©2022 International Transaction Journal of Engineering, Management, & Applied Sciences & Technologies

ISSN 2228-9860 eISSN 1906-9642 CODEN: ITJEA8

International Transaction Journal of Engineering, Management, & Applied Sciences & Technologies
http://TuEngr.com

Sustainable Solid Waste Management of Teaching and Learning Material at Skills Training Workshop

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Paper ID: 13A13L
Volume 13 Issue 13
Received 23 July 2022
Received in revised form 18 October 2022
Accepted 25 October 2022
Available online 01 November 2022

Keywords:
Engineering; Sustainable; Risk Assessment; Hazard Identification; Green Environment

Abstract

Implementation of skills training in a mechanical workshop at the Skill Training Centers in Malaysia indirectly generates solid waste and needs to be managed properly. The generation of solid waste in this situation consists of hazardous and scheduled waste, and without proper management, it would disrupt the implementation of the training sessions and indirectly contribute to environmental pollution. In this study, the solid waste category was identified, and major components of waste composition and its associated fraction were analysed, then presented in percentage value accordingly. The generated solid wastes were classified and analysed using the Hazard Identification, Risk Assessment and Risk Control (HIRARC) in identifying the potential and severity of hazardous situation occurrences. This study proposed to establish a waste management system for solid waste disposal and Standard Operating Procedure (SOP) as a guide to managing solid waste in the skill training workshop. Ultimately, the proposed sustainable solid waste management system does contribute to the green environment.

Discipline: Skill training Management, Teaching and Learning, Sustainable Solid Waste Management.

Cite This Article:

Mohd Salleh, M.N., Yusoff, N., Mohd Noh, M.H., and MohdAbbas, N. (2022). Sustainable Solid Waste Management of Teaching and Learning Material at Skills Training Workshop. *International Transaction Journal of Engineering, Management, & Applied Sciences & Technologies, 13*(13), 13A13L, 1-15. http://TUENGR.COM/V13/13A13L.pdf DOI: 10.14456/ITJEMAST.2022.263

1 Introduction

National Occupational Skills Standard (NOSS) serves as a guide in skills training to ensure that the output of skills training is competent and meets the needs of the engineering sector industry. Good training management is essential in ensuring the quality of training and ensuring the output of skilled training. The management of solid waste has become a challenging task in recent years, particularly in urban areas as well as rapidly developing cities for developing countries throughout the world (Kathirvale et al., 2004). It is important to identify safe and appropriate solutions for the disposal of solid waste and this has become a big concern for the waste management industry. This indirectly affects the local authorities which need to make the best decision between alternative strategies for sustainable solid waste disposal in the related communities.

For a developing country, 20-50% of the annual budget is allocated for solid waste management; however, the allocation is only sufficient for waste management services for less than 50% population in the cities. In comparison, collection alone in developed countries accounts for 80-95% of overall spending on solid waste, while the figure is much smaller in developed countries, costing less than 10% of the annual budget(Harir et al., 2015).

In Malaysia, municipal solid waste generation and waste management have become a major concern of the government as it affects the environment and public health. Waste compositions, waste generation rate, and people's attitudes towards sustainability of waste management practices are equally important in the solid waste management issue.

For municipal solid waste management, about 80-95% of the collected waste is disposed of at landfill sites. Currently, about 5% of the waste is recycled. Although more than 30% of the waste collected in Malaysia is recyclable, only 5% is retrieved and processed by the service provider. Also, about 45% of the waste produced is organic and biodegradable. Towards the sustainability of solid waste management, one of Malaysia's plans is to adopt the incineration system; however, it is still in the initial stage.

The Government of Malaysia's 8th Malaysian Plan inclusive of urban waste management in Malaysia included waste minimisation, promoting reuse, developing a recycling-oriented and implementing pilot recycling initiatives as part of its key policy agenda for waste management across the country. In the 9th Malaysian Plan, more focus was placed on the continuation of the reduction, reuse, recovery, and recycling of waste, as well as the extension of the use of goods based on environmentally sustainable materials(Anwar Zainu et al., 2017). A more integrated and comprehensive municipal waste management system enhances service quality and encourages productivity (Mei et al., 2016) .

2 Literature Review

2.1 Generation of Hazardous Waste

Waste may generally be characterized as anything left over, unused by-products from agricultural, commercial, domestic, or other operations, or may be represented as surplus to that sector. Waste by-products of large or small businesses, training institutes and even daily activities have the potential of generating waste.

In the industrial industry, waste production will regularly relate to medium-to large-scale producers, as most small non-manufacturing companies still generate hazardous waste. Other than that, a metal processing plant may have hazardous waste generation when cleaning and painting the goods, or a big printer may have hazardous ink waste.

When referring to practical training in skills training content and implementation, waste generation occurs during preparation sessions, execution training sessions and the final process of training. The preparation session of material or specimens for practical training will generate debris and become waste. During the training session, waste has the potential to be generated and at the end of the training session, the product is tested and analysed. Certain products will be kept as reference samples, while most training end products will become waste since there is no further use and urgent need for storage (Akhtar et al., 2015; Paraskevas et al., 2015).

Waste separation at the initial step needs to be accomplished, and the related bins are needed to segregate reusable or recyclable material bins. Several sites or areas will be dedicated to the disposal of significant volumes of waste within the project site to facilitate the sorting of waste for recycling. Any of the products obtained would have value itself in the open market. There may be ways to reuse and recycle aluminum cans and certain containers such as glass bottles, paper, cardboard, pallets, barrels, logs, oils and scrap metal-based materials.

2.2 Metal Based Waste

Metals may broadly be described as ferrous or non-ferrous metals. Ferrous metals are hybrids of iron and carbon, such as cast iron, carbon steel, alloy steel and wrought iron, while non-ferrous metals include aluminum, lead, copper, and zinc. Precious metals such as silver, gold, platinum, iridium, and palladium are in the non-ferrous metal category. Another factor that should be considered in the separation of iron-related solid waste is the size of the solid waste generated. The most common materials used in training workshops are mainly mild steel material based, stainless steel material based, and aluminum material based. The general characteristic listed below briefly describes the properties of iron used for identification (Puangprasert & Prueksasit, 2019).

- Steel and Iron: In terms of weight, steel is commonly one of the cheapest and heaviest metals. To identify it in the easiest way, it will stick to a magnet.
- Copper: Used internally in electrical components. Wire and cable are mostly copper-based material, while heater pipelines and other electromagnets components are based on copper

material. Copper is one of the most valuable metals that can be recycled.

- Aluminum: Physically like steel but aluminum does not stick to magnets like the latter. It is generally used with components that need a material with characteristics of high corrosion resistance and light in weight such as frames for windows, bicycle frame bodies, engine head blocks etc.
- Stainless steel: It contains 70% iron. It is one of the non-ferrous metals but is slightly costly compared to steel since it contains at least 8% nickel. Generally, stainless steel is used in kitchen appliances, automotive and aerospace equipment and other products that need high resistance to corrosion and high strength material base.
- Brass: A combination of zinc and copper which is commonly used in keys, valves, door knobs, etc. This heavy metal has a yellowish colour and becomes greenish when exposed to an open environment for a prolonged period.
- Bronze: Has the proportion of several metals including copper, manganese, zinc, aluminum, and nickel. Bronze has characteristics of high water and corrosion resistance.
- Lead: Industrial properties lead has soft physical attributes, corrosion resistance, excellent malleability, and a relatively poor conductor of electricity.

2.3 Metal Waste Management

Metal waste that is generated needs to be collected and placed according to its category. Therefore, it is critical to collect and segregate the waste according to its category. As such, it is a must to develop a Standard Operating Procedure (SOP) for managing solid waste as a guide to managing solid waste more effectively. In the real world, we are surrounded by metal-based peripherals and products in our daily lives.

As a leading actor in the scrap supply chain, the scrap metal collector is a supplier to scrap dealers. Scrappers offer an invaluable service to ensure that end-of-life metals are gathered and diverted to the recycling stream to be reused. Appropriate guidelines on solid waste management promote a greener environment as well as sustainable income generation (Indrawati & Permata Sari, 2015); (Rick Leblanc, 2021).

3 Method

3.1 Research Methodology Description

This case study research starts by conducting a literature review on skills training. Then, it explains the approach being used to identify the solid waste generated from skills training activities at the workshop according to its categories. Next, it analyses the hazard that may occur in handling or managing those materials by conducting Hazard Identification, Risk Assessment and Risk Control (HIRARC) analysis. A Standard Operating Procedure is established to ensure the procedure for managing the solid waste at the skills training workshop is completed accordingly. As shown in Figure 1, the methodology flowchart to complete this research is presented.

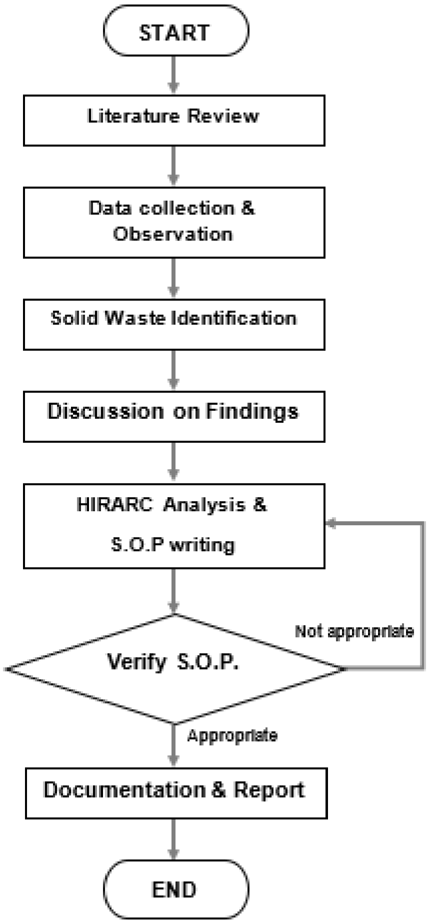

Figure 1: Methodology flowchart.

Solid waste generation from training activities especially in skills training needs to be segregated according to its specific categories. The scope of the study narrows to focus more on skills training in the mechanical field, by referring to welding and manufacturing workshops where solid waste generated is metal-based materials.

Furthermore, observations and analysis of information and findings are made to meet the purpose and objectives of this dissertation. The next chapter states the data and information obtained and the results of the analysis. In closing, this paper concludes by discussing the limitations during which the project is implemented as well as the constraints encountered during the research.

3.2 Data collection and Observation

The main purpose of data and information collection is to achieve the objectives of the study. In obtaining the information, observations in the relevant workshop are implemented for sessions before, during and after related training sessions. The courses involved are long-term and short-term courses.

Observation is one of the processes to obtain information for research conducted in real situations. Training processes in stage preparation, execution and verification have been observed and information related to solid waste generation is recorded for analysis. In addition, a field study was used to examine solid waste management in the study area. The composition of the solid waste generated in the relevant workshops was observed for analysis by HIRARC and S.O.P. in the next stage.

3.3 Solid Waste Identification

As a result of observations on the training process that took place in the workshop, the generation of solid waste was recorded in terms of its characteristics, while the components were weighed, and the readings were recorded. Waste generation patterns and weights are made further observations to obtain their generation patterns.

The main features of solid waste generated are classified into several categories according to the physical factors and metallurgy factors of the waste.

- The size of the solid waste generated in the training process depends on the task and design of the task that needs to be produced.
- The type of solid waste generated in the training process involves the use of basic materials for the workpiece that needs to be welded or processed.

3.4 HIRARC Analysis

HIRARC analysis is vital in mitigating risk and analysing potential accidents that might occur. In conducting HIRARC analysis, the steps, as mentioned below, are followed (Chen & Zhao, 2012); (Buchari et al., 2018) :

- Identify the hazards,
- Evaluate and classify risks categories in terms of low, medium, and high,
- Assess the existing control measures and establish any additional measures that might be necessary.

A table consisting of elements is constructed based on the observations and findings of this study. Initially, hazardous factors for training activities should be identified. Hazard assessments must be made with reference to specific scenarios, such as work processes, related equipment, and machinery as well as and products used in the execution of tasks that have certain potential hazards.

Techniques such as direct observation and interviews have been used to collect information. The risk assessment must be conducted after a hazardous factor has been found, and the risk is further classified in terms of its specific risk categories and current risk categories.

3.5 Hazard Control Measure

Effective controls of hazards will protect personnel from workshop hazards, and prevent injuries, illnesses, disabilities, and unwanted accidents while mitigating or reducing safety and health risks. Indirectly, it would create a balanced and safe working environment. The mechanism to be explained would help to prevent and control the occurrence of the hazard. Referring to the guidelines issued by NIOSH, the evaluation of the control hierarchy is made by referring to the control methods from the most effective to the least effective as the information below:

- Elimination - Equipment or hazardous condition physically removed,
- Replacement - Equipment or hazardous conditions are replaced with other equipment or a safer work environment,
- Engineering Control - Isolating individuals from sources of danger,
- Administrative Control - Change and guide on how to work safely,
- PPE - Use of personal protective equipment.

3.6 Standard Operating Procedure (SOP)

Training conducted in workshops has to comply with the requirement of the National Occupational Skills Standard, NOSS. Therefore, trainees are required to be competent for each element of duty and task as well as pass both knowledge and performance assessments. To equip trainees with specific skills, hands-on training and performance assessment are performed. The basic processes in implementing skills training practice, especially in relation to practical skills training are preparation, execution, and verification stages. In each stage, there is the potential waste generation, and the explanation of the generation of solid waste in each stage of training according to the manufacturing and welding training workshop is presented in Table 1.

Table 1: Waste generation according to training stages.

Training Stages	Waste Generation At Manufacturing And Welding Workshop
Preparation	The remaining balance of the material preparation process. Metal fragments resulting from the process of preparation of training materials. Balance of grinding disc or cutting materials Excess of unused material.
Execution	Metal fragments resulting from the training activities. Metal dust Balance of grinding disc
Verification	Scrap metal Product of training that has been inspected, tested, and evaluated

4 Result and Discussion

In machining and manufacturing-related workshops, trainees must be competent in doing calibration and measurement works initially before proceeding to train that uses hand tools and related machinery such as lathe machine, grinding machine, milling machine, power saw, measurement verification using Coordinate Measurement Machine (CMM) and other related machines. Trainees shall be able to schedule, plan, execute and resolve the system fault in accordance with the required maintenance services and the relevant rules and regulations. Trainees are equipped with skills in machine troubleshooting preparation, troubleshooting activities, repair or replacement work and producing maintenance reports.

In welding-related workshops, trainees must perform various welding techniques such as Shielded Metal Arc Welding (SMAW) or known as Manual Metal Arc (MMA) welding, Gas tungsten arc welding (GTAW) and other welding methods. The trainees are briefed on the preliminary steps before performing the actual welding work. The quality of the welding work performed by the trainees is verified by the instructor.

The implementation of the skills training indirectly contributes to the generation of solid waste in the workshops where practical training sessions are conducted. Therefore, it is vital to manage the waste to avoid negative effects on the training environment as well as the environment.

The main benefit of this study is to improve waste management at training workshops. Initially, the waste generation is observed, recorded, analysed, and classified according to its categories such as type of materials, sizes, and other related categories. HIRARC analysis will give information that will ensure the procedure for managing solid waste at the skills training workshop in proper ways. With this, it will create more environmentally friendly working conditions at the workshop area in particular and the whole institution in general, while a sustainable waste management system helps to reduce the global warming effect thus improving the green environment.

The next section discusses in more detail the stages in the training process that generates solid waste in the workshop as illustrated in Figure 2. It generally shows that there is waste generated in almost every stage of training in the workshop observed. Based on the observations made, the information related to solid waste generation is recorded, analysed and categorized according to the needs of this study. Details of the analysis are described in subheadings that have been divided according to the suitability of the study.

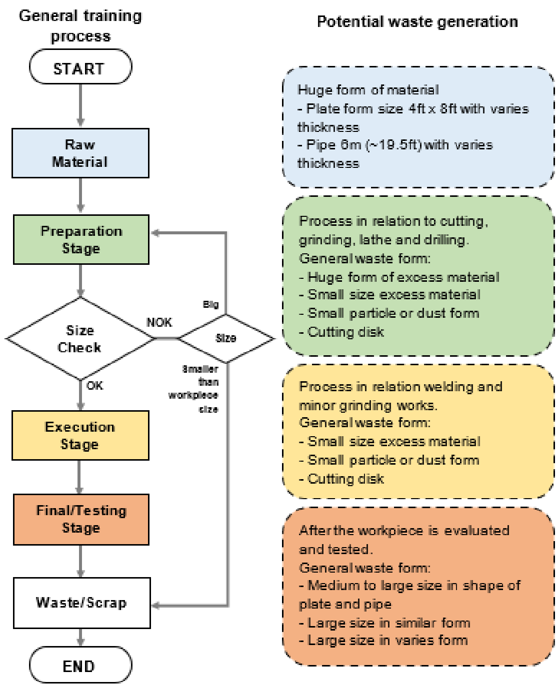

Figure 2: Flow of training process related to solid waste generation.

4.1 Observation on Current Solid Waste Disposal Management

Series of visits and observations were made in the workshop especially in the welding workshop through situation analysis aimed at obtaining information related to the existing solid waste management based on the courses conducted. Based on observations at certain times, solid waste, especially metal-based waste, has been removed and mixed according to its type, size and some of this waste are mixed with other waste. There is also dumping of metal waste in special bins provided as there is no written guideline that can be referenced for better solid waste management. Figure 3 and Figure 4 show the condition of solid waste especially metal based in the workshop during the observation made.

Figure 3: Temporary collection point for solid waste in the workshop.

Figure 4: Steel-based waste mixed with other workshop waste.

4.2 HIRARC Analysis of the Workshop

Based on observations on the relevant processes for the implementation of training, HIRARC analysis is made as each handling of materials or equipment has its potential hazards. For this study, HIRARC analysis is divided into three stages, namely the preparation stage, training implementation stage and verification or final inspection stage. Table 2 shows the sample of

HIRARC analysis of the welding workshop at the preparation stage. Based on the HIRARC analysis, several control measures have been proposed to be implemented as an improvement to reduce the risk of hazards in the workshop while performing tasks involving related machinery and equipment. In conclusion, the selection and use of appropriate PPE is the main step that needs to be emphasized. The work area should be in the appropriate area and the distance between the observer and the work area should be spaced within the appropriate distance. Appropriate signage is necessary especially when doing work involving heat or high temperature while fast movement machines need to be well maintained. Visual inspection is made before operating the machine by ensuring the machine maintenance records are well-updated.

Table 2: HIRARC analysis of the welding workshop based on the preparation stage.

Hazard Identification					**Risk Analysis**			**Risk Control**
No.	Work Activities	Hazard	Which can cause / Effect	Existing risk control	Likelihood	Severity	Risk	Recommended Control Measure
1	Grinding and drilling: Fix on table machine and portable machine	Sharp edges on workpiece	Minor injuries or cut	On machine protecting apparatus Handle machine appropriately according to machine manual Avoid working continuously for a long period of time	3	3	9	PPE: Wear goggle or face shield, appropriate gloves, ear plug and safety footwear Extra precautions especially around pinch points such as drive rolls. Control area and signage when work in progress Periodic inspections on all electrical equipment and update the electrical equipment maintenance records (on equipment) Excess material container
		Small particle (Flying metal or dirt)	Minor injuries or cut Possibility for deep cut Slipped due to small debris on the floor		3	3	9	
		Noise	Hearing damage or loss		4	3	12	
		Continuous vibration	Allows discomfort while working. Bad grip while doing work and it is possible that the hand tools or work tools are loose from the handle		4	3	12	
		Electric current leakage	Electric shocks or burns using damaged devices		2	4	8	

4.3 Welding Workpiece Information

Workplace information is required to continue research and further analysis related to solid waste sponsorship in the workshop. To obtain a weighted reading, a sample of the workpiece is taken at random after each training session is completed and weighed using an analogue weighing device in the workshop. Weight readings are recorded in Table 3, and general information on the size of the workpiece is also recorded for future reference. At this stage, the main purpose is to obtain an estimate of the weight of the object that has been welded during the previous training session and used for the calculation of solid waste generation in further analysis.

Table 3: Welding workpiece information.

Types	Workpiece information	Dimension	Weight after welding processes
Plate 	Materials: Carbon steel	200mm X 80mm X 3mm X 2pcs	0.8kg
Plate 	Materials: Aluminium	200mm X 80mm X 3mm X 2pcs	0.3kg
Plate 	Materials: Carbon steel	200mm X 80mm X 6mm X 2pcs	1.5kg
Plate 	Materials: Stainless steel	200mm X 80mm X 6mm X 2pcs	1.6kg
Plate 	Materials: Carbon steel	250mm X 100mm X 9mm X 2pcs	3.6kg
Plate 	Materials: Stainless steel	250mm X 100mm X 9mm X 2pcs	3.7kg
Plate 	Materials: Carbon steel	250mm X 100mm X 10mm X 2pcs	4.0kg
Pipe 	Materials: Carbon steel	12 inches X diameter 4inch. Sch. 40	5.0kg
Pipe 	Materials: Carbon steel	12 inches X diameter 6inch. Sch. 80	13.0kg

4.4 Welding Products

Basic welding training products are in the form of a flat plate, a 'T' shape plate, pipe and pipe attached to plate form. The final welding training output may vary when it involves special tasks of projects whether the trainee needs to produce a specific structure form such as instructions from questions or a physical form that needs to be constructed by the trainee based on their own design or group to complete a project as illustrated in Figure 5.

Figure 5: Welding structure on a specific form and varies welding project

4.5 The Waste Generation Analysis and Discussions

The welding results that have been made by trainees and course participants are tested and evaluated with reference to the content and course requirements. After the referral and evaluation process is made, workpieces or welding products are eventually scrapped, and these synonyms are categorized as solid waste. Towards sustainable solid waste management, welding products are classified according to their size and type. Solid waste resulting from the workpiece preparation process and during the welding process is also collected and segregated according to its type. With this, the generation of solid waste based on the results of training in terms of weight can be obtained.

Factors that contribute to the generation of solid waste are welding technique and positions, the number of trainees or course participants, and welding tasks such as plate, pipe, specific product design, or custom projects. In relation to solid waste generation during raw material preparation steps and implementation of training, the amount is small compared to the weight of the workpiece used for the welding process as presented in Table 4.

Based on the observations and information collected in relation to the generation of solid waste in the workshop after the practical training is carried out, generally, the most solid waste is those based on carbon steel followed by solid waste based on stainless steel and solid waste based on aluminium.

Table 4: Waste generation in workpiece preparation stage.

Materials	Material form	The average weight of material (kg)	Remarks
Aluminium	Small particles and fragments	< 2.0	Less than 5kg as it is only used for certain tasks in training
Carbon Steel	Small particles and fragments Plate balance	< 15.0	The biggest contributing factors are the thick plate-shaped workpiece and the remaining pipe-shaped workpiece
Stainless Steel	Small particles and fragments	< 10.0	The biggest contributing factors are the thick plate-shaped workpiece

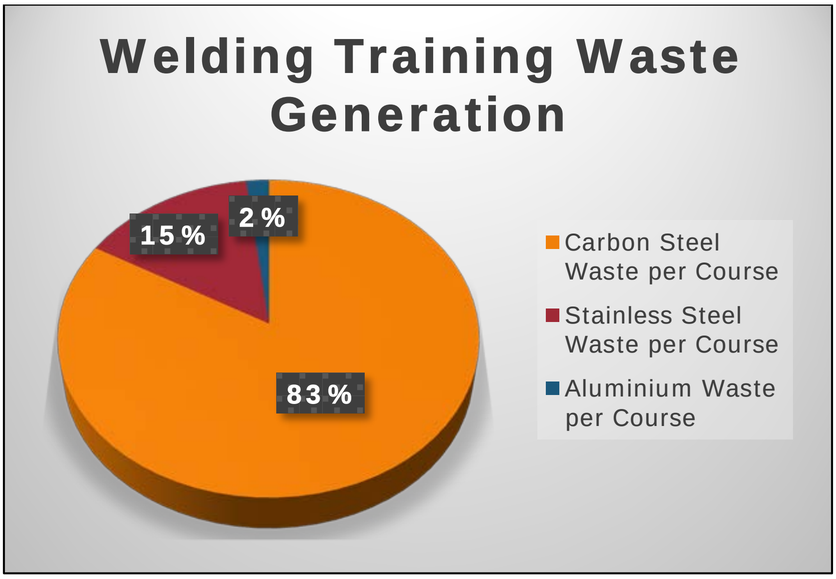

Figure 6: Welding training waste generation by percent.

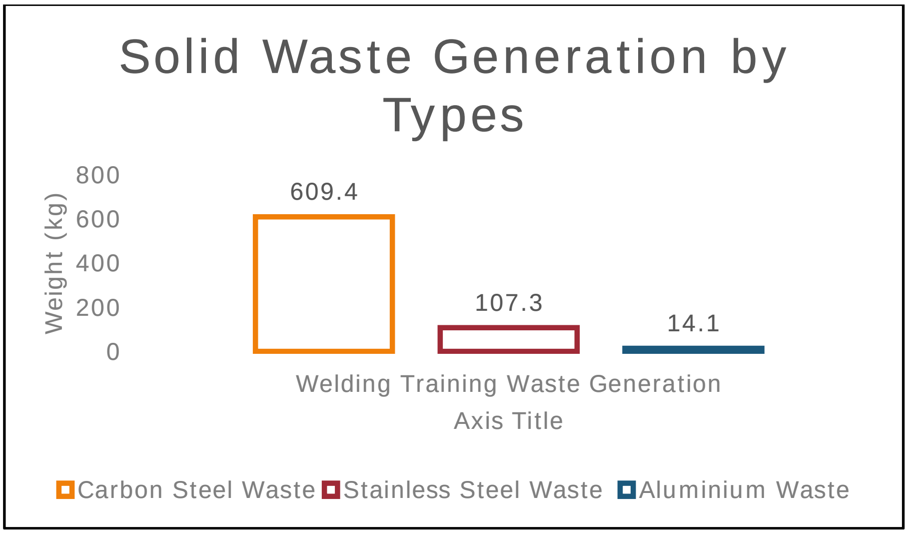

Figure 7: Solid waste generation by material types

Figure 6 and Figure 7 show the welding training waste generation by percent and weight based on its types. Overall, solid steel-based solid waste generated 83% and weighed 609.4kg, stainless steel solid waste generated 15% and weighed 107.3kg while aluminum-based solid waste generated 2% and weighed 14.1kg. This is because the basic material for welding training is carbon steel based and the thickness variation is also wider by referring to the training requirements. Besides, the cost of purchasing is also lower than stainless steel and aluminum.

5 Conclusion

The implementation of skill training that involves engineering work generally contributes to the generation of solid waste. The amount of waste generated is directly related to the number of trainees as well as the number of courses implemented. However, the implementation of effective solid waste management is necessary to avoid the greenhouse effect. In this study, solid waste generation for a practical exercise was carried out using the HIRARC approach. The analysis reveals the information related to the hazardous level of task execution that produces solid waste as well as recommends the control measure referring to the work concerned. Guidelines or Standard Operating Procedure (SOP) on solid waste management was established to ensure that sustainable solid waste management activities are being carried out in the skill training workshop. Ultimately, this study promotes a green environment and sustainable management of solid waste in the engineering education practice.

6 Availability of Data and Material

Data can be made available by contacting the corresponding author.

7 Acknowledgement

The authors would like to thank Universiti Teknologi MARA, Shah Alam, Selangor for providing support.

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