CHEMISTRY STUDENTS' KNOWLEDGE AND PRACTICES OF CHEMICAL WASTE MANAGEMENT IN CHEMISTRY LABORATORIES

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ABSTRACT

The study investigated chemistry students' knowledge and practices of chemical waste management in chemistry laboratories in a higher educational institution in Ghana. Descriptive survey design was employed, and the stratified sample comprised of 93 chemistry major students who were selected from levels 100, 200 and 300 in University of Education, Winneba. Questionnaires and unstructured interview were used to collect data which were then analyzed by descriptive statistics (mean and standard deviation) and inferential statistics (t-test and correlation). The results revealed students' good knowledge of, yet poor practices of chemical waste management in the various chemistry laboratories. The t-test conducted revealed a statistically significant difference ($p=0.000<0.05$) in students' knowledge and practices of chemical waste management in the school's chemistry laboratories. Also, a Pearson correlation ($r=0.415$) corroborated the finding that students weakly put their good knowledge in chemical waste management into practice. It is recommended for tertiary educational institutions to build a culture of sustainability and environmental protection in accordance with Sustainable Development Goals (SDG 6 and SDG 11) [3] among science students to by encouraging them to put their knowledge about waste management into practice and protect the environment. *[African Journal of Chemical Education—AJCE 13(3), July 2023]*

INTRODUCTION

Educational institutions are engaged in training students in the field of science and this cannot be properly done without laboratory investigations and research from both students and lecturers. The main subject areas that science students read include Chemistry, Physics and Biology. Scientific institutions and educational research activities commonly produce a wide variety of hazardous wastes in relatively small volumes including new materials of unknown toxicity and hazards [1]. These could represent a significant risk to human health and the environment unless it is identified, contained and disposed in accordance with applicable laws, regulations and best waste management practices.

Waste management is the collection, transport, processing, recycling or disposal, and monitoring of waste materials [2]. It usually relates to unwanted materials produced by human activities, and is generally undertaken to reduce their effect on health, the environment or aesthetics as well as resource recovery. Chemical wastes can be solid, liquid, gaseous or radioactive substances which requires different methods and fields of expertise in their management. It is expected that institutions which train young scientist and researchers in science should put in place waste management strategies so that chemical wastes generated do not negatively impact on the environmental compartments such as water, air and soil. According to [3], factors that significantly contribute to waste generation in schools include students' gender ratio, students' awareness level, administrative and staff background.

Waste management practice is a difficult and multidisciplinary activity that requires knowledgeable and innovative practices of implementation, supervision, monitoring and compliance of policies. This implies that institutions, especially tertiary institutions of education must stand for and apply ethical and social responsibility guidelines so as to transmit and build a culture of sustainability and environmental protection in accordance with Sustainable Development Goals (SDG 6 and SDG 11) [3]among its science students; especially chemistry students who deal more with chemical substances.

The environmental impact caused by teaching and research with regard to chemical waste is of increasing concern and attempts to solve the issue must be made consciously and conscientiously. Education and research-related institutions, in most laboratory and non-laboratory activities, contribute to the generation of small quantities of waste, many of which are highly toxic. Some of these activities and wastes are listed by government agencies who are concerned about environmental pollution as detrimental to the planet. A few of these are disposal of acids, metals, solvents, chemicals and selected synthesized toxic products, whose toxicity is often unknown [4]. According to [5], generation and poor management of chemical wastes and their activities in school laboratories, could subtly lead to environmental pollution. The potential risks and hazards caused by such subtle pollution as well as inappropriate management and disposal of liquid wastes could bear directly on users of the contaminated space. In other words, the lack of effective measures to dispose toxic wastes could cause environmental pollution and pose harm to laboratory staff. [6] also stated

that school laboratories consume less chemicals than factories, however, the wide variety of chemicals used in schools increase the complexity of the management, storage and disposal of laboratory chemicals.

In Ghana, most second cycle and third cycle schools run science programs and have laboratories purposely for practical activities. During school laboratory activities, a lot of chemicals with varied toxicity are used and released into the environment. Although, many studies [7]; [8]; [9]) have reported on solid waste management practices in Ghanaian schools, none of them reported on how other laboratory chemical wastes, beside solid waste, are managed. In addition, the population of these educational institutions (Senior High Schools and universities) are increasing just as those who study chemistry and perform laboratory work with chemicals are also increasing. This means that the generation of chemical wastes would invariably increase and so its management practices must be taken into consideration.

[8] opined that the population of educational institutions, especially Senior High Schools in Ghana, is increasing rapidly due to introduction of free Senior High School education by the Government of Ghana. The subsequent increase in the number of students reading science courses which include chemistry at the tertiary level could deepen the already existing problem with management of generated waste laboratory chemicals and their improper or indiscriminate disposal. Furthermore, some school laboratories have become business-oriented and analyses a lot of research samples from industrial to domestic waste for individuals and corporate organizations. [10] asserted

that safety system for laboratory liquid waste disposal has become an important issue in the environmental protection, safety, and hygiene of all universities. It is, therefore, important to assess the waste management practices and management plans in university laboratories and find out about their waste management and sustainability plans. Although there are many universities in Ghana, this study assesses chemistry students' knowledge and practices of chemical management in chemistry laboratories in a teacher training university and possible sustainability plans for their environment and the nation at large.

Objectives of the study

The objectives of the study were to:

i. assess the knowledge of students in a teaching chemical laboratory on management of chemical waste
ii. examine the practice of chemical waste management by students in a teaching chemical laboratory towards sustainability

Hypothesis

Ho_1: There is no significant difference in the knowledge and practice of chemical waste management among chemistry students in chemical laboratory.

METHODOLOGY

Research design

In this study the descriptive survey design was employed. [12], explained that survey research designs are procedures in quantitative research in which investigators administer a survey to a sample or to the entire population of people to describe the attitude, opinions, behaviors, or characteristics of population. According to [11] descriptive research is devoted to the gathering of information about prevailing conditions or situations for the purpose of description and interpretation. The method of research which concerns itself with the present phenomena in terms of conditions, practices beliefs, processes, relationships, or trends invariably is termed as descriptive survey study [12].

The survey design that employed a cross-sectional approach was used in this study because it allowed for comparison of variables at the same time but not desire its cause-and-effect relationships. It also allowed for observation of the sample at both the group and individual levels. It further allowed for quantitative studies. It, however, could not be used to analyse behaviour over time.

Population and sample

The population of the study involved all the science students in University of Education, Winneba (UEW). The target population was all the chemistry students reading chemistry while the accessible population were only chemistry major students. Random sampling techniques was used

to select 93 chemistry major students comprising of 30 level 100, 31 level 200 and 32 level 300 students.

Research Instruments

Questionnaires were administered to provide quantitative data to ensure objectivity, generalisation and reliability [13]. It was used to assess knowledge about the nature of chemicals, storage, waste generation and waste management towards sustainability. The questionnaire which consisted of a set of Likert scaled questions were to obtain candid facts about existing laboratory practices, chemical waste generation, waste management plans and general awareness of effect of chemical waste on ecosystems. In addition, the students' knowledge and practices of chemical waste management were scored for analysis.

An unstructured interview was used to solicit for information which were not captured by the questionnaire.

Validity

In order to ensure that the questionnaire items were valid, it was given to a senior lecturer at the Department of Chemistry Education who assessed to ensure that the items were relevant to the objectives of the study.

Reliability

Reliability of the questionnaire was assessed by using Cronbach's alpha test to determine the internal consistency of the instrument. Poorly constructed items were deleted and some redefined to

avoid ambiguity in understanding and responding to questions. The Cronbach coefficient alpha for items were acceptable (above 0.68) and that implied items were consistent with each other and could together represent construct under study. The reliability coefficients for items on knowledge was 0.70 while that of practice was 0.76. [14] reported that Cronbach alpha coefficient of 0.7 and above is an indication of acceptable reliability. Also, a general accepted rule is that α of 0.6-0.7 indicates an acceptable level of reliability, and 0.8 or greater a very good level [15].

Ethical consideration

Permission was sought from the University and Dean of Science Education for clearance to carry out the research. Student participants were then briefed on the nature of the study so that they could make informed decisions on their participation or otherwise. After the briefing, consent forms were given to them to sign. Each category of students was engaged with at different times to avoid intimidation and allow freedom of interaction with the researchers at a briefing session.

Data analysis

The administered questionnaires were all collected and analysed using Statistical Package for Social Science (SPSS) version 25 [16]. Descriptive statistics such as mean and standard deviation were used to analyse and bring meaning to data collected. Also, inferential statistics such as t-test and Pearson correlation were used to establish relationship between students' knowledge and practice of chemical waste management.

RESULTS

Presented in Table 1 is a summary of the demographic information of the student respondents.

Table 1: Demography of student respondents

s/n	Variable	Frequency	Percentage (%)
1	**Age**		
	15-20	8	8.6
	21-25	43	46.2
	26-30	28	30.1
	31-35	14	15.1
2	**Sex**		
	Male	71	76.3
	Female	22	23.7
3	**Level**		
	100	30	32.3
	200	31	33.3
	300	32	34.4

Table 1 shows that 8 (8.6%), 43(46.2%), 28(30.1%) and 14(15.1%) of the respondents were aged between 15-20, 21-25, 26-30 and 31-35 respectively. Among the student respondents 71(76.3%) were male while 22(23.7%) were female. The number of respondents in level 100 were 30 (32.3%), level 200 were 31(33.3%) and level 300 were 32(34.4%).

Students' responses to the items on knowledge of chemical waste management in the laboratory were summarized into means and standard deviations. These have been presented in Table 2.

Table 2: Knowledge of Science Students on Chemical Waste Management in the Laboratory

s/n	Statement	Mean	SD
4	Containers used for the accumulation of hazardous waste should be in good condition and free of leaks	2.94	0.27
5	A waste accumulation container should be opened only when it is necessary to add waste, and should otherwise be capped.	2.89	0.40
6	Hazardous waste must not be placed in unwashed containers that previously held incompatible materials.	2.69	0.59
7	Waste containers must be compatible with chemical wastes placed in them (for example, acid should not be stored in metal cans).	2.87	0.42
8	Waste containers must be properly labeled	2.95	0.27
9	Proper waste categorization can help avoid unnecessary, inappropriate, and costly waste handling, treatment, storage and disposal.	2.89	0.31
10	It is possible to convert a laboratory procedure to a micro-scale method that uses significantly less sample and reagents.	2.55	0.62
11	Procurement of hazardous material should be initiated only if a non-hazardous substitute is not available	2.42	0.72
12	Good laboratory record keeping and labeling of all chemicals and chemical wastes containers help to prevent accidents, like explosions.	2.91	0.41
13	Any chemical material that is potentially recyclable should not be contaminated with other chemicals for disposal.	2.90	0.33
	Mean of means	2.81	0.43

From Table 2, the students scored a mean of 2.94 (SD=0.27)) to agree that chemical containers used for accumulation of hazardous waste should be in good condition and free from leaks. They agreed (mean=2.89; SD=0.40) that hazardous waste containers must be opened only when it is necessary to add waste and should be capped. Students scored means of 2.69(SD=0.59) and 2.87(0.42) to agree that chemical waste must be compatible with their containers and other chemicals waste substances respectively. The students agreed (mean=2.89; SD=0.31) to proper waste categorization and agreed (mean=2.55; SD=0.62) that in the teaching laboratory a macro-scale activity can be converted to a micro-scale method so as to use less reagents and sample. The

respondent did not know or were not sure (mean=2.42; SD=0.72) that in procurement of chemicals, hazardous materials are initiated only when a non-hazardous substitute is not available. They agreed (mean=2.90; SD=0.33) that good laboratory record keeping and labeling of all chemicals and chemical wastes containers help to prevent accidents, like explosions and were knowledgeable (mean=2.9; SD=0.33) on the fact that any chemical material that is potentially recyclable should not be contaminated with other chemicals for disposal. The mean of means (mean=2.81; SD=0.43) shows that students have good knowledge on chemical waste management in the laboratory.

DISCUSSION

The knowledge of science students who generate chemical wastes was assessed and the results indicated that they have good knowledge on chemical waste management. From Table 2, the mean of means for students' responses to items which assessed their knowledge was 2.81 (SD=0.43). The mean score indicated that chemistry students agreed to have good knowledge on chemical waste management practices in their laboratories. The small standard deviation is an indication of chemistry students' consistency to demonstrate high knowledge in chemical waste management since most of them scored 2.8 or a value closer to this to agree on having good knowledge. This was confirmed by the mean score (mean=8.33; SD= 1.84) that they obtained relating to their knowledge in chemical waste management. They agreed that chemical containers used for accumulation of hazardous waste should be in good condition and free from leaks, chemical waste must be compatible

with their containers, chemical waste containers must be properly labeled to facilitate waste segregation in the laboratory and micro scale laboratory work are encouraged in teaching laboratories to minimize chemical waste that get into the environment. They added that chemical waste that can be recycled should not be contaminated to enhance reuse of materials in chemical laboratories and agreed that good laboratory record keeping and labeling of all chemicals and chemical wastes containers help to prevent accidents, like explosions. The importance of having good knowledge on chemical waste management is to promote sustainable development.

Human actions are at the heart of environmental issues and sustainable development ultimately depends on knowledge and behavior changes [17]. Students' good knowledge on chemical waste management protect them from explosions and other harm due to improper waste management in the laboratories. Also, this knowledge helps to protect fishes and other aquatic organisms who are mostly affected when chemical waste gets into water bodies. Similarly, [18] opined that good knowledge on waste management practices contribute to economically viable and ecologically sustainable human future. This study contradicts the findings of [17]who reported that teachers in training lack knowledge regarding waste management. As in industries, the universities have started to worry about the wastes generated in their teaching and research activities, since they are composed by a great variety of substances, potentially toxic and harmful, which should go through adequate treatment before being disposed, aiming to avoid environmental problems and contamination of living beings [19]. The respondents, however, did not know that procurement of

hazardous material should be initiated only if a non-hazardous substitute is not available. This means that when they are working in the laboratory any chemical appropriate for the task can be used regardless of its toxicity.

Students' responses to items that sought to assess their chemical waste practices in the laboratory were analyzed using descriptive statistics (computed into means and standard deviations) and presented in Table 3.

Table 3: Science Students' Chemical Waste Management Practices in the Laboratory

s/n	Statement	Mean	SD
14	Certain used organic solvents are distilled and reused in the laboratory.	2.27	0.81
15	Hazardous analytical reagents are replaced with non-hazardous reagents	2.32	0.82
16	Glassware and some disposable equipment are often decontaminated and re-used	2.58	0.79
17	Chemical waste containers are picked up and the waste disposed of regularly at the laboratory premises	2.57	0.78
18	Chemical wastes that have the potential to react with each other are not placed in the same container	2.80	0.52
19	Chemical wastes generated in the laboratory are disposed of into the sink.	2.68	0.63
20	Chemical wastes (especially expired chemicals) are disposed with the help of Environmental Protection Agencies (EPA)	2.65	0.58
21	Chemical waste disposal is in compliance with EPA regulations	2.67	0.54
22	Chemical stocks are rotated (first in, first out) in the laboratory to help avoid expiration.	2.61	0.55
23	Wastes generated in the laboratory are segregated according to the hazard class and packed into cardboard boxes.	1.48	0.57
24	Certain hazardous chemical wastes are rendered non-hazardous by specific neutralization or deactivation laboratory procedures.	1.40	0.62
	Mean of means	**2.37**	**0.66**

From Table 3, the students were not sure (mean=2.27; SD=0.81) whether certain used organic solvents are distilled and reused in the laboratory. They were not sure (mean=2.32; SD=0.82)

hazardous analytical reagents are replaced with non-hazardous reagents. The students however agreed (mean=2.58; SD= 0.79) that glassware and some disposable equipment are often decontaminated and re-used in their laboratories. Again, they agreed (mean=2.57; SD=0.78) that chemical waste containers are picked up and disposed of regularly at the laboratory premises and also agreed (mean=2.80; SD=0.52) that chemical wastes that have the potential to react with each other are not placed in the same container.

Furthermore, the students scored above a mean of 2.5 to agree that they dispose of chemical waste into sinks but mentioned that chemical waste and expired chemicals are disposed in compliance with the Ghana Environmental Protection Agencies (EPA) regulations. Also, they agreed (mean =2.61; SD=0.55) to practice chemical stock rotation (first-in, first-out) in the laboratory to help avoid expiration. In addition, students disagreed that wastes generated in the laboratory are segregated according to the hazard class and packed into cardboard boxes. Also, they disagreed that laboratory procedures such as neutralization or deactivation laboratory procedures are used to render hazardous chemical wastes non-hazardous. The mean of means for practicing chemical waste management was 2.37 (SD=0.67). This suggests that most of the students were not sure or did not know about most of the chemical waste management practices in their laboratories.

The principles involved in chemical waste management system covers waste avoidance, Waste reduction, Waste reuse and Waste disposal. These principles cut across safe waste management practices to ensure the safety of people and the environment. In this study, the students

were not sure about the practice of waste reuse in their laboratory. They were not certain that hazardous chemicals are usually replaced with non-hazardous ones. In effect, chemical waste treatment and reusing of some chemical wastes were not practiced in the school chemistry laboratories. According to [20]students' awareness on the correct conditioning, segregation, and identification of the waste generated in laboratories is an important aspect of chemical waste management plan. In order to ensure green chemistry, science educators should raise awareness of the academic community about the importance of the correct disposal of chemical waste.

The results revealed that some liquid chemical wastes were disposed into sinks. This indicates that chemical contaminant such as heavy metals and acids are frequently introduced into drains and nearby environment. The untreated hazardous wastes disposed into the environment cause potential hazard to human health or the environment (soil, air, and water) when it is poorly managed. This practice does not enhance sustainable chemistry.

Chemical stock rotation (first-in, first-out) in the laboratory is very vital to reduce the amount of chemical waste that expires and are discarded. This practice is in line with waste prevention strategy employed in waste management. Waste prevention and waste reuse are important practices that ensures green chemistry. Preventing the use of excess materials, reusing materials, recycling, and buying recycled-content products reduce a school's impact on the environment by saving energy, mitigating climate change by reducing greenhouse gas emissions, reducing the need for raw materials to make new products, and decreasing the amount of material put into landfills. It is

importance for schools to broaden the adoption of green principles in academics by training the next generation of chemists to prioritize green and sustainable practices in their undergraduate and post graduate laboratories [21].

The students indicated that waste segregation was not practiced based on hazard class of chemicals. In a follow-up interview, the students mentioned that waste segregation practiced was only to separate waste into either solid or liquid waste. This type of waste segregation can result in laboratory accidents in situations where two or more solid or liquid chemical wastes can react violently. Similarly, [22] asserted that incorrect classification and overlooked compatibility of chemicals can lead to follow-up hazards and threaten the safety of the campus. In addition, it does not enhance recycling of laboratory waste which are plastics and papers. In order to ensure sustainable waste management practices in schools, segregation of waste should be considered as scientific and social responsibility of all the teachers, staff and students working in any laboratory using chemicals. Also, all the teachers, entire laboratory staff and students should be trained to carry out waste segregation in designated waste containers with appropriate labelling. The lack of effective measures of disposal of hazard wastes may cause environmental pollution and pose harm to laboratory staff and users [10].

In addition, neutralization or deactivation laboratory procedures were not practiced in the school's chemistry laboratories. This suggests that chemical waste do not receive any treatment before they are discarded. The lack of standard operational management, and relevant disposal

channels of chemical waste can cause secondary pollution to the environment [23]and mitigate the achievement of the United Nations sustainability goals (SDGs 6 and 11) by the set attainment date [3]

Ho_1: There is no significant difference in the knowledge and practice of chemical waste management among patrons in teaching chemical laboratory.

A t-test was used to compare the means of students' scores on their knowledge of chemical waste management to their practices of chemical waste management in order to respond to the null hypothesis. The results are presented in Table 4.

Table 4: t-test comparison of students' knowledge and practice of waste management

Item	N	Mean	SD	t- value	p-value	r- value
Score on knowledge	93	8.45	1.72	47.14	0.00	0.415
Score on practice	93	6.56	2.83	22.36		

The mean score of students' knowledge in chemical waste management was 8.45 (SD =1.72) while that of their practice was 6.56 (SD = 2.83). The small standard deviation obtained for knowledge indicates that most of the students obtained scores close to this mean value and hence were consistent with having good knowledge on chemical waste management than how they practice it. A t-test conducted revealed a significant difference ($p=0.000<0.05$) in students' knowledge and practices of chemical waste management in school laboratories. It suggests that a student may have good knowledge in chemical waste management but how it is put into practice is poor. The null hypothesis is therefore rejected. Pearson correlation revealed that students weakly (r=0.415) put their

good knowledge in chemical waste management into practice. The inability of students to properly practice waste management makes the environment susceptible to pollution and hence, is a concern for both environmental and public health. In order to achieve quality water supply, protect life under water, ensure food security, and promote the attainment of sustainable development goals, efforts should be made to inculcate into students the proper ways of managing chemical waste both at home and in school.

CONCLUSION

The practice of chemical waste management by students in their chemistry laboratories does not reflect on the good knowledge they have in chemical waste management. It is important for educational institutions, in this regard UEW to provide all needed materials and support to students at all levels of education to enhance proper practices of chemical waste management to protect our environment. It is, therefore, recommended that educational institutions particularly at the tertiary level must build a culture of sustainability and environmental protection in accordance with Sustainable Development Goals (SDG 6 and SDG 11) [3] among its science students; especially chemistry students who deal more with chemical substance to facilitate achievement of the SDG goals.

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