic analysis following Braun and Clarke's (2006) framework that is Familiarization with data, Coding of meaningful units, Category development, Theme generation and review, Synthesis and interpretation. Themes focused on safety culture, institutional barriers, knowledge gaps, and policy deficiencies.

### 3.5.3 Triangulation

Findings from inventories, observations, and interviews were triangulated to enhance credibility and reduce bias.

## 3.6 Validity, Reliability, and Trustworthiness

### 3.6.1 Quantitative Validity

Instruments were reviewed by chemistry educators and laboratory experts.

### 3.6.2 Qualitative Trustworthiness

**Credibility:** Triangulation across sources and member checking with respondents

**Transferability:** Thick, contextual descriptions of school condition

**Dependability:** Consistent use of interview protocol and audit tools

**Confirmability:** Audit trail documenting decisions during analysis

## 3.7 Ethical Considerations

Ethical approval was obtained from the relevant Zanzibar research authority. Key considerations included: Informed consent from all participants; voluntary participation and the right to withdraw; anonymity and confidentiality of schools and respondents; secure storage of audio recordings and transcripts; no photographs or chemical handling without permission and reporting hazards to school administrators where immediate risks were identified.

The study prioritized participant safety and avoided interference with ongoing laboratory operations.

## 4. Results and Discussion

### 4.1 Nature of chemicals, Safety in the laboratory and Storage conditions

The following tables present the inventory data, including the frequencies and percentages of expired chemicals, the proportions of chemicals in harmful or degraded states, and the documented deficiencies in safety equipment and storage conditions (Tables 1, 2, and 3)."

**Table 1. Inventory of Chemicals by Expiry Status in 10 Schools**

School	Total Chemicals	Expired	% Expired	Highly Degraded	Leaking/Corroded
S1	53	29	54.7%	12	7
S2	45	27	60%	14	10
S3	29	17	58.6%	7	4
S4	33	22	66.7%	14	5
S5	25	18	72%	10	4
S6	18	13	72%	9	5
S7	26	17	65.4%	10	6
S8	61	40	65.6%	19	8
S9	33	21	63.6%	12	7
S10	49	30	61.2%	21	5

(Table Assertion: 5<sup>th</sup> September, 2025)

**Mean % expired** = % expired ÷ 10 schools = 63.98% (average expired chemicals across schools)  
**Proportion of highly degraded chemicals** Sum of all degraded chemicals ÷ sum of total chemicals = 128/372 x 100 = 34.4%

**Frequency of leaking containers** Total leaking/ corroded observed: 61 incidents of potentially hazardous storage failure

**Table 2. Frequency of Safety Equipment in Schools**

Safety Equipment	Present (Yes)	Not Present (No)	% Availability
Fire extinguisher	4	6	40%
PPE (gloves, goggles)	3	7	30%
Chemical cabinets	2	8	20%
Fume hood	0	10	0%
Spill kit	0	10	0%
First aid kit	5	5	50%

**Analysis Average safety equipment availability** =  $(40 + 30 + 20 + 0 + 0 + 50)/6 = 23\%$ , thus indicates **extreme safety deficits** consistent with your findings.

**Storage Condition Assessment**

The table below shows the analytical results for storage condition

**Table 3. Storage Condition Ratings**

Variable	Good	Moderate	Poor	% Poor
Ventilation	1	3	6	60%
Labeling	0	2	8	80%
Shelf stability	2	0	8	80%
Segregation of chemicals	1	1	8	80%
Security (locked cabinet)	2	2	6	60%

**Analysis Mean % poor storage** =  $(60+80+80+80+60)/5 = 72\%$ . This confirms severe storage deficiencies. A total of 372 chemicals were documented across the ten schools surveyed, of which 62.9% (234) were expired. Over one-quarter (34.4%) of the expired chemicals had degraded into solid or crystalline forms, while 61 containers showed evidence of leakage or corrosion. Safety equipment availability was extremely low, with an average of only 23% of required safety tools present. Observation data further indicated that 72% of storage parameters were rated as poor, particularly labeling (80% poor) and chemical segregation (80% poor). These numerical patterns confirm widespread chemical accumulation and unsafe laboratory conditions.

**4.2 Qualitative Data Analysis (Thematic Analysis)**

All interviews were transcribed verbatim and observation notes organized by school and laboratory. Key statements were coded and grouped into categories that were further refined into broader themes. Table 4 below presents this integrated summary, showing how each theme is supported by recurring codes across the dataset and illustrated with direct participant quotations. Together, the themes highlight the intertwined knowledge gaps, infrastructural constraints, and governance weaknesses shaping unsafe laboratory conditions in Zanzibar’s secondary schools.

**Table 4 shows combined summary of themes, categories, codes, and illustrative quotes**

Theme	Categories	Representative Codes	Illustrative Participant Quotes
<b>1. Persistence of Long-Term Chemical Stockpiling</b>	Accumulation of expired chemicals	<ul style="list-style-type: none"> <li>Chemicals stored since early 2000s</li> <li>Expired for 10–20+ years</li> <li>Large volumes unused</li> </ul>	<i>“We have some chemicals that have been here since the 2000s. I am afraid to touch them.”</i>
	Physical deterioration of reagents	<ul style="list-style-type: none"> <li>Crystallized/solidified compounds</li> <li>Color-changed solutions</li> <li>Leaking containers</li> </ul>	<i>“Some bottles have become powder inside; others are leaking slowly.”</i>
	Improvised/unsafe storage	<ul style="list-style-type: none"> <li>Open shelves</li> <li>Rusty cabinets</li> <li>Shared rooms with broken equipment</li> </ul>	<i>“Storage is a problem, so everything ends up in one small room.”</i>
<b>2. Weak Safety Culture and Limited Risk Awareness</b>	Low hazard identification	<ul style="list-style-type: none"> <li>Inability to read hazard symbols</li> </ul>	<i>“Honestly, we were never trained to identify dangerous chemicals.”</i>

		<ul style="list-style-type: none"> <li>• No MSDS knowledge</li> <li>• Mislabelled containers</li> </ul>	
	Unsafe handling practices	<ul style="list-style-type: none"> <li>• Storing incompatible chemicals</li> <li>• Handling without PPE</li> <li>• No segregation of acids/bases</li> </ul>	<i>“We just keep them the way we found them; no one showed us proper arrangement.”</i>
	Lack of safety equipment	<ul style="list-style-type: none"> <li>• No gloves/goggles</li> <li>• Expired fire extinguishers</li> <li>• No functional fume hood</li> </ul>	<i>“Even if we want to be careful, we have no equipment—no gloves, no working hood.”</i>
<b>3. Structural and Institutional Barriers</b>	Poor laboratory infrastructure	<ul style="list-style-type: none"> <li>• Congested rooms</li> <li>• Low ventilation</li> <li>• Damaged storage facilities</li> </ul>	<i>“This lab is too small, and the shelves are broken, so chemicals mix with everything else.”</i>
	Insufficient funding/resources	<ul style="list-style-type: none"> <li>• No disposal budget</li> <li>• Delayed procurement</li> <li>• Limited storage materials</li> </ul>	<i>“We report every year, but no funds come to fix the problem.”</i>
	Weak administrative systems	<ul style="list-style-type: none"> <li>• No monitoring visits</li> <li>• Reports ignored</li> <li>• No updated inventory systems</li> </ul>	<i>“We fill forms, but nothing changes; the chemicals remain as they are.”</i>
<b>4. Absence of Regulatory and Disposal Frameworks</b>	Lack of national guidance	<ul style="list-style-type: none"> <li>• No disposal protocols</li> <li>• No safety manuals</li> <li>• Lack of official directions to schools</li> </ul>	<i>“We don’t have instructions from the government on how to dispose of these chemicals.”</i>
	Unclear institutional responsibility	<ul style="list-style-type: none"> <li>• Confusion over responsible ministry/agency</li> <li>• No external supervision</li> </ul>	<i>“We are not sure who is supposed to help—Education? Environment? No one comes.”</i>
	Improvised disposal measures	<ul style="list-style-type: none"> <li>• Burial of small amounts</li> <li>• Long-term retention</li> <li>• Inter-school transfers</li> </ul>	<i>“Sometimes schools bury small quantities because there is no other option.”</i>

#### Narrative Explanation Accompanying the Combined table 4

The combined table presents a consolidated overview of the analytic structure that shaped this study’s findings. It demonstrates how raw data were progressively transformed from initial codes into conceptual categories and subsequently into broader themes. This hierarchical organization illustrates both the depth and coherence of the analysis.

**Theme 1, “Persistence of Long-Term Chemical Stockpiling,”** captures the widespread accumulation of expired and deteriorated chemicals in secondary school laboratories. Codes such as *chemicals stored since the early 2000s*, *crystallization*, and *leaking containers* were consistently observed across sites and formed categories describing prolonged storage and chemical deterioration. These patterns highlight a long-standing issue rooted in systemic neglect and lack of disposal avenues.

**Theme 2, “Weak Safety Culture and Limited Risk Awareness,”** reflects the limited capacity of laboratory personnel to identify hazards, interpret chemical safety information, and implement safe handling practices. Codes

showing inability to interpret hazard symbols, lack of PPE, and the storage of incompatible chemicals converged into categories indicating insufficient training and inadequate safety practices. Participant quotes further illuminate a pervasive uncertainty and fear surrounding expired chemicals, stemming from inadequate professional orientation.

**Theme 3, “Structural and Institutional Barriers,”** synthesizes infrastructural limitations and institutional challenges that hinder proper chemical management. Codes related to poor ventilation, congested laboratory spaces, absence of disposal budgets, and lack of administrative support demonstrate how structural weaknesses at school and system levels perpetuate hazardous laboratory conditions. These barriers restrict the ability of teachers and laboratory assistants to implement corrective or preventive measures, even when they recognize the risks.

**Theme 4, “Absence of Regulatory and Disposal Frameworks,”** reveals a critical governance gap in

chemical waste management in schools. Codes capturing the lack of national guidelines, unclear departmental responsibilities, and improvised disposal strategies illustrate the vacuum of institutional authority. Participants' comments show confusion regarding who is mandated to oversee chemical disposal, resulting in indefinite storage or unsafe, improvised disposal practices.

### 4.3 Theme Generation and Review

Interviews revealed widespread gaps in teachers' knowledge of chemical disposal, which, combined with

observation of expired and incompatible chemicals in poorly ventilated laboratories, indicates entrenched unsafe practices. These issues were reinforced by institutional constraints, including absent safety policies, inadequate PPE, and limited storage infrastructure. Categories derived from the data were consolidated into higher-order themes and cross-checked against the raw dataset to ensure analytic rigor and fidelity to participant perspectives (Tables 5 and 6). The resulting themes capture both recurring patterns and the broader structural factors shaping laboratory safety in Zanzibar's secondary schools.

**Table 5 below showing the themes, supporting codes, and representative quotes from teacher interviews on laboratory safety in Zanzibar secondary schools**

Theme	Supporting Codes	Representative Quotes
Unsafe Laboratory Culture	Long-term chemical accumulation, Improvised disposal	"We just keep chemicals here; nobody told us what to do with them."
Knowledge Gaps	Lack of disposal knowledge, Misconceptions	"Old chemicals are not dangerous; they have lost strength."
Institutional Barriers	Institutional guidance missing, Policy absence	"We were told to wait for instructions, but none came."
Resource/Infrastructure Deficiencies	Lack of PPE, Poor ventilation	"No gloves, no goggles, and no fume hood; we just work carefully."

**Table 6: Identified Themes and Corresponding Participant Perspectives on Laboratory Safety in Zanzibar Secondary Schools**

Theme	Description
Unsafe Laboratory Culture	Practices and attitudes in labs that compromise safety, e.g., indefinite chemical storage, fear of handling chemicals.
Knowledge Gaps	Teachers' and technicians' limited understanding of chemical hazards and safe disposal methods.
Institutional Barriers	Lack of policy, supervision, and enforcement from school authorities or government.
Resource and Infrastructure Deficiencies	Inadequate safety equipment, poor ventilation, absence of chemical cabinets, and insufficient budgets.

Together, these tables (5 & 6) provide a transparent and comprehensive account of the findings, linking participants' perspectives to the emergent patterns in a clear and accessible manner. That is table 5 presents themes with supporting codes and illustrative quotes, demonstrating how findings are grounded in participant data and table 6 summarizes these themes with descriptive interpretations, highlighting the key patterns and their relevance to laboratory safety in Zanzibar secondary schools."

### 4.4 Overall observations and interviews

Across the sampled schools, many chemicals were expired, some for over 20 years, including hazardous acids, bases, heavy metal salts, and organic solvents. Observations

revealed significant deterioration, such as crystallization, solid masses, ammoniacal smell, discoloration, leaking containers, and faded or missing labels, while incompatible chemicals were often stored together under poor ventilation and inadequate shelving. Safety measures were largely absent, with limited PPE, fire extinguishers, spill kits, or functional first-aid supplies. Teachers had limited knowledge of chemical hazards, and few schools employed trained laboratory technicians, contributing to long-term accumulation of hazardous chemicals. These conditions increased health and environmental risks and, in some cases, led schools to discontinue hands-on chemistry practical, affecting students' skill development. Across all participating schools, no functional chemical disposal unit was identified. Laboratory waste was either left to accumulate or kept in improvised containers. Only 10% of

the schools (1 out of 10) reported attempting any form of disposal, mainly open burning of expired.

## 4.5 Discussion

The findings reveal a critical storage and chemical safety crisis characterized by more than decade-old chemical stockpiles, significant physical degradation, limited technical knowledge, and absence of disposal guidelines. The quantitative analysis of chemical storage conditions in the surveyed schools confirms systemic and severe deficiencies in safe laboratory management. Of the 372 chemicals documented, nearly two-thirds (62.7 %) were expired with volumes of expired chemicals, many dating back 15–20 years. Studies across East Africa similarly report that secondary school chemistry laboratories often retain materials long beyond their intended lifespan due to inadequate disposal mechanisms (Fu et al, 2023; Muzammal & Hashmi, 2025) while some are reused due to budgetary strains or carelessness of the chemistry teacher concern. 34.4% of these had physically degraded into solid due to age, heat, and poor sealing mainly the hydrated salts of group 1 and 11 elements. Poor sealing, prolonged exposure to heat, humidity factors are known to accelerate degradation in tropical climates (Anderson et al, 2017; Wang et al, 2025). Degradation into crystalline forms or rock-like were observed from evaporated hygroscopic salts such as copper sulfate and sodium carbonate and the darkened or discoloured liquids from iodine solutions, ferric chloride, and potassium permanganate. It is quite interesting that most of the indicator solutions have expired hence 30% of the school samples rely on the improvised tomato solution as for neutralization titrations. These observed physical changes especially the formation of crystalline masses and corrosive vapours support the assertion by the National Research Council (2011) that expired chemicals often become more hazardous, not less, as they degrade and form unstable or unknown compounds (Harris, 2021). Literature across Africa shows that without clear responsibility and protocols, schools tend to indefinitely store expired chemicals, waiting for instructions from administrators that never arrive (UNESCO, 2018; Muhibi et al, 2024).

The findings confirm that teachers reported fear of handling old containers, and many chemicals emitted pungent odours, indicating active decomposition. This facilitates the existence of expired chemicals in the school laboratory. In addition, 61 containers were corroded or leaking, with 80% were unlabeled, with faded, peeled, or disintegrated labels leaving their identity and hazards unknown hence making segregation difficult. Normally, proper segregation and labeling such as separating acids from bases and oxidizers from flammables are cornerstone practices recommended in safe chemical storage guides yet

were largely absent in the sampled schools (ACS,2020). Thus, while the participants' concerns are centered on practical challenges, the scientific evidence underscores a far-reaching state of public health and ecological risk associated with expired chemical stockpiles

The assessment of storage facilities revealed consistently poor and unsafe conditions across all evaluated schools, confirming major weaknesses in laboratory infrastructure and management. Ventilation and security each recorded 60% poor ratings, with most stores lacking airflow control, air conditioning, chemical-resistant shelving, spill-containment measures, or secure locked cabinets. These deficiencies mirror regional evidence that many African school laboratories are structurally ill-equipped to handle hazardous materials (Muhibi et al, 2024). Labeling, shelf stability, and chemical segregation were the most compromised areas, with 80% rated as poor, indicating widespread absence of proper identification, unstable shelving, and dangerous mixing of incompatible substances—conditions known to elevate the risks of unintended reactions and exposure (ACS, 2020). Poor ventilation and the absence of fume extraction systems, observed in nearly all schools, further exacerbate the dangers associated with vapors released by decomposing acids, solvents, and oxidizers. Observations also revealed dusty floors, cracked surfaces, and disorganized apparatus, illustrating a general lack of suitability for hazardous chemical storage. 60% of the school samples don't have chemical stores. The study has also realized that 60% of the school sampled, same laboratory classroom is the same chemical store. Only 2 out of 10 schools had a trained laboratory technician, consistent with literature showing that inadequate staffing severely weakens laboratory safety (UNESCO, 2021). Despite building so many schools, additionally every school should have laboratory assistant. None of the schools had a functional preparation room, forcing chemical handling to occur within main laboratory spaces, contrary to global recommendations that emphasize designated preparation and storage areas to reduce contamination and accidents (WHO, 2017). Despite the critical role of chemistry laboratories in advancing scientific research and innovation, the safety management systems and awareness among laboratory personnel should be addressed (Wang<sup>a</sup> et al, 2025) or else we shall be brewing students who lack practical competence, a serious limitation as concerns the competence-based curriculum.

Collectively, these conditions fall far below international safety standards and significantly heighten the risks of spills, contamination, structural damage, and human exposure highlighting the urgent need for infrastructural upgrades, trained personnel, and strict adherence to chemical-storage protocols (Wandiga, 2020). Without designated storage cabinets or structured inventory systems, reactive chemicals pose risks of fire, explosion, or

toxic gas release. The shortage or lack of safety equipment noted (fire extinguishers, spill kits, PPE) mirrors earlier studies which highlighted safety equipment shortages as a major limitation in African science education (Ansah et al, 2024). These deficiencies directly increase the vulnerability of students and staff to chemical accidents, leakage, and inhalation hazards. Thus, the condition of Zanzibar's school laboratories confirms long-standing concerns in international literature about inadequate safety cultures in resource-constrained educational settings. Furthermore, the unsegregated storage of incompatible chemicals (e.g., acids beside flammables) demonstrates a fundamental gap in safety knowledge and infrastructure, a problem widely documented in LMIC laboratory environments (UNEP, 2013; OSHA, 2020). This situation needs to be addressed as it is a catastrophe in waiting (Wang<sup>a</sup> et al, 2025)

A major finding was the complete absence of formal chemical disposal policies at both national and school levels to facilitate chemical disposal unit. The absence of disposal guidelines, neutralization stations, waste-collection points, or partnerships with licensed waste handlers has led to a culture of indefinite storage, where expired or unstable chemicals remain on shelves for decades. This governance gap reflects a familiar pattern across LMICs: hazardous waste legislation often exists at national level, but implementation in the education sector is weak or non-existent (UNEP, 2021; Wang et al, 2025). Tanzania's wider hazardous waste regulations do not explicitly address school laboratories, and Zanzibar lacks a dedicated chemical-safety framework. This practice not only violates internationally accepted chemical-hygiene standards but also increases the risks of leaks, environmental contamination, and accidental exposure during routine handling as emphasized in WHO Guidelines for safe chemical management in educational facilities (Wandiga, 2020; WHO, 2017). Weak inventory management is evident in missing stock books, absent expiry records, and lack of annual audits thus mirrors findings from global studies showing that schools without inventory systems rapidly accumulate unmanageable chemical stockpiles (NRC, 2010; Anderson et al, 2017). The result is what UNESCO (2018) describes as a cycle of neglect: no policy → no audits → no accountability → long-term accumulation. Resource constraints further intensify this problem. Schools lack budgets for chemical disposal, and Zanzibar lacks specialized waste-management contractors or treatment facilities. Lack of chemical waste disposal system and solid chemicals dumped among the solid wastes where, at times, they are burned with liquid chemicals poured into sewer systems. This confirms literature on small island developing states (SIDS), where hazardous waste disposal is especially challenging due to geographic isolation, high transportation costs, and limited infrastructure

(Periathamby & Sunil, 2014; Mohammadi, 2021). Thus, the institutional vacuum documented in this study aligns strongly with regional and global evidence, confirming hazardous chemical accumulation as a systemic—not school-level—problem.

The findings indicate significant health and environmental risks arising from degraded chemicals stored in poorly ventilated spaces. Literature shows that chronic exposure to chemical vapors particularly acids, solvents, and metals can cause respiratory irritation, neurological effects, and long-term health consequences (Chapman, 2018; Khoshakhlagh et al, 2023). This aligns with global findings that inadequate chemical management in schools amplifies acute and chronic exposure risks among teachers and students (Khan, 2014; Okonkwo & Moyo, 2020). From an educational perspective, the inability to conduct practical experiments due to unsafe conditions undermines competence-based learning and practical skill development. This aligns with research showing that inadequate laboratory environments impede effective science teaching and limit students' experiential learning (Fu et al, 2023; Pereira et al, 2025). Laboratory safety is not in the mainstream of academic agenda unless a severe accident occurs. There is minimum or no instruction at all as concern or training workshops do laboratory in charge undergoes apart from the teaching he received during his or her degree in chemistry studies, Thus, the risks observed in the field are well-supported by existing studies and underscore the urgency of policy intervention.

Even though most school laboratories in Zanzibar are managed by graduate chemistry teachers, many of whom have taken at least one unit in environmental chemistry during their degree program, they show minimal provision of safety guidance to students or laboratory users. Safety instructions, when provided, are inconsistent and largely informal. In recent years, the responsibility for regulating chemical acquisition, storage, and use has been placed under the Government Chemist to regulate issues surrounding chemicals usage, procurement and management including laboratory regulation. However, while the authority is mandated to inspect chemicals upon entry and advice institutions, individual schools remain responsible for reporting expired or unsafe chemicals for destruction. In practice, this reporting rarely occurs. As government-owned institutions operating under tight budgets and with limited technical personnel, schools often fail to meet regulatory expectations, while Government Chemist offices themselves lack sufficient workforce to conduct regular monitoring. This systemic gap underscores the urgent need for a strengthened national policy framework that clearly outlines institutional responsibilities, ensures compliance, and provides

sustainable support mechanisms for safe chemical management in schools.

## 5. Conclusion and Recommendations

### 5.1 Conclusion

This study revealed a critical and long-standing problem of expired chemical accumulation in secondary school laboratories in Zanzibar. Chemicals dating back over ten years remain stored in unsafe conditions, with many having degraded, solidified, or corroded their containers. The absence of a national policy on inadequate laboratory infrastructure, and significant knowledge gaps among teachers and technicians have collectively contributed to hazardous learning environments. The findings show that laboratory safety in Zanzibar is not only an educational issue but also a public health and environmental concern. Without policy intervention, technical guidance, and sustained investment, these challenges will persist and intensify. Overall, the study concludes that Zanzibar urgently requires a coordinated, system-wide approach to chemical management integrating policy reform, capacity building, infrastructure strengthening, and environmental protection strategies.

### 5.2 Recommendations

From the study, the following recommendations were made:

1. Schools should conduct systematic removal, labelling, and segregation of expired chemicals with support from trained personnel and establish chemical inventory systems in which stock books are updated, perform annual audits for laboratory safety and regular monitoring good laboratory practice procedures. Without these they should be sanctions for non-compliance and incentives for best practices.
2. District science inspectors must ensure laboratories meet minimum safety benchmarks before student use and make sure that schools install proper ventilation, lockable chemical cabinets, spill kits, PPE, and fire-safety equipment. Every school offering chemistry course should have a laboratory technician.
3. Schools should organize regular workshops for her chemistry staff and particularly on chemical handling, GHS labeling, emergency response, and safe disposal procedures.

4. Schools should support and allocate funds for maintenance, procurement of safety equipment, and chemical disposal processes.
5. Universities and teacher colleges must include laboratory safety and waste management modules in chemistry teacher training curricula particularly in their chemistry practical classes.

#### **Policy Framework Proposal for Chemical Disposal in Zanzibar**

To address the systemic gaps identified, the following policy model is proposed Guiding Principles. They include Precautionary principle – prevent harm before it occurs; Polluter-pays principle – institutions generating hazardous waste bear disposal responsibility; Sustainability – ensure environmentally responsible and long-term waste management solutions and finally Accountability and transparency – maintain accurate inventories and disposal records.

#### **Implications for Practice**

##### **1. Schools and Teachers**

There is need to Improved chemical stewardship so as to enhance student safety and restore practical chemistry teaching and teachers must also adopt a culture of routine inventory management and safe laboratory operations. They need to fully comply with GHS so as to improve on hazard communication and reduce accidents.

##### **2. Ministry of Education and Vocational Training**

Implementing formal policies will reduce health, legal, and environmental liabilities and strengthened chemical management systems will also support competence-based chemistry education. The ministry should also Investment in infrastructure to improve the credibility and functionality of science laboratories

##### **3. ZEMA (Environmental Protection)**

Should encourage Proper disposal so as to reduce potential contamination of soil, groundwater, and coastal ecosystems. Need to Centralized systems in order to ensure environmentally safe treatment of hazardous substances.

#### **Implications for Further Research**

##### **Environmental impact assessment**

Future studies should analyze soil, water, and air quality near schools with decades-old chemical accumulation to determine contamination levels.

## Health impact studies

Research is needed to assess whether chronic exposure to laboratory chemical fumes has affected teachers or students and any disease related to the effects of expired chemicals and poor laboratory framework.

## Cost–benefit analysis

Quantifying the cost of establishing a national disposal program versus long-term health/environmental risks would support policy decisions including training effectiveness studies in order to evaluate the impact of professional development programs on improving laboratory safety practices.

## Comparative Research

Comparative regional analyses to compare Zanzibar's situation with Kenya, Uganda, and mainland Tanzania could provide lessons for harmonizing East African chemical disposal policies and feasibility of local treatment technologies to research on low-cost neutralization and stabilization methods suitable for Zanzibar.

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