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Study on the Carbon Footprint Reduction Through Recycling Activities in UTHM: Effect of COVID-19 Pandemic

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Abstract: Recycling is an excellent method to manage institutional solid waste and reduce the environmental carbon footprint. However, the outbreak of the COVID-19 pandemic has caused unprecedented chaos and affected recycling activities in UTHM. Therefore, the trend of carbon reduction through recycling activities in UTHM was determined to investigate the impact of the COVID-19 pandemic on the trend of carbon reduction. The data was collected from the recycling center in UTHM and the carbon reduction was further calculated to compare the difference before and after the pandemic outbreak. The weight of paper products collected was the highest, accounting for more than 75%, while the weight of aluminium collected was the lowest, accounting for less than 1%. Furthermore, it was found that the trend of carbon reduction increased steadily in 2019. However, the outbreak of the COVID-19 pandemic has caused the trend to plunge and approach zero in March 2020. Nevertheless, once the COVID-19 pandemic was under control, the carbon reduction trend improved and peaked again in 2021. In addition, paper products achieved the highest of the total carbon reduction at 5143.072 tCO2e while aluminium was the lowest at 0.357 tCO2e. The highest total carbon reduction was achieved in 2019 with 1980.168 tCO2e while the lowest was recorded in 2020 with 1220.932 tCO2e. As a result, the Covid-19 Pandemic had a significant impact on the recycling rate in UTHM, which resulted in a reduction in the total amount of carbon reduction.

Keywords: Carbon reduction, recycling, COVID-19 pandemic

1. Introduction

As a result of population growth, efficient solid waste management is a challenge for the world's economic system. According to the Malaysian Investment Development Authority (MIDA), Malaysia's population is growing rapidly and is expected to reach 32.8 million people by 2021 [1]. This will result in a huge amount of solid waste generation, which is expected to reach 38,427 metric tonnes per day (1.17 kg/capita/day) in 2021 of which 82.5% of this waste will be

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disposed of in landfills [1]. Without systematic waste management, this will almost certainly lead to disaster, negatively impacting public safety and health and the environment, and even increase the cost of waste management and disposal. In Malaysia, solid waste can be categorized into public solid waste, import waste, household solid waste, institutional solid waste, commercial solid waste, construction waste, special solid waste, and industrial waste [2]. This study focuses on institutional solid waste. In the Solid Waste and Public Cleansing Management Act 2007, the institutional solid waste means any waste which is produced by any premises approved under any written law or by the State authority to use solid waste and public cleansing wholly or mainly for the purpose of prayer or for charitable, any premises occupied by any Department of the Federal Government or the State, any local authority or any statutory body, any premises of education, any health care facilities including hospitals, clinics and health centres or any premises used as a public zoo, museums, public, public libraries and orphanages [2].

The composition of institutional waste may consist of recyclable and non-recyclable waste. Typically, recyclable materials such as plastic, paper, aluminium, metal, newspaper, and used clothing are taken to a recycling facility provided by the university through either a single-stream or multi-stream recycling system [3]. Waste that could not be recycled will be disposed of in a landfill as a final disposal method. Meanwhile, food waste generated at the cafe is usually used for composting. As Malaysia is committed to support the circular economy in addressing global challenges such as climate change, biodiversity loss, waste and pollution, recycling requires little effort but can have a significant impact on combating waste and pollution issues. Recycling is the process of converting waste into a new or usable product, thereby avoiding waste disposal while creating new products [4]. In addition, waste recycling significantly reduces carbon emissions, improves the environment, and conserves natural resources [5]. Recycling could be a method to reduce greenhouse gas emissions from waste management, which would help reach the goal of the UN Framework Convention on Climate Change.

One of the problems related to global warming is the excessive emission of greenhouse gases such as carbon dioxide (CO2) produced by a person, event, organization, service, place, or product [6]. To combat global warming, it is important to determine the carbon footprint of an activity in order to take action and implement projects to reduce it as much as possible. Typically, the carbon footprint is quantified in tonnes of carbon dioxide produced. In most cases, recycling minimizes the use of available resources. Paper recycling, for example, helps to reduce environmental impact by avoiding methane emissions and lowering energy requirements for a variety of paper products. The U.S. Environmental Protection Agency reports several benefits of paper recycling, such as expanding fibre supply and contributing to carbon sequestration, saving significant landfill space, energy and water use, and reducing the need for disposal [7]. According to [8], paper recycling would save up to 600 to 2,500 kg of CO2 per tonne of recycled material. For other recyclable materials, recycling would save 4,000 to 17,000 kg CO2 per tonne of recycled aluminium, 400 to 2,000 kg CO2 per tonne of recycled steel, 80 to 600 kg CO2 per tonne of recycled glass, and 500 to 2,000 kg CO2 per tonne of recycled plastic. Therefore, recycling is an excellent way to reduce emissions of greenhouse gases that cause global warming.

Unfortunately, the discovery of coronavirus disease 19 (COVID-19) in Wuhan, in late 2019 has swept countries around the world, bringing numerous adverse consequences in terms of education, employment, economy and mental health. In addition, the trend toward second and third waves of the pandemic is visible in many regions despite early success in containing the number of cases [9]. However, no one knows when the transmission of the virus will end as the future is still unknown [10]. Due to the outbreak of the COVID-19 pandemic, recycling activities at the University Tun Hussein Onn Malaysia (UTHM) are also affected. Therefore, this study focused on the recycling of waste materials and the amount of carbon reduced by recycling activities in UTHM.

2. Overview of Carbon Reduction Through Recycling Activities

Many international researchers have proven that recycling waste materials can help reduce greenhouse gas (GHG) emissions. The reason is that by recycling waste materials, the waste can be transformed into new products or materials to replace the production of primary products that consume a lot of energy and virgin materials. In order to understand the impact of GHG emissions on the environment as well as to identify opportunities to reduce GHG emissions, it is important to evaluate the GHG emissions from recycling waste materials to achieve the national GHG emissions reduction target [11].

In general, GHG emissions are often evaluated using emission factors (EFs) which equate the amount of a pollutant emitted to a unit of activity. Emission factors (EFs) for different GHGs are often combined and expressed as CO2 equivalents (CO2e) per unit of activity. In the context of waste recycling, EFs are frequently expressed as per tonne of waste material recycled (kg CO2e/t). In this case, life cycle assessment (LCA), a common methodology for measuring the emissions of a product or system, is applied either partially or fully to determine GHG EFs for waste recycling. In addition, numerous studies have shown the GHG EFs for waste recycling. For example, a carbon metric has been developed by WRAP (Waste and Resources Action Programme) to assist the Scottish government in analyzing their national solid waste management system in terms of GHG impacts and to identify opportunities for improvement that can be made [11].

In the study conducted by [11], the calculated emission factors were summarized and compared with the emission factors from the literature review. Table 1 shows the comparison of the data. In Table 1, the calculated gross and net emission factors are presented and compared with the emission factors from the literature. The gross value represents the

total GHG emissions before taking into account the consumption of energy and primary materials used, while the net value represents the total GHG emissions including the avoided primary production and the negative figure represents a saving in GHG emissions [11].

Table 1 - Comparison of calculated emission factor and literature emission factors for a different type of materials

Type of Material	Calculated Emission Factor		Literature Emission Factors	
	Gross ($kg CO_2e/t$)	Net ($kg CO_2e/t$)	No. of reference	Range ($kg CO_2e/t$)
Glass	395	-314	6	-762 to -201
Paper	1576	-459	7	-3891 to 390
Card	559	-120	5	-3439 to -280
Aluminium cans	1113	-8143	7	-19340 to -5040
Metal scrap	883	-3577	3	-4828 to -2573
Mixed plastics	339	-1024	6	-2324 to 1470
Wood	502	-444	5	-2712 to 1
Tyres	206	-636	2	-1910 to -430
Rubble	16	-2	4	-9 to 2
Automotive batteries	938	-435	2	-563 to -487
Soil	41	27	2	-2 to 2
Plasterboard	59	4	2	-139 to 33
Paint	364	86	1	-

3. Materials and Methods

This section discussed the methodology to achieve the objectives of the study which included data collection through to the final results of the study. Figure 1 shows the methodological framework for this study. In Figure 1, the methodology was divided into three stages which are Stage I, Stage II and Stage III. Stage I involved data collection from the recycling centre in UTHM to determine the weight of recyclable materials such as paper, metal, glass and plastic. Stage II analyzed the data and calculated the carbon reduction of the recyclable materials. Furthermore, Stage III compared the data and discussed the calculated carbon reduction before and after the COVID-19 pandemic.

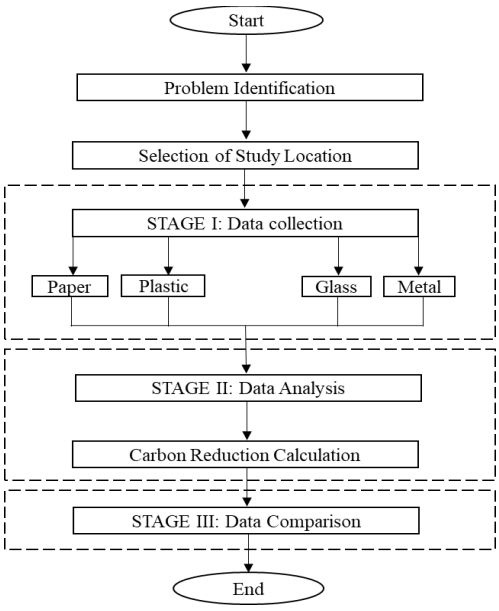


Fig. 1 - Methodology framework of the study

3.1 Data Collection

The study site was located at the main campus of Universiti Tun Hussein Onn Malaysia (UTHM), 86400 Parit Raja, Batu Pahat Johor, Malaysia. At UTHM, there is a recycling centre established by the Sustainable Campus Office (SCO), also known as the Resources Recovery Learning House (RPPS) (in Figure 2), which aims to improve waste management on campus through resource recovery activities. The RPPS also acts as a focal point for coordinated implementation of various recycling-related activities. In addition to the establishment of the recycling centre, numerous activities have been implemented to encourage the community to participate in recycling activities and increase their knowledge of recycling. These activities include office recycling, posters, a reward system and others [12].

Fig. 2 - The Resources Recovery Learning House (RPPS) in UTHM

In general, it is difficult to recycle waste with very low value such as plastic and paper packaging, glass, old clothes, furniture and others. As a result, this waste is sent to a landfill for final disposal. For this reason, UTHM has established a recycling collection centre under the Recycling@U programme, which is available to UTHM residents and the local community. All recyclable waste is dropped off at the recycling centre and then weighed, and the recyclers will receive a monetary reward based on the types of waste that has been sent.

3.2 Data Analysis

Based on the collected data, the data was further analyzed by calculating the carbon reduction for each recyclable material. In order to calculate the carbon reduction, the Department for Environment, Food & Rural Affairs (DEFRA) [13] formula was used to calculate the carbon reduction, which is shown in Eq. 1. According to Eq. 1, the total weight of each recyclable material collected was multiplied by the emission factor of each recyclable material and divided by one thousand (1000) to obtain the unit tonne. Thus, the carbon reduction of each material was calculated.

$$CO_2\ reduced = \frac{Total\ waste\ recycle\ (kg)\ x\ Emission\ Factor\ (\frac{kgCO_2e}{tonne})}{1000\ (convert\ to\ tonne)} \quad \text{Eq.1}$$

In this study, the data were calculated and analysed using Microsoft Excel software. The formula in Eq. 1 was inserted into the Excel file and the results were tabulated. After calculating and determining all the values, the results were presented in chart or graph format by using the same software. In addition, the results were further discussed.

3.3 Data Comparison

Numerous environmental issues arise from the outbreak of the COVID-19 pandemic including impacts on the waste management system. As a result of the change in consumer behaviour in terms of resource consumption, waste disposal patterns and waste diversion activities were also affected during the lockdown period [14]. Therefore, carbon reduction data for each recyclable material was compared before and after the COVID-19 pandemic outbreak. The carbon reduction for the year 2019 indicates the reduction value before the COVID-19 pandemic outbreak, while the years 2020 and 2021

indicate the reduction value during and after the COVID-19 pandemic outbreak. The carbon reduction trend was further discussed.

4. Results and Discussions

The results and discussion section presents the data obtained from the recycling centre in UTHM. The data from the recycling centre included the weight of each waste material collected each month and the data was further analysed in terms of carbon reduction from recycling activities in UTHM. Due to the outbreak of the COVID-19 pandemic, many sectors are affected including educational institutions, industrial activities, human daily activities and many other social activities. Recycling activities are also among the activities that are significantly affected by the emergence of online shipping and food delivery services [15]. Therefore, the results were further compared to determine the difference caused by the COVID-19 pandemic outbreak.

4.1 Recycling Trend in UTHM

At UTHM, the Resources Recovery Learning House (RPPS) adopts the multi-stream recycling system to separate recyclable materials where these wastes are separated at source according to the recycling bins provided. From the information that was gathered from the recycling centre at UTHM, the most common types of recyclable materials are paper products, metal, plastic, and aluminium. The weight of recycled materials collected for 2019 is shown in Table 2, and the composition of each type of material is illustrated in Figure 3.

From the data, a total of 1896.1 kg of paper products were collected, accounting for 78% of the total recycled materials collected, 367.4 kg of plastic (15%), 135 kg of metal (6%), and 37.3 kg of aluminium (1%). However, glass was not collected in this study as it has no recycling value and starting from there, the demand for recycled glass is low and thereby recycling operators have stopped collecting glass-based material from the public. Since UTHM is an educational institution, the amount of paper needed for examinations, assignments, and also for documentation can be considered as the reason for the highest percentage of recycled material collected in UTHM. Therefore, the study revealed that paper is collected the most compared to other recycled waste. With good management strategies and successful university programs and awareness campaigns, the recycling program has successfully delivered the right strategy for waste management on campus. In this way, eco-friendly ways of turning recycled goods into new products have been made, which have helped reduce pollution and boost the economy [16].

Table 2 - Weight of recycled materials collected in UTHM in 2019

No	Composition	Weight (kg)
1	Paper	1896.1
2	Plastic	367.4
3	Metal	135.0
4	Aluminium	37.3
5	Glass	0.00

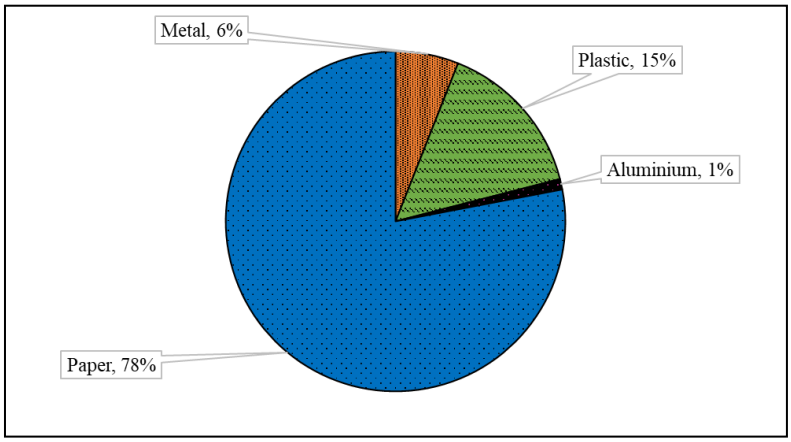


Fig. 3 - Composition of waste collected in UTHM in 2019

However, in 2020, the COVID-19 pandemic had spread throughout the world. As a safety precaution to prevent the spread of COVID-19, the Malaysian government implemented a movement control order (MCO) that restricted people's daily activities. Therefore, all industrial and educational sectors were temporarily closed and everyone was forced to stay at home. Table 3 shows the weight of waste materials collected in UTHM for 2020 while Figure 4 shows the composition of each type of material. From the results, the amount of recycled materials has decreased. The amount of paper products collected is 1170.2 kg (85%), plastic is 193.9 kg (14%), metal is 8.6 kg (1%) and aluminium is 1.2 kg (less than 1%). During MCO, the students and staff worked from home, and online classes were conducted through online platforms such as Zoom, Google Meet, Webex and other applications. As a result, very few students and staff were on campus and recycling activities were impacted.

The outbreak of the COVID-19 pandemic also significantly changed the waste cycle and consumption habits or patterns of consumers. In addition, the government-imposed sit-still policy led people to adopt new lifestyles and online shopping spread, requiring a lot of paper and plastic for packaging. As a result, waste generation increased, and in some cases, it is not recyclable and is not well separated by consumers to be recycled [17].

Table 3 - Weight of recycled materials collected in UTHM in 2020

No	Composition	Weight (kg)
1	Paper	1170.2
2	Plastic	193.9
3	Metal	8.6
4	Aluminium	1.2

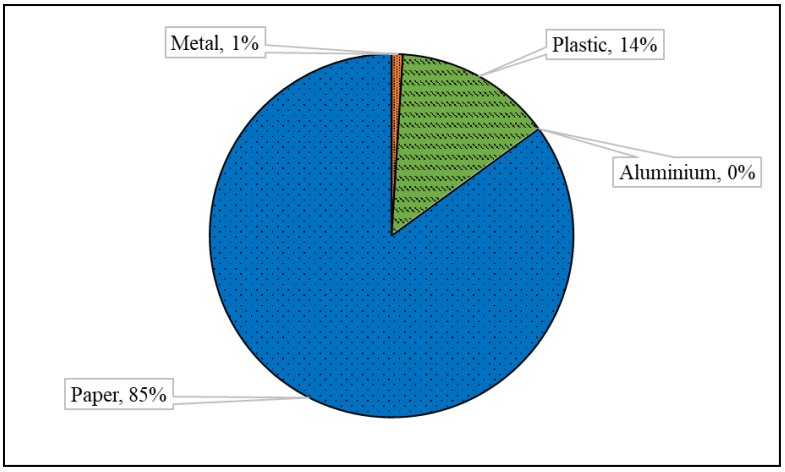


Fig. 4 - Composition of waste collected in UTHM in 2020

In 2021, the COVID-19 pandemic is under control and the government has gained more experience in dealing with it. Although MCO was still restricted, the country slowly opened up and people were allowed to carry out daily activities in compliance with standard operating procedures (SOPs), such as scanning "Mysejahtera" and using disinfectants frequently to prevent the spread of the virus. In addition to the lockdown strategy, personal hygiene, tracing, social distancing, and quarantine can also help control the infectious virus in some countries [18]. Table 4 shows the weight of waste materials collected in UTHM for 2021 while Figure 5 shows the composition of each type of material. The total weight of paper products collected is 1870.4 kg (92%), plastic is 141.3 kg (7%), metal is 25.8 kg (1%) and aluminium is 1.6 kg (less than 1%).

The education sector worldwide was closed in early 2020 due to the COVID-19 pandemic outbreak. Since educational institutions lack relevant experience in dealing with such unpredictable situations, all possible solutions were tested to find the best strategy and how effective the mitigation strategy could be [19]. However, educational institutions in Malaysia allow some of the students to return to campus for courses that require face-to-face activities such as laboratory work and practical applications, using SOP and certain rules as a control measure to prevent the spread of the virus. As a result, recycling activities at the university are gradually recovering.

Table 4 - Weight of recycled materials collected in UTHM in 2021

No	Composition	Weight (kg)
1	Paper	1870.4
2	Plastic	141.3
3	Metal	25.8
4	Aluminium	1.6

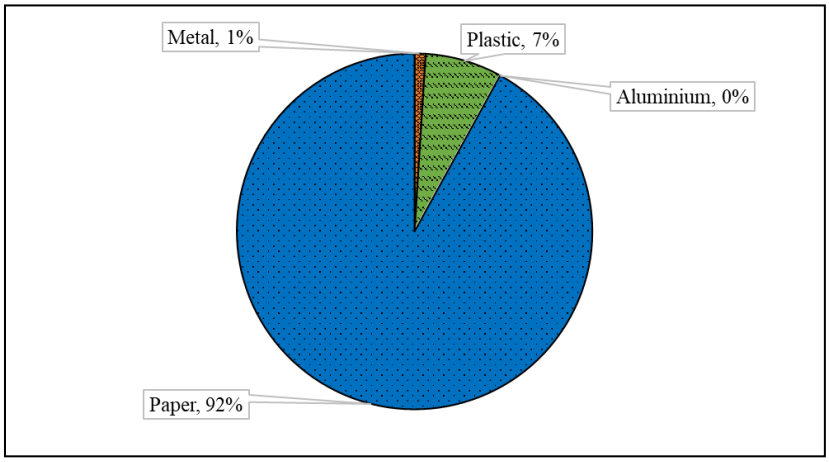


Fig. 5 - Composition of waste in UTHM in 2021

4.2 Carbon Reduction Through Recycling Activities in UTHM

As recycling is one of the best ways to reduce carbon footprints, the amount of carbon saved by recycling in UTHM is then calculated using the DEFRA formula [13], which uses a different emission factor for each recycled material. Figure 6 shows the carbon reduction for each recyclable material from 2019 to 2021. The figure shows that the carbon reduction in 2019 is 1975.364 tCO2e for paper, 3.271 tCO2e for plastic, 1.202 tCO2e for metal and 0.332 tCO2e for aluminium. In 2020, the carbon reduction for paper products was 1219.119 tCO2e, 1.726 tCO2e for plastic, 0.077 tCO2e for metal, and 0.011 tCO2e for aluminium. In 2021, the carbon reduction for paper products was 1948.59 tCO2e, 1.258 tCO2e for plastic, 0.230 tCO2e for metals and 0.014 tCO2e for aluminium. Compared to the types of recyclables collected in recycling activities, paper has the highest carbon reduction compared to other recyclable materials each year. As previously discussed, due to the nature of UTHM as an educational institution, the amount of paper required for exams, assignments, and also for documentation can be considered as the source of the highest percentage of recycled materials collected at UTHM. Recycling paper can save the trees used for virgin paper from being cut down. According to a study conducted in China, the consumption of paper products is increasing dramatically, especially in developing countries. As a result, the emission of greenhouse gases by the paper industry is extremely high, and it is also considered one of the industries with the highest energy demand. Therefore, recycling waste paper is an effective method to reduce carbon emissions and energy consumption [20].

Plastic and aluminium are commonly used in almost all fields, including the production of packaging. In RPPS, plastic and aluminium are usually collected in the form of plastic bottles and aluminium cans, which are often used for packaging food and beverages. However, with the effective campaigns and awareness programs in UTHM, the total amount of plastic and aluminium was quite low compared to paper waste. In addition, the absence of staff and students during the MCO is one of the factors in reducing waste on campus.

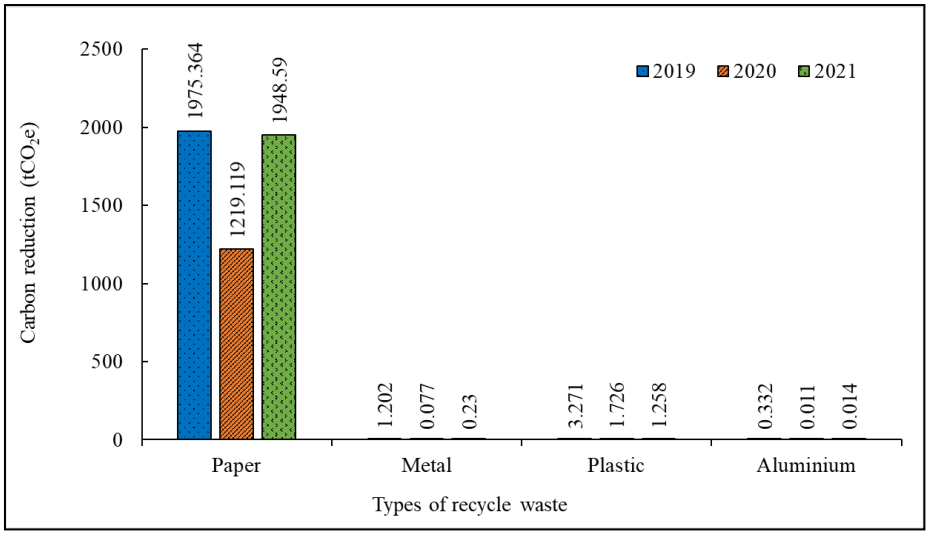
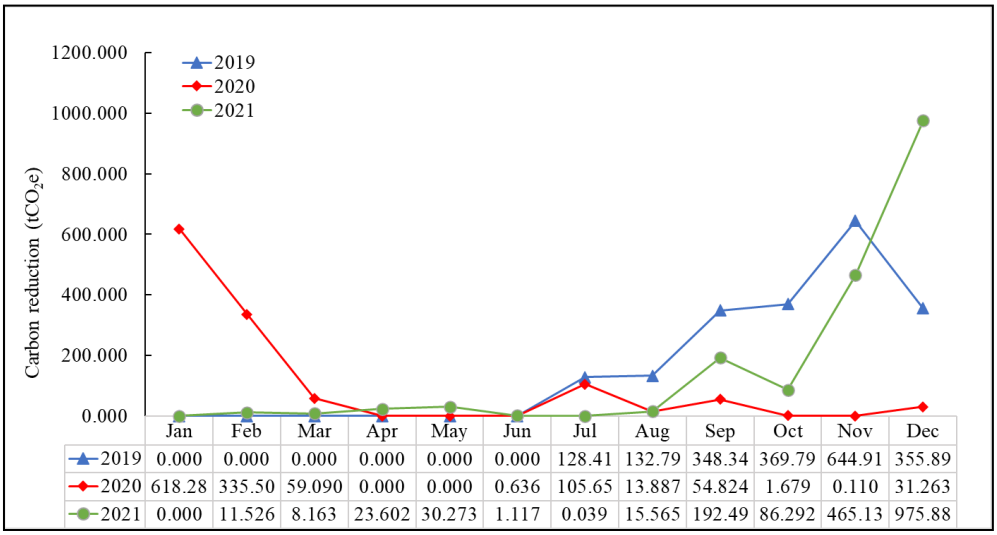


Fig. 6 - Carbon reduction of each material for the year 2019, 2020 and 2021

Figure 7 shows the pattern of monthly collection of recyclable materials from 2019 to 2021 in terms of carbon reduction. From January to June 2019, there was no collection for all types of recyclables in UTHM. From July to December 2019, the collection of recyclables increased, thus increasing the total carbon reduction for that period. However, the implementation of MCO announced by the Prime Minister in March 2020 significantly reduced the collection of recyclable waste, which reduced the total carbon reduction in UTHM. However, from June 2020 onwards, the government announced the implementation of the Recovery Movement Control Order (PKPP) to replace the Conditional Movement Control Order (CMCO), with most economic and social activities allowed. Therefore, the collection of recyclables will become active again during this period. However, the total carbon reduction in 2020 is still lower than at the end of 2019 and 2021.

With the gradual entry of university students to replace the online courses that were previously conducted during the lockdown, a very significant change in the amount of carbon reduction achieved was noted. This is due to the fact that UTHM students and staff were allowed to return to campus to work in the laboratories and complete important tasks, thus recycling activities reached a peak again. The same situation occurred in Brazil, where the recycling industry was restricted due to safety measures to prevent viral infection. It was found that the uncollected recycled materials amounted to about 17,000 tonnes, and these materials continued to be stored in landfills, resulting in losses for the recycling industry [5].



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2019	0.000	0.000	0.000	0.000	0.000	0.000	128.41	132.79	348.34	369.79	644.91	355.89
2020	618.28	335.50	59.090	0.000	0.000	0.636	105.65	13.887	54.824	1.679	0.110	31.263
2021	0.000	11.526	8.163	23.602	30.273	1.117	0.039	15.565	192.49	86.292	465.13	975.88

Fig. 7 - Carbon reduction through recycling activities for the year 2019, 2020 and 2021

5. Conclusion

In summary, carbon footprint reductions from recycling activities were identified in UTHM. In addition, the difference in carbon reduction before and after the COVID-19 pandemic outbreak was compared and the factors affecting carbon reduction were discussed. The carbon reduction of recyclable materials was compared before and after the COVID-19 pandemic outbreak. Before the COVID-19 pandemic broke out in 2019, the SCO had been actively encouraging recycling since June 2019. This led to a steady decrease in carbon emissions. But when the COVID-19 pandemic broke out in Malaysia in 2020, the trend of UTHM reducing carbon through recycling activities dropped sharply. This was due to the movement restrictions imposed by the government and the introduction of MCO as a control measure to prevent the spread of the virus. Nevertheless, the carbon reduction trend improved in 2021 and climbed back to the peak in October. This was due to the government slowly opening up the country and relaxing rules and regulations on social and economic activities. As a result, recycling activities in UTHM gradually recovered, as well as the trend of carbon reduction. The highest carbon reduction was achieved in 2019, before the outbreak of the COVID-19 pandemic, amounting to 1980.168 tCO2e. The lowest was achieved in 2020, when the COVID-19 pandemic broke out globally, and the total reduction was 1220.932 tCO2e. In short, recycling is a great method to reduce the negative impact on the environment. Recycling activities help to reduce the carbon footprint of the earth, thus improving air quality and reducing harm to humans. Therefore, the public should actively participate in recycling activities to protect nature. Based on the study conducted, some recommendations for future research are given below:

[1] Carbon reduction of recyclable materials can be evaluated and compared through different methods.
[2] The government could update the recycling data and make it more accessible to the public.
[3] A carbon reduction assessment of more uncommon recyclable materials such as clothing, wood, cooking oil and others can be conducted.

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