Chemistry Laboratory Waste Management Practices of Selected Universities and Colleges in Batangas City, Philippines

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Abstract – *Proper laboratory waste management is vital not only of manufacturing industries or testing laboratories but also for academic institution. Academic institutions that commonly operates chemistry laboratory where basic and specialized experiments and exercises are conducted. This study aimed to look into the chemistry laboratory waste generated and the waste management practices of the selected universities and colleges in Batangas City, Philippines. The researchers utilized survey, key informant interview and focus group discussion in the conduct of the study. Results showed that the amount of hazardous wastes generated from chemistry laboratory was 1-10 liters/year of liquid hazardous waste such as acid and alkali wastes, less than 1 liter/year of other liquid wastes such as plating liquid wastes and less than 1 kg/year of hazardous solid wastes. For the management of hazardous wastes in chemistry laboratory, the collection practices were employed to the great extent. Hazardous wastes such as acid, alkali, oxidizing agents, organic wastes were placed on separate collection bottles; excess liquid chemicals were placed in labeled containers while excess solid chemicals were stored in labeled containers. Source reduction through minimization or non-usage of carbon tetrachloride, chloroform and other toxic organic chemicals was employed to the great extent in chemistry laboratory. Treatment of hazardous waste in the chemistry laboratory such as neutralization of acids and bases was employed in a great extent while encapsulation of inorganic residues was employed to a least extent. Waste management practices employed in chemistry laboratory to a least extent require considerable attention.*

Keywords*:* *chemistry laboratory, waste management, hazardous wastes*

INTRODUCTION

Laboratory experiments contribute to a thorough understanding of concepts. This is based from the pragmatic theory that states that one learns by doing. Precisely, this is the rationale why students are required to try out for themselves activities that involve the use of liquid and solid chemical reagents and the apparatus, equipment and tools.

However, when experiments are conducted in the laboratory it is always accompanied with generation of wastes. Everyday generation of small amount of wastes may lead to accumulation. Such accumulation of chemical wastes from laboratory exercises or experiments may pose threat to human health and safety as well as to environment degradation when not properly managed.

Beeson cited an incident in a laboratory when smoldering boxes of hazardous wastes were improperly stored and disposed producing noxious smoke. Inside the box were 30 different chemicals including cyanide and pharmaceutical narcotics. According to the investigator, the mixed chemicals forming volatile substance was like a bomb waiting to go off.

Another incident happened in high school chemistry in Rogersville TN, United States when old chemical wastes that were loaded into a pickup truck for disposal caught fire and exploded [2].

In the University of Sto. Tomas, hazardous wastes from their laboratories threaten their foremost landmark – the 81 year old main building from corrosive effects of chemicals. These were caused by organic wastes and acid solutions thrown in the sink used during the experiments [3].

In Batangas City, an incident of chemical spill happened at a sugar factory and a shipyard that use similar chemicals commonly used in chemistry classes in school, thus, the danger is just the same. Since science laboratories of schools and universities produce

diverse wastes though in small quantities but in frequent generation, the amounts may cause direct or indirect negative impact on human beings, plants, animals, properties and environment as a whole.

OBJECTIVES OF THE STUDY

This study aimed to determine the common wastes generated and the waste management practices employed by the laboratory personnel in the chemistry laboratory of selected universities and colleges in Batangas City.

METHODS

The study utilized a descriptive research design using researcher-made validated questionnaire as the main data gathering tool. Focus group discussion and interviews were also conducted.

Respondents of the Study

The respondents of the study were the chemistry instructors and laboratory personnel of the five selected universities and colleges in Batangas City. A total of 56 respondents were involved in the study.

Data Gathering

The researchers utilized survey, key informant interview and focus group discussion in the conduct of the study.

The questionnaire used in the survey was composed of two parts. Part I dealt with the volume of waste generated and Part II dealt the responses on the extent of the waste management practices of the respondents. A scale of 1 to 5 where 1 refers to least extent and 5 for great extent was used in the study.

Key informant interview and Focus Group Discussion (FGD) were conducted to substantiate the data gathered from the survey. All respondents were invited but only those who were available attended. Guide questions were prepared to ensure the smooth conduct of the activity. Request Letters were signed by proper authorities before the conduct of any research activity. Consent of the respondents was also sought after explaining to them the purpose of the study. Relative frequency, weighted mean and One-way Analysis of Variance (ANOVA) were used in analyzing and interpreting the results of the gathered data.

RESULTS AND DISCUSSION

Common Wastes Generated from Chemistry Laboratory

The common wastes generated from Chemistry laboratory were categorized by the researchers into hazardous and non-hazardous wastes and assessed by the respondents in terms of the approximate rate or amount of waste generated.

The following table presents the assessment of the respondents on the amount of waste generated from the Chemistry laboratories in Batangas.

Table 1 presents the assessment of respondents on the amount of waste generated from chemistry laboratory.

Table 1. Amount of Wastes Generated From Chemistry Laboratories in Batangas

Wastes	WM	VI
Liquid		
Hazardous		
Plating wastes (waste with cyanide)	1.18	<1liter/year
Acid wastes (e.g. sulfuric; hydrochloric; nitric acid; etc.)	1.74	1-10 liters/year
Alkali wastes (e.g. caustic soda; ammonium hydroxide; potash; etc.)	1.61	1-10 liters/year
Wastes with inorganic chemical (e.g. Barium; lead; mercury & their compounds; etc.)	1.29	<1liter/year
Reactive chemical wastes (e.g. Oxidizing agents; explosives; chemicals; etc.)	1.24	<1liter/year
Paints/Resins/Latices/Inks/Dyes(aqueous based; solvent based; ink formulation)	1.26	<1liter/year
Wastes organic solvents (halogenated & non-halogenated)	1.21	<1liter/year
Organic wastes (e.g. wastes with specific non-halogenated toxic organic chemicals; ODS; PCB wastes; etc.)	1.21	< 1liter/year
Non-Hazardous		
Oil	1.45	1-10 liters/year
Liquid cleaning agents (e.g. detergents; soaps; cleaning solutions)	1.71	1-10 liters/year

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Table 1 (cont.) Amount of Wastes Generated From Chemistry Laboratories in Batangas

Wastes	WM	VI
Solid		
Hazardous		
Plating wastes (waste with cyanide)	1.11	< 1kg /yr
Alkali wastes (e.g. caustic soda; ammonium hydroxide; potash; etc.)	1.29	< 1 kg/ yr
Wastes with inorganic chemical (e.g. barium; lead; mercury & their compounds; etc.)	1.08	< 1 kg/ yr
Immobilized wastes (encapsulate wastes, chemically fixed wastes)	0.97	< 1 kg/ yr
Organic wastes (e.g. waste with specific non-halogenated toxic organic chemicals; ODS;PCB wastes; etc)	1.11	< 1 kg/ yr
Non-Hazardous		
Reagent Bottles	1.55	1 – 10 kg/yr
Solid wastes (e.g. filter paper; pH paper; broken glass wares; etc.)	1.68	1 – 10 kg/yr
Solid cleaning agents (e.g. detergent soaps)	1.89	1 – 10 kg/yr

As shown in Table 1, hazardous wastes generated from Chemistry laboratory with largest amount (1-10 liters per year) were alkali and acid wastes. Other hazardous liquid wastes such as plating wastes and wastes with inorganic chemicals, reactive chemical wastes, waste organic solvents, organic wastes and paints, resins, lattices and inks were generated at the amount of <1 liter/year. On the other hand, solid wastes were generated from the Chemistry laboratory at the amount of <1 kg/year.

In the interviews with some of the respondents, they revealed that acids and alkali wastes were generated from experiments in all chemistry subjects while wastes with inorganic chemicals like barium, lead, mercury and their compounds were generated from inorganic and analytical chemistry experiments.

Results showed that small to moderate amount of hazardous wastes were generated from chemistry laboratories in Batangas. These wastes should be properly managed to avoid negative impact on humans, animals, plants and properties.

Alkali and acid wastes which were generated in highest amount are both corrosive and if not properly managed, they might corrode the fixture in the laboratory room and the entire building.

Wastes from inorganic chemicals such as barium, lead, mercury and their compounds were considered toxic. According to [4] exposure to mercury may lead to brain damage while problems in the synthesis of hemoglobin, effects on the kidneys, gastrointestinal tract, joints and reproductive system and acute or chronic damage to the central nervous system are the consequences of exposure to high level lead.

On the other hand, plating wastes such as metal wastes with cyanide which are considered toxic and may pose dangers on groundwater.

Moreover, halogenated organic wastes such as chloroform, carbon tetrachloride and polychlorine biphenyls (PCBs) had negative effect on the atmosphere. These compounds might cause ozone layer depletion. In addition, carbon tetrachloride and PCBs are considered carcinogen.

On the other hand, solid nonhazardous waste such as reagent bottles, solid waste and cleaning agents were generated at higher amount of 1-10 kg/ year while liquid non-hazardous wastes such as oil and liquid cleaning agents were generated at the rate of 1-10 liters/ year. These wastes should be managed properly to avoid negative effects.

Waste Management Practices Employed in the Laboratories

The waste management practices in chemistry laboratory employed by the respondents in terms of collection, source reduction, reuse, recycling, treatment and final disposal were also determined.

Table 2 shows the assessment of the respondents on the waste management practices employed in the Chemistry laboratory in terms of collection. The table revealed the proper hazardous waste collection practices described in [5] were employed to a great extent by the respondents. This implies that the respondents employed proper waste collection practices. Results further indicate that the respondents were aware and knowledgeable on the proper collection practices of hazardous and non-hazardous wastes that were generated in their respective laboratories.

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Table 2. Waste Collection Practices in Chemistry Laboratories

Collection Practices	WM	VI
Hazardous		
Acid, alkali, oxidizing agents, organic wastes are placed on separate collection bottles.	3.84	Great Extent
Excess liquid chemicals are placed in labelled containers.	4.08	Great Extent
Excess solid chemicals are placed in labelled containers.	4.11	Great Extent
Composite Mean	**4.04**	**Great extent**
Non- Hazardous		
Broken glasswares are placed in a designated container.	4.11	Great Extent

Table 3. Source Reduction Practices in Chemistry Laboratories

Source Reduction Practices	WM	VI
Hazardous		
Carbon tetrachloride, chloroform and other toxic organic chemicals are minimized/ prevented in usage.	4.16	Great Extent
Mercury-containing apparatus like thermometer are substituted with alcohol-based apparatus.	3.61	Great Extent
Microscale experiments or similar techniques are used.	3.76	Great Extent
Classroom demonstration instead of individual-based experiment is used for those experiments that utilize hazardous chemicals.	3.61	Great Extent
Interactive teaching software and demonstration videos, in place of experiments that generate large amounts of chemical wastes are used.	2.84	Moderate Extent
Chemical exchange is practiced wherein chemicals no longer in use or in excess of one school can be used by other schools, or in case of schools with extension campuses, by their other campuses.	2.34	Least Extent
Composite Mean	**3.4**	**Moderate extent**
Non-Hazardous		
Microscale experiments or similar techniques are used.	3.76	Great Extent
Interactive teaching software and demonstration videos, in place of experiments that generate large amounts of chemical wastes are used.	2.84	Moderate Extent
Chemical exchange is practiced wherein chemicals no longer in use or in excess of one school can be used by other schools, or in case of schools with extension campuses, by their other campuses	2.34	Least Extent
Composite Mean	**2.98**	**Moderate Extent**

Table 3 shows the source reduction practices employed by chemistry instructors and laboratory personnel from different colleges and universities in Batangas City. As revealed in the table, some of the proper waste management practices described in [6] were employed in the Chemistry laboratory to the great extent.

This indicates that respondents were aware and knowledgeable of the negative effects of carbon tetrachloride, chloroform mercury and other toxic chemicals. This was the reason why they practiced waste reduction. According to [7], waste reduction is prevention of future hazardous waste problem. The use of alcohol based thermometer / apparatus prevented possible release of mercury in the environment. Micro scale experiments and class room demonstration could reduce material consumption and waste which were generated from three to five times depending on the size of laboratory class.

Based on FGD, the use of interactive teaching software and demonstration video was limited due to inadequate facilities in the colleges and universities in Batangas City. On the other hand, to facilitate chemical exchange among schools and universities, a network among chemistry laboratories should be established as suggested by the respondents.

On the other hand, for non-hazardous wastes, microscale experiments or similar techniques was employed to a great extent.

Table 4 presents the waste management practices employed by the respondents in terms of recycling. The data from the table revealed that recycling practices were employed to a least extent.

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Feedbacks from the FGD participants show that limited employment of recycling practices was due to inadequate training on this technique and lack of facilities for glass blowing.

Table 4. Recycling Practices in Chemistry Laboratory

Recycling Practices	WM	VI
Chemistry		
Non-Hazardous		
Broken glasswares are converted into microscale apparatus through glass blowing.	2.32	Least Extent
Hazardous		
Used solvents are redistilled	2.13	Least Extent
Composite Mean	**2.22**	**Least Extent**

Table 5 presents the waste management practices employed by the respondents in terms of reuse. Reuse is a waste minimization measure which involves the direct reuse of a waste material in its original or slightly altered form, which helps extend the life of that material. The reuse option saved the cost of buying new materials and products and reduced the amount of waste generated. It generally required a little more effort than the reduction measure.

Table 5. Reuse Practices in Chemistry Laboratory

Reuse Practices	WM	VI
Non-Hazardous		
Used reagent containers are utilized as reagent bottles.	3.79	Great Extent
Large used reagent containers are utilized as waste bottles.	3.92	Great Extent
Composite Mean	**3.44**	**Moderate extent**

As shown in Table 5 tertiary colleges and universities in Batangas employed reuse of non-hazardous wastes to a great extent.

Table 6 presents the waste management practices employed by the respondents in terms of treatment. This waste management practice is applicable only to hazardous wastes since non-hazardous wastes do not require treatment prior to disposal.

As shown in the table, neutralization of acids and bases was employed to a great extent with weighted mean of 3.63. While conversion of reactive reagents into non-reactive form and chemical conversion/treatment of wastes to non-hazardous or more stable forms were employed only to a moderate extent with weighted means of 2.92 and 2.74. This indicates that the common treatment practices in chemistry laboratory were employed in colleges and Universities in Batangas.

Table 6. Treatment Practices in Chemistry Laboratory

Treatment Practices	WM	VI
Hazardous		
Acids and bases are neutralized.	3.63	Great Extent
Reactive reagents are converted into non-reactive form.	2.92	Moderate Extent
Metal ions are treated by precipitation and adsorption in activated carbon.	2.47	Least Extent
Chemical conversion/treatment of wastes to non-hazardous or more stable forms is performed.	2.74	Moderate Extent
Inorganic residues are encapsulated.	2.11	Least Extent
Composite Mean	**2.77**	**Moderate extent**

Precipitation and adsorption in activated carbon of metal ions and encapsulation of inorganic residues were assessed to be employed to a least extent. This indicates that respondents were not familiar or capable on these techniques. Encapsulation was done by sealing wastes in a variety of matrices such as organic polymers, resins, fly ash/cement mixtures [8]. At present this was being practiced in DOST-ITDI.

Table 7 shows the waste management practices in terms of final disposal. The employment of final disposal in the chemistry laboratory by the respondents conforms to the proper ways cited in the literature. However, these practices should be further improved to ensure the safety of the school properties, environment and human health.

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Table 7. Final Disposal Practices in Chemistry Laboratory

Final Disposal Practices	WM	VI
Hazardous		
Neutralized acids and bases are disposed into the sink and flushed with plenty of water.	4.03	Great Extent
Toxic wastes are disposed into sanitary landfill.	2.61	Moderate Extent
Professional, licensed hauler/transporters are contacted to ensure appropriate disposal.	2.92	Moderate Extent
Composite mean	**3.19**	**Moderate Extent**
Non-Hazardous		
Non-toxic liquid wastes such as oils are disposed into the sink and flushed with plenty of water.	4.08	Great Extent
Non-toxic solid wastes are disposed into the trash can.	4.24	Great Extent
Collected broken glasswares are disposed in a rigid box that is marked as "broken glasswares".	3.97	Great Extent
Solid chemical wastes are disposed into waste bins as regular trash.	3.42	Moderate Extent
Composite Mean	**3.93**	**Great extent**

CONCLUSION AND RECOMMENDATION

The amount of hazardous wastes generated from chemistry laboratory was 1-10 liters/year of liquid hazardous waste such as acid and alkali wastes, less than 1 liter/year of other liquid hazardous wastes such as plating liquid wastes and less than 1 kg/year of hazardous solid wastes. Non-hazardous wastes like oil and liquid cleaning agents were generated at a rate of 1-10 liters/year. Other non-hazardous wastes like reagent bottles, solid wastes and solid cleaning agents were generated with an average volume of 1-10 kg/year.

The waste management practices in terms of collection and final disposal were employed in the Chemistry laboratory to a great extent, source reduction, reuse and treatment practices were employed to a moderate extent and recycling practices are employed to a least extent.

It can be gleaned from the results that there is a very small portion of wastes being generated from schools and colleges in Batangas City, however, most chemicals need not to be of large volume to be of danger to human and other living organisms.

It is worthy to note also that in the waste minimization pyramid, it is the source reduction practice that should the topmost priority in management, however, it is practiced in moderate extent only, same with treatment, reuse and recycling.

The chemistry teachers and laboratory personnel of Colleges and Universities in Batangas should be trained on recycling, source reduction, enhancing the practices of the instructors and laboratory peruse and treatment techniques to enhance their capabilities on proper waste management practices.

The study did not consider the determination of the compliance to certain laboratory protocols or guidelines. Furthermore, biology, computer and physics laboratory that generate special wastes were not also included, thus, a study on that area is highly recommended.

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