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Enhancing Chemical Management Practices and Waste Efficiency: A Survey on Awareness Among UTHM Students and Staff

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Abstract

The environment and public health are seriously threatened by chemical waste, which is a major concern. With an emphasis on comprehending the knowledge, practices, and safety precautions among University Tun Hussein Onn Malaysia (UTHM) students who have hands-on experience with laboratory systems, this study aims to evaluate laboratory safety in the context of chemical exposure. The institution may be able to cut expenses if the research produces insightful information while it also can help in creating a safer atmosphere by avoiding direct chemical exposure, which may present health hazards to people. Besides, the study might help staff members and students concentrate on safe chemical handling and storage procedures. The majority of the respondents is female which is 77.03% while male is 22.97%. Thus, the study has been conducted using descriptive analysis for the behaviour in the laboratory. The survey's results show that participants have an acceptable level of awareness, and most of them indicate that they would like to learn more about handling chemicals. Then, this study examines the ranking factor that affect the waste of chemicals by using Friedman test while the practices to prevent waste of chemicals by using Spearman Rank test. The results highlight that lack of proper training is the main factor that affect the waste of chemical. These findings highlight the complex combination of variables influencing waste prevention techniques. As a conclusion, organisations are urged to put in place comprehensive training programmes in order to achieve the goal of thoroughly analysing chemical safety and awareness for reducing chemical waste. Additionally, may play a major role in reducing chemical waste, safeguarding human health, and protecting the environment by adopting sustainable practices and cultivating a culture of continuous learning.

1. Introduction

Synthetic chemicals have become an essential part of modern life, affecting everything from clothes and food to equipment and pharmaceuticals. Despite the necessity of these chemicals, it is critical to recognise the risks they pose to the environment and public health. A startling 160 million distinct compounds are listed by the World Health Organisation (WHO), of which 40,000 to 60,000 are currently in use and about 6,000 account for more than 99% of all chemical sales worldwide [1].

The chemical industry has difficulties since more than a thousand new chemicals are launched each year with little safety testing [2]. The sector is predicted to roughly treble between 2017 and 2030. The health of people, animals, plants, and ecosystems is at risk from hazardous compounds such as pesticides, heavy metals, phthalates, polychlorinated biphenyls (PCBs), and persistent pharmaceutical pollutants [3]. Chemicals are essential to many industries and raise living standards by producing agrochemicals, fertilisers, and pharmaceuticals. The chemical industry is made up of companies that produce goods where chemicals are crucial for production processes [4,5]. The three primary product categories used by the chemical industry are bulk (commodity), fine, and specialty chemicals. Fertilisers, petrochemicals, and polymers are examples of bulk chemicals that are manufactured in enormous numbers. Fine chemicals are complex substances that are manufactured in small amounts according to precise specifications. They are essential to many different types of chemical reactions. Scents, lubricants, and adhesives are just a few of the businesses that benefit from specialty chemicals made in batch processes [6].

Malaysia's economy is heavily influenced by the chemical industry, particularly petrochemicals and oleochemicals. Malaysia, a major exporter and producer in the area, gains from a business-friendly environment, government restrictions, and a plenty of feedstock [7]. But there are obstacles that affect manufacturing activity as a whole, such as inflationary pressures. Even with these financial benefits, inappropriate handling of chemical waste becomes an international issue. The increasing amount of toxic waste, which includes hazardous materials, electrical waste, and heavy metals, is a serious threat to animals, water sources, and the ecosystem as a whole [8]. Resolving appropriate waste management is important for reducing these threats to the environment and public health.

Trash includes everything that is thrown away, such as solids, liquids, gases, sludge, and leftovers from production. To protect the environment and public health, these compounds must be handled, transported, treated, and disposed of properly due to their poisonous, corrosive, combustible, reactive, or infectious characteristics [9]. There are several ways that hazardous waste might appear: solid, liquid, or gaseous. What qualifies as dangerous depends on several attributes that indicate a high degree of risk. Hazardous waste is any residue or mixture that poses a harm to persons or the environment [10]. These wastes could be from home, commercial, or biological sources. The environment may be harmed by improper handling of hazardous trash. In hazardous waste management, thorough risk assessments are necessary because they help decision-makers determine what needs to be done and how to best manage risks. These evaluations give priority to the risks connected to hazardous waste, which helps to create a more thorough and long-lasting approach to waste management [11].

There are three primary goals this study seeks to accomplish. First, to evaluate laboratory safety regarding chemical exposure by investigating the knowledge, practices, and safety measures. The second goal of the study is to investigate the elements that lead to chemical waste in work environments. Finally, it seeks to analyse chemical safety and awareness that can prevent chemical waste at the workplace. By achieving these goals, the project hopes to offer insightful information about improving general safety procedures and reducing environmental effect in workplace and laboratory settings.

This study may contribute some useful information about chemical usage and management which can help university to cut the excessive cost. This also may help by keeping the best environment and avoid human being exposed directly on the chemical substances. It may give higher risk towards their health. Lastly, it may help the students and staffs to give more focus on handling the chemical or store it properly afterwards

2. Materials and Method

2.1 Research Questionnaire

This survey comprises five sections (A to D) with close and ended question. Section A gathers demographic information such as gender, race, age, and respondent category which in total consists of four questions. There are six questions in Section B focuses on respondents' personal experiences with chemical usage at their workplace, using multiple-choice questions. Section C explores respondents' general knowledge about factors affecting chemical waste, utilizing a ranking scale which have nine factors that affect waste of chemical. Likert-scale questions are employed in Section D, concentrating on eight practices in chemical management that can prevent waste.

2.2 Pilot Test

For a research project to provide results that are up to par, careful planning and execution are necessary. A pilot study, which is the first stage of the research process, is used to evaluate feasibility prior to the major study, also known as a large-scale main trial [12]. The consistency with which items on a scale measure the same construct is evaluated by this statistic. Validity must be ensured by assessing internal consistency of a test before using it for study or evaluation [13]. In order to support reliable information, sound reasoning, effective research, critical thinking, well-informed decision-making, and general dependability when navigating the complexity of information and knowledge, validity is essential. Cronbach's Alpha is one the pilot test that can be used in this survey research. Here is the equation for the Cronbach's Alpha (1):

$$\alpha = \frac{N \cdot \bar{r}}{1+(N-1) \cdot \bar{r}} \tag{1}$$

where:

α = Cronbach's Alpha value

N = Number of questions

$\bar{r}$ = mean correlation between the question

2.3 Descriptive Analysis

In the first step of statistical analysis called descriptive analysis, we look at one thing at a time, like gender and age. We summarize this data using numbers and graphs like pie charts or bar graphs. These helps to show how the data looks like. There are two main parts to this analysis: central tendency (finding typical values with mean, mode, and median) and variability (seeing how spread out the data is with measures like variance and standard deviation). It requires figuring out the normal or standard values and estimating how variable the data is.

2.4 Friedman Test

When identifying geographic differences between many groups, Friedman's test can be a helpful alternative to the F-test in a completely randomised block design [14]. It is also helpful when handling continuous data that deviates from the presumptions required to perform a one-way ANOVA with repeated measures. The value of statistical test can be calculated using formula below (2).

$$FM = \frac{12}{Nk(k+1)} \cdot \sum R^2 - [3N(k+1)] \tag{2}$$

where:

N = sample size

k = number of groups

R = sum of rank per column

2.5 Spearman's Rank Correlation Test

Precisely measuring differences in velocity standards is made possible by the Spearman rank coefficient, which shows the statistical link between two variables [15]. According to [16], the null hypothesis states that there is a positive correlation between the means of the results for the two groups. The Spearman rank correlation coefficient is computed to determine whether two variables agree on the order of results. The strongest positive and negative correlations are shown by the coefficient, which runs from -1 to 1. The null hypothesis is rejected by hypothesis tests, which are carried out at a 95% confidence level with a P-value of less than 0.05. This can be calculated using the equation below (3).

$$\rho = 1 - \frac{6\Sigma\, d_i^2}{n(n^2-1)} \tag{3}$$

where:

ρ = Spearman's rank correlation coefficient

d = difference in ranks for each paired observation

n = number of observations

2.6 Chi-square Test and Cramer's V Rule

Notably, one of the best statistical techniques for testing hypotheses using nominal variables is the Chi-square test of independence. This test identifies the precise categories causing the observed differences in addition to determining the significance of the differences. Researchers view this statistical method as a useful analytical tool because of the quantity and quality of information it can yield [17]. Nonetheless, [18] list a few presumptions for this test, such as the necessity of variables being mutually exclusive, the randomness of data selection from the population, and the acceptability of values in cells when expected counts are greater than or equal to 5. Below is the equation to calculate Chi-square test (4).

$$X_c^2 = \sum \frac{(O_i - E_i)^2}{E_i} \tag{4}$$

where:

X_c^2 = Chi-square statistic

O_i = observed value

E_i = expected value

3. Result and Discussion

3.1 Cronbach Alpha Test

Evaluating the Likert-scale question's reliability regarding practices to prevent chemical waste is essential. The findings are based on a total of 74 respondents. For behavioral and marketing research, a sample size of 30 to 500 is considered suitable, following [19, 20] advice. So that, a sample size that fell inside this specified range has been chosen in order to guarantee the validity of our current investigation [20]. With the goal of achieving efficient and understandable findings, a practical sample technique was carefully chosen. Random sampling has been chosen because it was simple to use, accessible to respondents, and relevant to the measuring item.

Table 1 : Result of Cronbach's Alpha test

Statements	Cronbach's Alpha
Maintain an accurate inventory (S1)	0.8301
Proper handling and usage (S2)	0.8012
Correct dilution and mixing (S3)	0.8254
Proper storage and shelf (S4)	0.7987
Accurate measurement (S5)	0.7916
Safety Data Sheet (S6)	0.8325
Waste disposal regulation (S7)	0.8387
Training and education (S8)	0.8273

Table 1 displays the result of Cronbach's Alpha test. The value of it is in between 0.815 and 05052. Hence, the questionnaire is reliable for the real survey.

3.2 Descriptive Result

3.2.1 Demographic

This section shows the descriptive analysis of the demographic survey for Section A.

Table 2 : Result of demographic section

Personal information	Type	Percentage
Gender	Male	22.97 %
	Female	77.03 %

Age	Below 20 years old	1.35 %
	20 – 25 years old	95.95 %
	26 – 30 years old	1.35 %
	Above 30 years old	1.35 %
Race	Malay	74.32 %
	Indian	6.76 %
	Chinese	18.92 %
Category	Undergraduate student	94.59 %
	Postgraduate student	2.70 %
	Staff	2.70 %

Table 2 shows the percentage of four respondents' personal information. There are 74 respondents who participated with 77.03% of them are female and 22.97% of them are male. Then, the majority of the respondents' age are between 20 to 25 years old which is 95.95%. However, the respondents which below 20 years old, between 26 to 30 years old and above 30 years old have the same value which is 1.35%.

Next, this survey also received respondents from different races which are Malay, Indian and Chinese. Malay has the highest number of respondents which is 74.32%, followed by Chinese which is 18.92% while Indian has the minority respondents which is 6.76%.

Lastly, there are a few respondents' categories which are undergraduate student, postgraduate student and staff. Undergraduate students the highest respondents that participated in this survey which is 94.59% while postgraduate students and staff share the same percentage which is 2.70%.

3.2.2 Chemical Usage in The Laboratory

This section illustrates the descriptive analysis of laboratory safety consist of knowledge, procedures and safety measures for Section B.

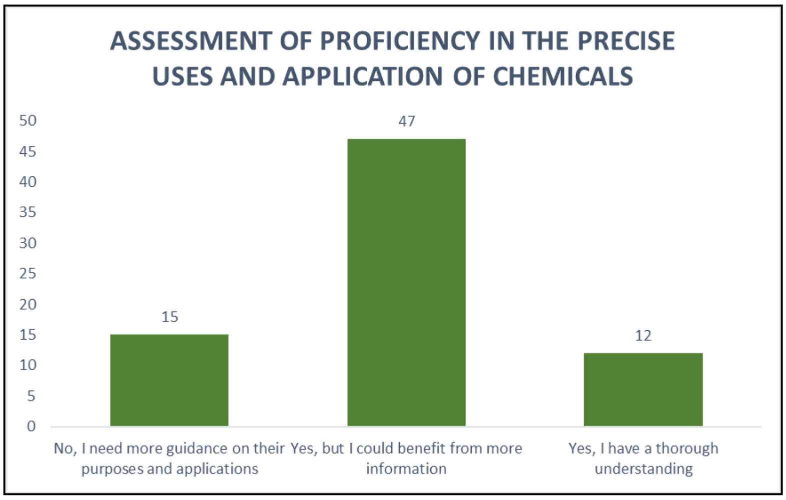

Fig. 1 Result of assessment of proficiency in the precise use and application of chemicals

Fig. 1 shows that 47 out of 74 respondents chose the second choice which is 'Yes, but I could benefit from more information'. This shows that they have basic understanding but believe there is room for improvement and believe additional information can enhance their comprehension. Next, 15 of the respondents chose 'No, but I need more guidance on their purposes and applications'. This shows that they feel uncertain about specific uses and applications of the chemicals and require further guidance. Lastly, 12 of them chose 'Yes, I have a thorough understanding' which means they are confident with their knowledge and can handle the chemicals appropriately in the laboratory.

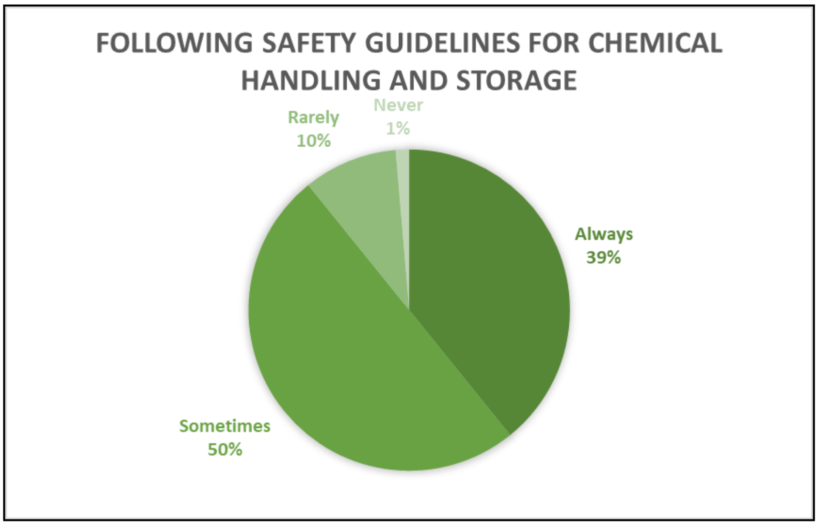

Fig. 2 Result of following safety guidelines for chemical handling and storage

Based on the Fig. 2, 39% of the respondents always refer to established procedures and safety precautions when handling and storing chemicals in laboratory. Then, 50% of the respondents refer to established procedures and safety precautions for certain times. However, there are a few respondents which are rarely and never refer to established procedures and safety precautions when handling and storing chemicals in the laboratory which are 10% and 1% respectively.

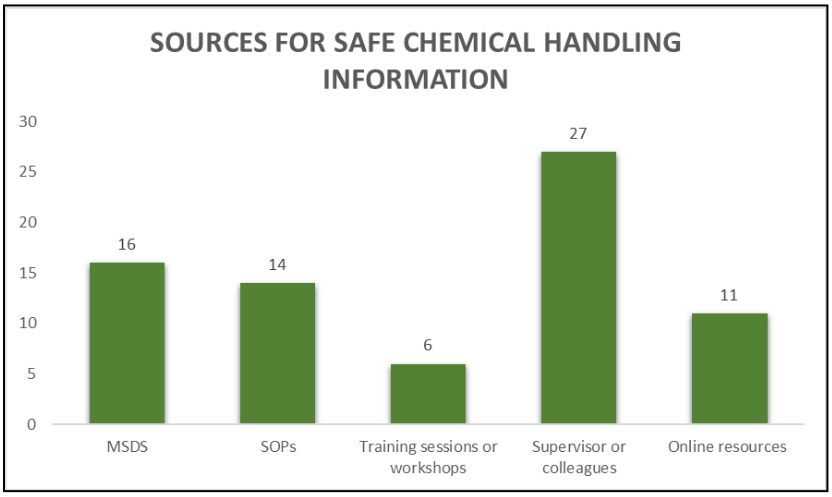

Fig. 3 Analysis of sources for safe chemical handling information

Fig. 3 shows that supervisors or colleagues is the majority respondents' sources for safe chemical handling information which is 27 out of 74. Next, followed by Material Safety Data Sheet (MSDS) and standard operating procedures (SOPs) which is 16 and 14 respondents chose it as their sources respectively. Then, online resources also one of their sources for safe chemical handling information which has 11 respondents. Lastly, 6 out 74 respondents joining training sessions or workshops as their sources for this.

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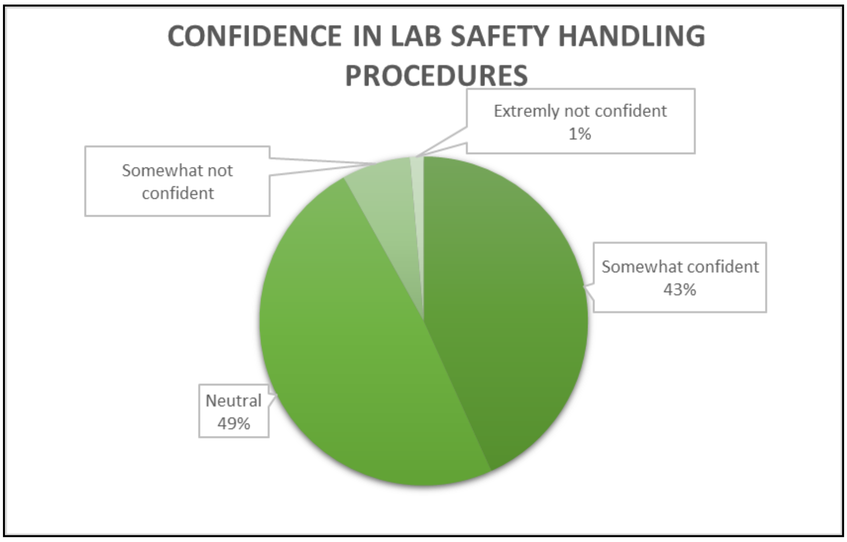

Fig. 4 Analysis of level confidence in lab safety handling procedures

Referring to the Fig. 4 above, the pie chart shows the level of confidence in lab safety handling procedures. Majority of the respondents' level of confidence are neutral which is 49%. It indicates a balanced perspective. Next, 43% are somewhat confident which means they feel reasonably assured but acknowledge some room for improvement. However, some of the respondents are somewhat not confident (7%) and extremely not confident (1%). This shows that the respondents have a very basic understanding and some of them are lack of confidence in a laboratory setting.

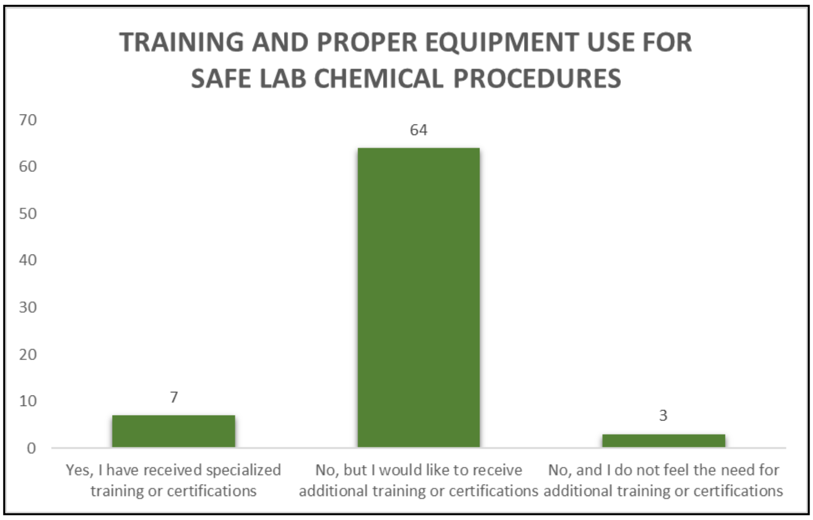

Fig. 5 Result of training and proper equipment use for safe lab chemical procedures

Fig. 5 displays 64 out 74 respondents do not have well training but openly want to receive additional training or certifications as their improvement. Then, 7 of them have received specialized training or certifications while the other 3 do not have well training and certification but do not need for other additional training or certifications.

3.3 Friedman Test

This section examines the factors that affect the waste of chemical in Section C. Hypothesis statements are formed before starting the Friedman test. Accepting or rejecting the null hypothesis are depending on the value of asymptotic (p-value).

Here is the hypothesis for Friedman test:
H_0: Ranking of factors has no significant influences that affect waste of chemical.
H_1: Ranking of factors has significant influences that affect waste of chemical.

Table 3 : Result of Friedman test

Statements	Mean Ranking
Lack of proper training (F1)	2.15
Poor measurement and dispensing (F2)	3.92
Improper storage and handling (F3)	4.67
Inefficient equipment (F4)	6.21
Overstocking and expiry (F5)	6.38
Inadequate planning and batch sizes (F6)	6.81
Inadequate record keeping (F7)	6.89
Environmental factors (F8)	8.03
Regulatory compliance (F8)	8.35

Table 3 illustrates the mean rankings obtained from the Friedman test for various factors. The ranking scale ranges from 1 (most attractive) to 9 (least attractive). F1 which is lack of proper training emerges as the predominant factor influencing chemical waste at UTHM, securing the lowest mean ranking of 2.15 among the nine factors. Subsequent rankings are F2 (3.92), F3 (4.67), F4 (6.21), F5 (6.38), F6 (6.81), F7 (6.89), and F8 (8.03). Notably, F9 which is regulatory compliance is identified as the least impactful factor on chemical waste, with the highest mean ranking of 8.35. This suggests that regulatory compliance may have minimal influence on chemical waste.

3.4 The Chi-square Test and Cramer's V Analysis

This method used to identify the association and the strength between proficiency in understanding in chemical usage with practices that can prevent waste. Here is the hypothesises on Chi-square and Cramer's V:
H_0: There is no association between proficiency in understanding about chemical usage and practices to prevent chemical waste.
H_1: There is an association between proficiency in understanding about chemical usage and practices to prevent chemical waste.

Table 4 : Analysis of Chi-square test and Cramer's V test

Statements	p-value	Cronbach's Alpha
Maintain an accurate inventory (S1)	0.002	0.176
Proper handling and usage (S2)	0.001	0.184
Correct dilution and mixing (S3)	0.003	0.218
Proper storage and shelf (S4)	0.015	0.147
Accurate measurement (S5)	0.001	0.183
Safety Data Sheet (S6)	0.007	0.155
Waste disposal regulation (S7)	0.001	0.209
Training and education (S8)	0.001	0.185

The Cramer's V results reveal in Table 4 is range between 0.147 and 0.218 for the eight statements. Cramer's V falling within the 0.10 to 0.20 range suggests a weak association between the variables. Statements S1, S2, S4, S5, S6, and S8 demonstrate a weak association with respondents' proficiency in understanding chemical usage. Conversely, statements S3 and S7 exhibit a moderate association with proficiency, as their Cramer's V falls within the 0.20 to 0.40 range. This indicates a connection between understanding chemical usage proficiency and the adoption of practices for chemical waste prevention. The varying levels of proficiency among respondents may influence their commitment to waste prevention measures.

3.5 Spearman's Rank Correlation Test

This section is investigating about the correlation between practices that can prevent waste in Section D. The hypotheses are developed as below:
H_0: There is no correlation between the eight practices that can prevent waste of chemical.
H_1: There is a correlation between the eight practices that can prevent waste of chemical.

Table 5 : Analysis of Spearman's Rank correlation test

	S1	S2	S3	S4	S5	S6	S7	S8
S1	1	0.59	0.557	0.753	0.615	0.702	0.574	0.695
S2	0.59	1	0.882	0.541	0.765	0.511	0.69	0.618
S3	0.557	0.882	1	0.513	0.847	0.441	0.711	0.62
S4	0.753	0.541	0.513	1	0.678	0.826	0.622	0.813
S5	0.615	0.765	0.947	0.678	1	0.594	0.626	0.765
S6	0.702	0.511	0.441	0.826	0.594	1	0.637	0.737
S7	0.574	0.69	0.711	0.622	0.626	0.637	1	0.643
S8	0.695	0.618	0.62	0.813	0.765	0.767	0.643	1

The correlation results in Table 5 indicates a positive association among the practices aimed at preventing chemical waste. Specifically, there is a low positive correlation between S3 and S6. Moreover, moderate positive correlations exist between various pairs, including S1 and S2, S1 and S3, S1 and S5, S1 and S7, S1 and S8, S2 and S4, S2 and S6, S2 and S7, S2 and S8, S3 and S4, S3 and S8, S4 and S5, S4 and S7, S5 and S6, S5 and S7, S6 and S7, and S7 and S8. Notably, high positive correlations are observed for S1 and S4, S1 and S6, S2 and S3, S2 and S5, S3 and S5, S3 and S7, S4 and S6, S4 and S8, S5 and S8, and S6 and S8. The correlation analysis highlights the interrelated nature of practices aimed at preventing chemical waste. Notably, we observe varying degrees of correlation between different pairs of practices, ranging from low to high positive associations. These findings emphasize the complexity of factors influencing waste prevention strategies. Understanding these correlations can guide targeted efforts in promoting sustainable practices and minimizing chemical waste in various contexts.

4. Conclusion

Some conclusions are summarized based on the analysis of the result. Based on the first objective, a comprehensive review of procedures, knowledge, and safety precautions offers important insights into accomplishing the goal to evaluate laboratory safety with reference to chemical exposure. The results of the survey show that respondents have a respectable degree of awareness, and most of them said they would be willing to learn more about handling chemicals. The results highlight how crucial it is to keep learning and refining laboratory safety procedures. The most significant conclusion of the survey is how strongly respondents desired further training or credentials. This proactive approach to skill development is consistent with the larger goal of creating a safer laboratory environment and shows a dedication to ongoing improvement.

Next, second objective has been achieved which reveals that the lack of proper training is the most prominent factor contributing to chemical waste, securing the lowest mean ranking. This indicates that addressing training gaps is crucial in mitigating chemical waste at UTHM. The study concludes by highlighting the vital role that procedures and training play in reducing chemical waste at work. Reducing waste can be significantly improved by giving priority to fixing training gaps and improving handling procedures. Furthermore, the finding that regulatory compliance has a less significant effect raises the possibility of reevaluating and possibly improving methods for bringing practices into meeting regulations. Overall, organisations can significantly reduce chemical waste by concentrating on focused interventions linked to handling procedures and training.

To sum up, the examination of knowledge on the use of chemicals and procedures meant to avoid chemical waste offers important information about how these elements relate to one another in the workplace. So that the last objective highlights the significance of modified interventions that take advantage of individual proficiency levels and address the interrelated nature of waste prevention activities in order to achieve the goal of analysing chemical safety and awareness to prevent chemical waste. Workplaces that are more environmentally friendly and waste-conscious can benefit from the implementation of thorough training programmes and the promotion of a holistic approach to chemical safety.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Nor Hanani Zakaria, Shuhaida Ismail;* ***data collection:*** *Nor Hanani Zakaria, Shuhaida Ismail;* ***analysis and interpretation of results:*** *Nor Hanani Zakaria, Shuhaida Ismail;* ***draft manuscript preparation:*** *Nor Hanani Zakaria, Shuhaida Ismail. All authors reviewed the results and approved the final version of the manuscript.*

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