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Assessment of expired chemical materials and storage safety practices in secondary school laboratories in Tobruk, Libya

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Abstract

Chemicals are essential components of school science laboratories; however, inadequate inventory management and improper storage may pose risks to human health, laboratory safety, and the environment. This study assessed chemical inventories, expired chemicals, and storage safety practices in eight secondary school laboratories in Tobruk City, Libya. A descriptive survey was conducted using direct observation, structured interviews, and a standardized chemical inventory checklist. The assessment focused on the quantities, expiration status, hazard classifications, physical condition, and storage practices of solid chemicals. A total of 132 solid chemicals, with a combined mass of 182.951 g, were recorded. Of this inventory, 27.611 g (14.52%) consisted of expired chemicals, indicating deficiencies in inventory control and chemical waste management. The proportion of expired chemicals varied considerably among schools, reaching 57.53% at Bab Al-Zaytoun School. Hazard classification showed that flammable chemicals represented the largest category (49.33%), followed by corrosive (32.87%), toxic (9.14%), and explosive (8.88%) chemicals. The assessment also identified shortcomings in chemical storage, segregation, and safety management. Although some chemicals showed visible signs of deterioration, their chemical stability could not be confirmed through visual inspection alone. These findings highlight the need for updated chemical inventories, regular

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expiration-date inspections, appropriate chemical segregation, and safe disposal procedures for expired chemicals. Regular safety training for laboratory personnel is also necessary to improve chemical handling and risk prevention. Strengthening inventory management and storage practices is essential for reducing chemical hazards and improving the safety of secondary school laboratories in Tobruk City, Libya.

KEYWORDS: Chemical inventory, chemical storage, expired chemicals, hazardous chemicals, laboratory safety.

تقييم المواد الكيميائية منتهية الصلاحية وممارسات سلامة التخزين في مختبرات المدارس الثانوية بمدينة طبرق – ليبيا

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الملخص

تُعد المواد الكيميائية من المكونات الأساسية لمختبرات العلوم المدرسية، إلا أن قصور إدارة المخزون والتخزين غير الملائم قد يشكلان مخاطر على صحة الإنسان وسلامة المختبر والبيئة. هدفت هذه الدراسة إلى تقييم المخزون الكيميائي والمواد الكيميائية منتهية الصلاحية وممارسات سلامة التخزين في مختبرات ثماني مدارس ثانوية بمدينة طبرق، ليبيا. أُجريت دراسة مسحية وصفية باستخدام الملاحظة المباشرة والمقابلات المنظمة وقائمة فحص موحدة لجرد المواد الكيميائية. وركز التقييم على كميات المواد الكيميائية الصلبة، وحالة صلاحيتها، وتصنيفها وفقًا لخطورتها، وحالتها الفيزيائية، وممارسات تخزينها. سُجلت 132 مادة كيميائية صلبة، بكتلة إجمالية بلغت 182.951 جم. وبلغت كتلة المواد منتهية الصلاحية 27.611 جم، بما يعادل 14.52% من إجمالي المخزون، مما يشير إلى وجود أوجه قصور في ضبط المخزون وإدارة النفايات الكيميائية. وتباينت نسبة المواد منتهية الصلاحية بدرجة ملحوظة بين المدارس، حيث بلغت 57.53% في مدرسة باب الزيتون. وأظهر تصنيف المواد الكيميائية حسب خطورتها أن المواد القابلة

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للاشتعال شكّلت الفئة الأكبر بنسبة 49.33%، تلتها المواد الأكّالة بنسبة 32.87%، ثم المواد السامة بنسبة 9.14%، والمواد المتفجرة بنسبة 8.88%. كما كشف التقييم عن أوجه قصور في تخزين المواد الكيميائية وفصلها وفقًا لخصائصها الخطرة وإجراءات إدارة السلامة. وعلى الرغم من ظهور علامات تلف مرئية على بعض المواد الكيميائية، فإنه لم يكن بالإمكان التأكد من استقرارها الكيميائي اعتمادًا على الفحص البصري وحده. وتؤكد هذه النتائج ضرورة تحديث سجلات المخزون الكيميائي، والفحص الدوري لتواريخ الصلاحية، والفصل المناسب بين المواد الكيميائية، وتطبيق إجراءات آمنة للتخلص من المواد منتهية الصلاحية. كما يُعد التدريب المنتظم للعاملين في المختبرات على إجراءات السلامة أمرًا ضروريًا لتحسين التعامل مع المواد الكيميائية والحد من المخاطر. وتُعدّ تعزيزات إدارة المخزون وممارسات التخزين السليمة ضرورية للحد من المخاطر الكيميائية وتحسين سلامة المختبرات المدرسية الثانوية في مدينة طبرق، ليبيا.

الكلمات المفتاحية: جرد المواد الكيميائية، تخزين المواد الكيميائية، المواد الكيميائية منتهية الصلاحية، المواد الكيميائية الخطرة، سلامة المختبرات.

INTRODUCTION

Chemicals are essential components of science laboratories and play an important role in supporting practical education in schools (Anderson et al., 2017). Laboratory chemicals are widely used in chemistry, biology, and physics experiments to enhance students' understanding of scientific concepts and develop their practical skills (Abedsoltan and Shiflett, 2024). The availability of properly stored and well-maintained chemicals is therefore necessary for effective science education (American Chemical Society, 2020). However, many educational institutions face challenges related to the storage, management, and disposal of chemical substances. Over time, chemicals may deteriorate due to environmental conditions, including temperature, humidity, light exposure, and improper storage practices. Expired or degraded chemicals may lose their intended properties and, in some cases, pose risks to human health and the environment (Anza and Kuma 2016). Furthermore, the accumulation of obsolete or expired chemicals in school laboratories may increase the risk of accidents, contamination, and inappropriate handling. Effective chemical management requires

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regular inventory control, proper labeling, suitable storage conditions, and safe disposal procedures (Babincakova, et al., 2020). International safety guidelines emphasize the importance of monitoring chemical stocks and identifying and appropriately managing expired or deteriorated substances to minimize potential hazards in educational laboratories (Benoit, 2002). Failure to implement these measures may compromise laboratory safety and negatively affect the quality of practical science education. Previous studies have highlighted the importance of chemical safety management in educational institutions and reported concerns regarding the storage and handling of outdated laboratory chemicals [9]. Nevertheless, limited information is available on the status of chemical inventories, expired chemicals, and storage safety practices in secondary school laboratories in Libya, particularly in Tobruk City. This lack of local information highlights the need to assess the condition of stored chemicals and identify potential weaknesses in inventory management and storage practices. Therefore, the main objective of this study was to assess the status of chemical inventories and storage safety practices in selected secondary school laboratories in Tobruk City, Libya. Specifically, the study aimed to, determine the types and total quantities of stored solid chemicals, identify and quantify expired chemicals, classify the chemical inventory according to hazard categories, and evaluate chemical storage and safety practices. The findings are intended to provide baseline data to support improved chemical inventory management, safer storage practices, and more effective handling and disposal of expired chemicals in secondary school laboratories.

MATERIALS AND METHODS

Study Area

This study was conducted in eight selected schools in Tobruk City, Libya, during the period from January to May 2024.

Study Design

A descriptive survey study was conducted to evaluate the condition of solid chemical substances stored in school laboratories and to assess the status of chemical inventories in the selected schools. A specially designed inventory checklist was used for data collection. The checklist included information on the chemical name, code,

physical condition, expiry date, manufacturer, and other relevant data related to chemical storage conditions and management practices.

Sample Selection

Eight secondary schools in Tobruk City, Libya, were selected using purposive sampling to assess the status of solid chemical inventories and storage safety practices in their science laboratories. Preliminary information was obtained from the Educational Supervision Office of the Ministry of Education in Tobruk City, which provided previous chemical inventory records for some schools. These records were used solely as supplementary information to support the selection of schools and provide background context for the study, rather than as the primary source of data. The main data for the present study were collected from the selected schools through direct observation of laboratory storage conditions, examination of available chemical labels and inventory records, and the use of a standardized checklist to document the types, quantities, expiration status, and hazard classifications of stored solid chemicals. Structure interviews with relevant school or laboratory personnel were also conducted, if applicable, to obtain additional information about chemical inventory management and storage safety practices. Therefore, the study findings were based primarily on data collected during the current assessment, while the previous inventory records provided by the Educational Supervision Office served only as a supplementary source.

Data Collection Methods

Eight secondary schools in Tobruk City, Libya, were selected using purposive sampling. Previous chemical inventory records obtained from the Educational Supervision Office of the Ministry of Education for some schools were used as supplementary information only, not as the primary data source. The primary data were collected using a structured inventory checklist completed by Basic Science teachers responsible for laboratory materials. The checklist documented the types and quantities of solid chemicals, expired chemicals, expiry dates, chemical sources, and physical condition (e.g., crystallized, solidified, corroded, or leaking). Storage conditions, including chemical segregation, ventilation, security, and the general storage environment, were also assessed.

Thus, the study findings were based primarily on data collected from the selected schools, with previous inventory records serving only as supplementary information.

The percentage of expired chemicals was calculated by dividing the total mass of expired chemicals by the total mass of all inventoried solid chemicals and multiplying the result by 100. The percentage of each hazard category was calculated using the corresponding category mass relative to the total mass of the chemical inventory, where applicable.

Data Analysis

Data were sorted, coded, entered, and analyzed using the Statistical Package for the Social Sciences (SPSS). Descriptive statistical methods were used to analyze the collected data. Quantitative data obtained from the inventory checklists were summarized using frequencies, percentages, and averages (Field, 2018). The results were presented in the form of tables, figures, and graphs to facilitate data interpretation. Appropriate descriptions were provided for each table and figure to explain the reported values and findings.

DISCUSSION & RESULTS

The present study evaluated the status of solid chemical substances stored in selected secondary school laboratories in Tobruk City, Libya. The inventory assessment identified 132 chemical substances with a total recorded mass of 193.401 g. Of this total, 165.889 g consisted of non-expired chemicals, whereas 27.511 g consisted of expired chemicals (Table 1) The percentage of non-expired chemicals was calculated by dividing their recorded mass by the total mass of the chemical inventory and multiplying the result by 100:

$$\textbf{Non-expired chemicals (\%)} = 165.880 / 193.401 \times 100 = 85.78\%$$

Similarly, the percentage of expired chemicals was calculated as follows:

$$\textbf{Expired chemicals (\%)} = (27.511 / 193.401) \times 100 = 14.22\%$$

The total recorded mass of chemicals was 193.391 g, comprising 165.880 g (85.77%) of non-expired chemicals and 27.511g (14.23%) of expired chemicals (Figure 1). Physical inspection

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revealed deterioration in some stored chemicals, including crystallization, solidification, discoloration, container corrosion, and leakage (Figure 2). These findings highlight the need for regular inventory monitoring, proper storage, routine inspections, and safe disposal procedures. Expired or deteriorated chemicals should be assessed by trained personnel before use or disposal. Improved inventory management and staff training could enhance laboratory safety and reduce environmental risks.

TABLE 1. Inventory of Chemicals at the chemical storages in all schools

	School	Total Chemicals Expired g	Expired %	Total Chemicals Not Expired g	Not Expired %
1	Al-Manara	2300	6.22	34650	93.78
2	Martyrs of the Poster	3150	6.80	43200	93.20
3	Saleh Al-Haddad	450	10.22	3950	89.77
4	Kambut	3610	10.18	31840	89.82
5	Omar Ibn Al-Aasis	350	5.26	6300	94.74
6	Bab Al-Zaytoun	9901	36.53	17199	63.46
7	Al-Amal	6650	23.62	21500	76.38
8	Al-Marsas	1100	13.17	7250	86.82
	Total	27511	14.22	165889	85.78

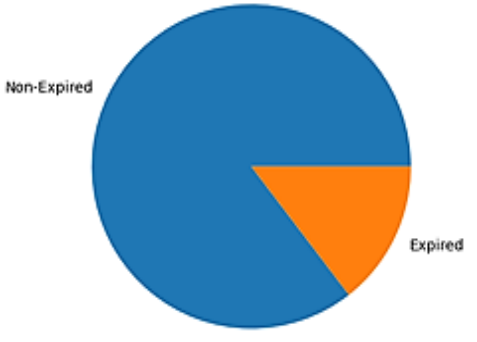


Fig 1. Expired & non-Expired chemicals

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Considerable variation was observed among the surveyed schools regarding the proportion of expired chemicals. As shown in (Figure 3), Bab Al-Zaytoun School recorded the highest percentage of expired chemicals (57.53%), followed by Al-Amal School (30.19%), whereas Omar Ibn Al-Aasis School exhibited the lowest percentage (5.56%). These findings suggest substantial differences in inventory management practices, chemical turnover rates, laboratory supervision, and implementation of storage policies among schools. Similar observations were reported by, who found that inadequate monitoring and disposal systems contributed to the accumulation of obsolete chemicals in secondary school laboratories.



Fig 2. Degradation of Chemical Containers During Storage

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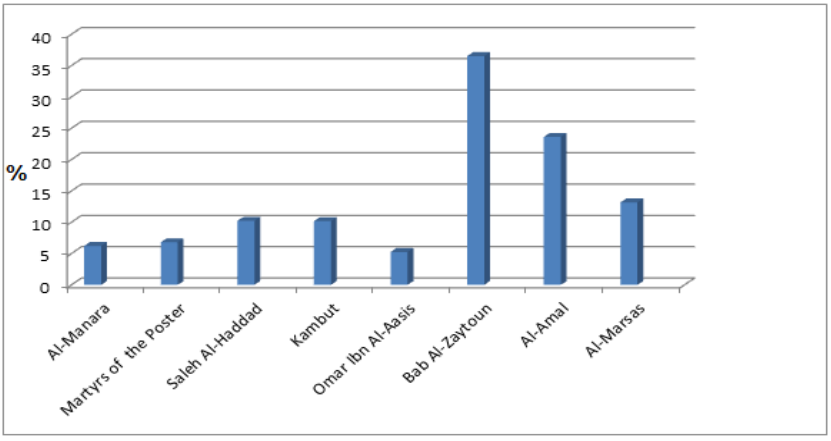


Fig 3. Expired chemicals School

The classification of expired chemicals according to their hazard characteristics showed that flammable substances represented the largest category (49.33%), followed by corrosive substances (32.87%), toxic substances (9.12%), and explosive substances (8.66%) (Table 2). The percentage of each hazard category was calculated by dividing the mass of chemicals in that category by the total mass of expired chemicals and multiplying by 100, using the following equation:

$$\textbf{Percentage (\%)} = \frac{\textbf{Mass of chemicals in each hazard category}}{\textbf{Total mass of expired chemicals}} \times \mathbf{100}$$

The percentages of corrosive, toxic, and explosive chemicals were calculated using the same equation, yielding 32.87%, 9.12%, and 8.66%, respectively. The sum of the reported percentages was 100% (49.33 + 32.87 + 9.12 + 8.66) As shown in (Figure 4).

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TABLE 2. shows the percentage of solid chemical substances according to their properties in all schools

	School	Toxic %	Flammable %	Corrosive %	Explosive %
1	Al-Manara	2.11	12.22	10.01	2.10
2	Martyrs of the Poster	1.99	14.80	11.03	2.21
3	Saleh Al-Haddad	0.20	09.22	0.54	0.82
4	Kambut	1.54	07.15	2.90	0.84
5	Omar Ibn Al-Aasis	0.98	5.26	0.40	0.40
6	Bab Al-Zaytoun	1.10	10.53	2.80	0.87
7	Al-Amal	1.22	09.89	1.04	0.37
8	Al-Marsas	1.01	04.15	3.43	1.12
	Total	9.12	49.33	32.87	8.66

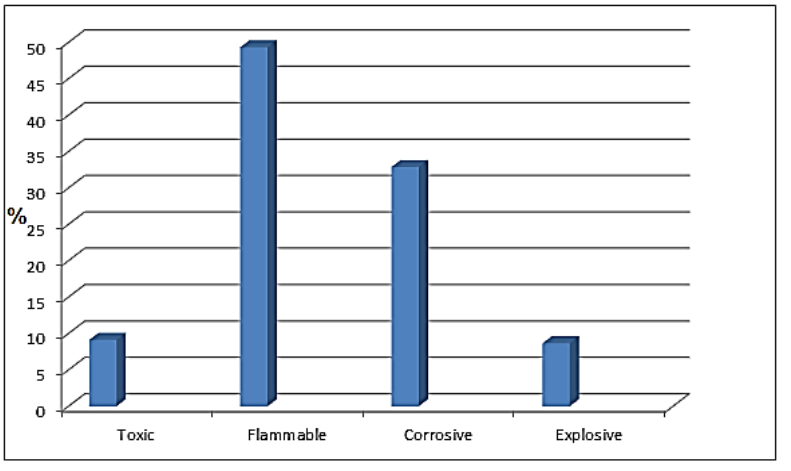


Fig 4. Hazarded Classification

The results indicate that flammable and corrosive substances represented the predominant reported hazard categories. This finding highlights the importance of appropriate chemical segregation, control of ignition sources, suitable storage conditions, and protective measures. Although toxic and explosive substances accounted for smaller reported proportions Figure 5, they still require careful management because their risks depend on their

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specific chemical properties, quantities, and storage conditions. Among the surveyed schools, Martyrs of the Poster School recorded the highest reported proportion of flammable chemicals (14.80%), whereas Saleh Al-Haddad School recorded the lowest reported proportion of toxic chemicals (0.20%). Interpretation of these school-level percentages depends on the denominator used in the original calculations and should be clearly specified in (Table 2). The assessment of storage facilities also revealed deficiencies in ventilation, temperature control, chemical-resistant shelving, segregation of incompatible chemicals, and secure storage cabinets (Figure 6). Such deficiencies may increase the risk of chemical deterioration, accidental exposure, and unsafe interactions during storage. Therefore, regular inventory inspections, appropriate segregation of incompatible substances, adequate ventilation, suitable storage facilities, and staff training are essential for improving laboratory safety and chemical management.



Fig 5. Chemicals Stored in Non-Compliant Containers

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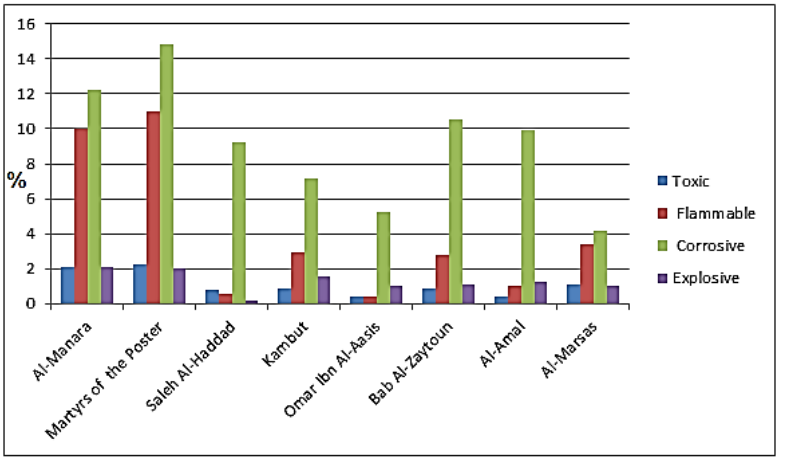


Fig 6. Hazard Categories by school

As shown in (Table 3), the percentage of expired chemicals varied among the eight surveyed schools. To quantify this variation, the mean percentage, sample standard deviation, minimum, maximum, and range were calculated from the school-level percentages. The mean was obtained by summing the percentages for all eight schools and dividing the total by eight. The sample standard deviation was calculated using the deviations of individual school percentages from the mean, while the range was determined by subtracting the minimum percentage from the maximum percentage. The standard deviation (SD) was calculated to measure the variability of the expired-chemical percentages among the eight schools using the following sample standard deviation equation:

$$SD = \sqrt{\frac{\sum_{i=1}^{i=n}(x_i - \bar{x})^2}{n-1}}$$

Where:

SD = sample standard deviation.

x_i = Expired-chemical percentage for each school.

$\bar{x}$ = Mean of the percentages.

n = Number of schools (8).

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The observed variation indicates that expired chemicals were not distributed uniformly among the surveyed schools. Differences in the proportions of expired chemicals may be associated with variations in inventory size, procurement practices, monitoring frequency, and the procedures used to identify and remove expired substances. However, these potential explanations should be interpreted cautiously because the present study did not establish a direct causal relationship between inventory management practices and the observed percentages. Schools with relatively high proportions of expired chemicals should therefore prioritize regular inventory reviews, accurate record keeping, and timely disposal procedures.

TABLE 3. Descriptive Statistical Summary of Expired Chemicals Among Surveyed Schools

	Statistic	Value
1	Mean	17.92
2	SD	18.24
3	Minimum	5.56
4	Maximum	57.53
5	Range	51.97

Conclusion

This study assessed the chemical inventory status, expired chemicals, and storage safety practices in eight secondary school laboratories in Tobruk City, Libya. The inventory included 132 solid chemical substances, with a total recorded mass of 193.400 g. Of this amount, 27.511 g (14.22%) consisted of expired chemicals, while 165.889 g (85.78%) was classified as non-expired. The proportion of expired chemicals varied among the schools, ranging from 5.26% at Omar Ibn Al-Aasis School to 36.53% at Bab Al-Zaytoun School, indicating differences in chemical inventory management and the accumulation of expired materials. The assessment also identified storage and container-related concerns, including physical deterioration of some containers and deficiencies in storage conditions and chemical segregation. Flammable and

corrosive chemicals require particular attention because inappropriate storage and handling may increase the risk of fire, chemical burns, and material damage. However, visual observations alone cannot confirm chemical degradation or determine the stability of expired substances. These findings highlight the need for regular inventory audits, improved labeling and segregation of incompatible chemicals, appropriate storage facilities, and systematic monitoring of expiry dates. Expired chemicals should be assessed and disposed of through appropriate procedures by trained personnel. Future studies should examine chemical stability and degradation using laboratory analyses and extend the assessment to a wider range of schools in Libya.

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Declaration of Conflicting Interests
The author declares no potential conflicts of interest with respect to the research, authorship, and / or publication of this article.

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