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The Determination of Green Criteria and Sub-Criteria for Pharmaceutical Waste Disposal Practices in Malaysia

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Abstract

The green element should be considered as one of the secure and safe methods of disposing of pharmaceutical wastes since they are categorized as hazardous substances. However, there are still many pharmaceutical wastes that are not disposed of in the right way, making the level of pollution arising. Hence, the research in this paper aims at determining the green criteria and sub-criteria for pharmaceutical waste disposal practices in Malaysia. The research adopted a qualitative research approach, involving three phases of the research process, which are (i) identifying the criteria and sub-criteria from the literature, (ii) verifying the green criteria and sub-criteria with the experts, and (iii) determining the meaningful green criteria and sub-criteria for pharmaceutical waste disposal practices that are suitable to be employed in Malaysia. Findings from this research suggested four main green criteria, namely economic, environmental, social, and technical, and 31 green sub-criteria, which have been grouped according to each main criterion specified for pharmaceutical waste disposal practices in Malaysia. The finding from this research can provide guidelines for the authorities and related parties who are responsible for managing pharmaceutical waste in selecting appropriate ways of disposing of the pharmaceutical waste by embedding the green criteria and sub-criteria in their strategies and policies planning.

Keywords *Hazardous substances · Malaysia · Refuse disposal · Green · Waste · Pharmaceutical preparations*

Introduction

Pharmaceutical waste, a substance that can pose a health threat to the community and pollute the environment, has been classified by the World Health Organization (WHO) as a highly dangerous waste. Expired, discarded, split and contaminated medications including vaccines and serum that are no longer in use are examples of waste generated from pharmaceuticals [5, 7, 14]. Furthermore, pharmaceutical waste also comprises discarded pharmaceutical handling items, like bottles or bins containing pharmaceutical traces, caps, goggles, connecting tubing, and medication vials, which makes it impermissible to be disposed of arbitrarily [15]. In Malaysia, SW403 and SW405 are codes assigned to pharmaceutical wastes, which refer to expired drugs and discarded drugs, respectively [4]. In addition, this pharmaceutical waste also has been classified according to Class I, Class II as well as Class III, and is segregated based on their hazardous level.

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In 2020, there are 471.20 metric tons (MT) of SW403 and 431.00 MT SW405 types of pharmaceutical waste have been disposed of in Malaysia [4]. The stated amount is the one that was successfully collected before disposal. However, beyond our knowledge, there are still many pharmaceutical wastes that are not disposed of in the right way, making the level of pollution arising. Furthermore, the technology or treatment used to dispose of pharmaceutical waste legally also remains questionable whether it is safe for public health and the environment. Thus, the government has outlined those treatments from the waste management sector, which adopted pharmaceutical waste disposal by meeting certain standard requirements to ensure the output is truly safe and green [11]. The terminology of 'green' abovementioned has been widely used all around the world due to its advantages in protecting and preserving the environment, as well as scaling down or eliminating environmental contaminations that traditionally did not apply green elements [19]. As a result, the plan to dispose of pharmaceutical waste in a greenway is a refined idea that should be supported.

Nonetheless, several criteria need to be considered when conducting green pharmaceutical waste disposal practices. Unfortunately, the green elements are not specified despite many researchers from other countries emphasizing the criteria and sub-criteria that need to be taken into account in pharmaceutical waste disposal practice. Furthermore, it may not be appropriate to implement the practices of pharmaceutical waste disposal by the other countries due to a variety of reasons, including geographical circumstances and technological readiness. Therefore, the main objective of this research is to determine the green criteria and sub-criteria for pharmaceutical waste disposal practices in Malaysia.

The Criteria and Sub-Criteria For Pharmaceutical Waste Disposal Practices

There are a few elements that have been considered in disposing of pharmaceutical waste. To this extend, many researchers have agreed and concluded that pharmaceutical waste disposal practices should include several criteria, such as economic, environmental, social, technical, and several other sub-criteria [1, 18].

Economic

In disposing of pharmaceutical waste, economics is one of the important criteria that must be taken into account to avoid excessive use of resources. This is because it will affect the financial position and profitability of the organizations, and/or authorities that manage pharmaceutical waste disposal. The best pharmaceutical waste disposal practices need to be employed to cater to this situation, which can be determined when the profits generated exceed the costs incurred. It enables the authorities to manage the waste disposal in reducing overall costs and increasing productivity by optimizing the management of pharmaceutical waste that arises. Therefore, to make these pharmaceutical waste disposal practices more economically oriented, the researchers have agreed to apply sub-criteria related to cost-saving treatments such as net cost per ton in the economic criterion [9, 10, 17]. Then, the researchers also integrate disposal cost while adding another sub-criterion, namely installation required into economic criterion [6, 8, 12, 16]. Nevertheless, the majority of them concurred that capital, operation, and maintenance costs, should be included as sub-criteria of economic, considering them to be implemented in disposing of pharmaceutical waste.

Environmental

Environmental is also one of the criteria that need to be emphasized in pharmaceutical waste disposal to avoid adverse effects that might harm the environment. Thus, the researchers have

agreed that any treatment for disposing of healthcare or medical waste must propose the extent of use of renewable energy, the risk level for communities, workers, and environment, resource recovery capabilities, odor, space requirement, mass and volume reduction as well as material consumption [6, 12, 16]. Afterward, Chen & Sun [2] altogether with the abovementioned scholars also claimed that emission of air and secondary pollutant, the efficacy of microbial inactivation, energy consumption per kg of waste, and water consumption per kg of waste are all relevant sub-criteria to be considered in environmental features. In other circumstances, release with health effects should also be considered [2, 9, 10, 17]. Finally, the majority of the researchers stated that noise and waste residuals must therefore be included as a sub-criteria of environmental criteria.

Social

Apart from economic and environmental, the societal aspects that can be defined as the level of acceptance and the impact throughout the pharmaceutical waste disposal activity, which include technology and policy used on the health and wellbeings of the society, should also be considered in green criteria for pharmaceutical waste disposal practices. This is due to the process of pharmaceutical waste disposal also bringing devastating effects to society, where immediate action must be taken to reduce or eliminate those impacts. Therefore, various research has suggested including public acceptance as a sub-criterion for social [2, 9, 10, 12, 17]. In addition, treatment acceptance, technology acquisition, acceptance of cost, land requirement, and policy level are also added into the sub-criteria of pharmaceutical waste disposal practices [2, 8, 16]. Not only that, acceptability of treatment residues by local landfills, the extent of necessary resettlement of people as well as visible or aesthetic impact have been as sub-criteria for social [6, 12].

Technical

Finally, the technical aspect also plays a crucial role as a criterion for pharmaceutical waste disposal practices. Defines as the recognition of the most appropriate procedure, technology or treatment to be used in disposing of pharmaceutical waste, which includes the readiness, capacity, and maintenance, the technical criterion should include reliability or ease and operation, treatment effectiveness or capability, and occupational hazards [2, 9, 10, 17]. The listed sub-criteria have also been agreed upon by Hinduja & Pandey as they introduced occupational hazards and treatment effectiveness with other new sub-criteria such as level of automation or sophistication as well as the availability of local expertise or skilled operators in their research [8]. Correspondingly, few authors have added the same sub-criteria with the additional of adaptability to future situations, ability to treat a wide range of infectious waste, availability of spare parts and usage of local materials or manufactured technologies, compatibility with existing technology and natural conditions, and track record on performance into the technical criteria [6, 12], whereby only Chen & Sun has incorporated security as a sub-criteria for technical [2].

It is concluded that economic, environmental, social, and technical aspects are used as the criteria for pharmaceutical waste disposal practices in most research related to pharmaceutical waste management. However, it can be seen that all of the criteria used are not consistent across the geographical locations of the practice. Therefore, it is suggested that Malaysia need to establish its own criteria and sub-criteria for pharmaceutical waste disposal practices. The next section applies the procedure of selecting those criteria.

Methodology

This section discusses the methodology used in this research to determine the green criteria and sub-criteria for pharmaceutical waste disposal practices in Malaysia. There are three phases of the research process involved: identification of the criteria and sub-criteria for pharmaceutical waste disposal practices based on findings from the literature review, verification of the green criteria and sub-criteria gathered from the literature by experts, and lastly, determination of the meaningful green criteria and sub-criteria for pharmaceutical waste disposal practices that are suitable to be employed in Malaysia. In Phase 1 of this research, the criteria and sub-criteria have been reviewed from previous studies that were published between the years 2015 and 2019. The keywords used are "pharmaceutical waste", "disposal practices" and "waste management".

Next, in Phase 2, a semi-structured interview with experts from the Engineering Services Division, Ministry of Health Malaysia (MOHM) has been conducted to select the appropriate and relevant criteria and sub-criteria according to Malaysian geographical conditions. This phase is considered vital as each crucial element obtained from the experts needs to be tailored into the research scope. The experts chosen are from the authorized departments that are responsible for taking care of pharmaceutical waste disposal. Purposive sampling is applied as it is a highly effective sampling method, which allows the generalization from a sample, regardless of conceptual, analytical, or practical issues [13]. For the sample size, it has been suggested by Creswell that a minimum sample size of three to ten respondents is sufficient for collecting significant information [3]. Thus, this research has chosen three respondents from the abovementioned organization. Next, a set of questionnaires are prepared and distributed to the experts to verify the green criteria and sub-criteria obtained in previous literature.

Finally, in Phase 3, the data regarding the green criteria and sub-criteria of pharmaceutical disposal practices obtained from the previous phase were finalized and determined as meaningful to be implemented in Malaysian practices. To summarize, all of the phases in the research process for this framework can be depicted in Fig. 1.

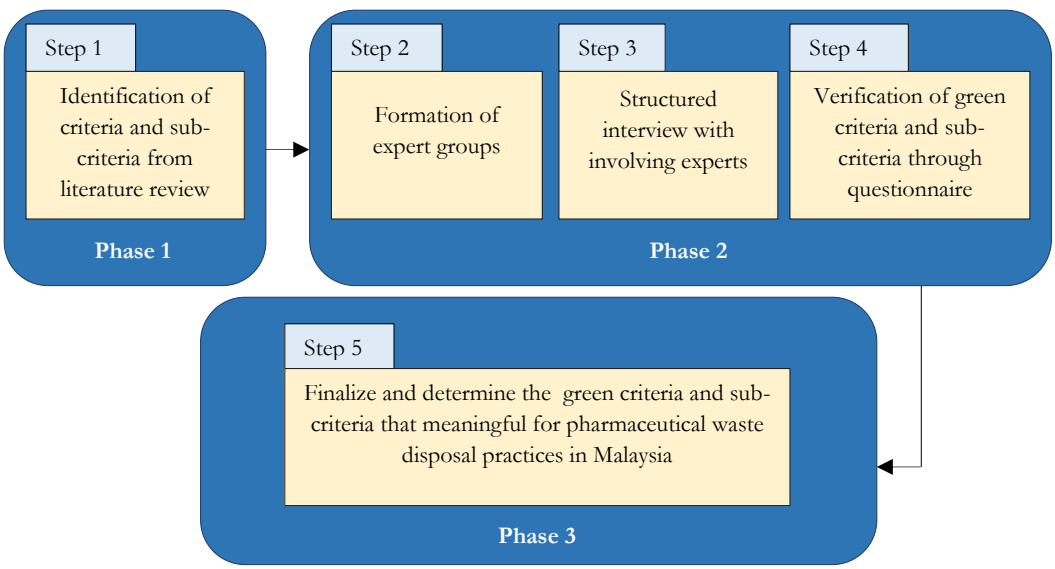

Fig. 1 Green Criteria and Sub-Criteria For Pharmaceutical Waste Disposal Practices Framework.

Result and Discussion

In this section, the findings of this research are discussed and organized into three sections. The arrangement made in this section is according to the phases of the research process specified in the methodology. In Section 4.1, the identification of criteria and sub-criteria in disposing of pharmaceutical waste obtained from the literature will be presented. Next, Section 4.2 discusses the green criteria and sub-criteria that have been shortlisted and verified by the experts. Lastly, the determination of green criteria and sub-criteria for pharmaceutical waste disposal practices that are meant to be implemented in Malaysia is presented in Section 4.3 which satisfied the main research objective.

Identification of Criteria and Sub-Criteria For Pharmaceutical Waste Disposal Practices

From the literature review on criteria and sub-criteria related to pharmaceutical waste disposal practices, there are four criteria and 39 sub-criteria have been identified and tabulated in Table 1.

Table 1 The Criteria and Sub-Criteria for Pharmaceutical Waste Disposal Practices.

Criteria	Sub-Criteria	Author(s)
Economic	Capital cost	Chen & Sun (2018); Hasan & Rahman (2018); Hinduja & Pandey (2018); Rafiee et al. (2016); Voudrias (2016)
	Disposal cost	Hinduja & Pandey (2018); Rafiee et al. (2016)
	Installation requirements	Hasan & Rahman (2018); Voudrias (2016)
	Net cost per ton	Xiao (2018); Lu et al. (2016); Liu et al. (2015)
	Operation and maintenance cost	Chen & Sun (2018); Hinduja & Pandey (2018); Rafiee et al. (2016); Voudrias (2016)
Environmental	Emission of air and secondary pollution	Chen & Sun (2018); Hasan & Rahman (2018); Rafiee et al. (2016); Voudrias (2016)
	Efficacy of microbial inactivation	Hasan & Rahman (2018); Rafiee et al. (2016); Voudrias (2016)
	Energy consumption per kg of waste	Hasan & Rahman (2018); Rafiee et al. (2016); Voudrias (2016)
	Extent of use of renewable energy	Hasan & Rahman (2018); Rafiee et al. (2016)
	Mass and volume reduction	Hasan & Rahman (2018); Rafiee et al. (2016); Voudrias (2016)
	Material consumption	Hasan & Rahman (2018); Rafiee et al. (2016)
	Noise	Chen & Sun (2018); Hasan & Rahman (2018); Xiao (2018); Rafiee et al. (2016); Liu et al. (2015)
	Odour	Hasan & Rahman (2018); Rafiee et al. (2016)
	Release with health effects	Chen & Sun (2018); Xiao (2018); Lu et al. (2016); Liu et al. (2015)
	Resource recovery capabilities	Hasan & Rahman (2018); Rafiee et al. (2016)

Criteria	Sub-Criteria	Author(s)
	Risk level for communities, workers and environment	Hasan & Rahman (2018); Rafiee et al. (2016)
	Space requirement	Hasan & Rahman (2018); Rafiee et al. (2016)
	Waste residuals	Hasan & Rahman (2018); Hinduja & Pandey (2018); Xiao (2018); Lu et al. (2016); Rafiee et al. (2016); Voudrias (2016); Liu et al. (2015)
	Water consumption per kg of waste	Rafiee et al. (2016); Voudrias (2016)
Social	Acceptance of cost	Voudrias (2016)
	Acceptability of treatment residues by local landfill	Hasan & Rahman (2018); Rafiee et al. (2016)
	Extent of necessary resettlement of people	Hasan & Rahman (2018); Rafiee et al. (2016)
	Land requirement	Hinduja & Pandey (2018)
	Policy level	Chen & Sun (2018)
Social	Public acceptance	Chen & Sun (2018); Hasan & Rahman (2018); Hinduja & Pandey (2018); Xiao (2018); Lu et al. (2016); Rafiee et al. (2016); Liu et al. (2015)
	Technology acceptance	Voudrias (2016)
	Technology acquisition	Chen & Sun (2018)
	Visible or aesthetic impact	Hasan & Rahman (2018); Rafiee et al. (2016)
Technical	Ability to treat a wide range of infectious waste	Hasan & Rahman (2018); Rafiee et al. (2016)
	Adaptable to future situations	Hasan & Rahman (2018); Rafiee et al. (2016)
	Availability of spare parts and usage of local materials or manufactured technologies	Hasan & Rahman (2018); Hinduja & Pandey (2018); Rafiee et al. (2016); Voudrias (2016)
	Availability of local expertise/skilled operators	Hasan & Rahman (2018); Hinduja & Pandey (2018); Rafiee et al. (2016); Voudrias (2016
	Compatibility with existing technology and natural conditions	Hasan & Rahman (2018); Rafiee et al. (2016)
	Level of automation/sophistication	Hasan & Rahman (2018); Hinduja & Pandey (2018); Rafiee et al. (2016)
Technical	Occupational hazards	Hinduja & Pandey (2018); Xiao (2018); Liu et al. (2015)
	Reliability/ease of operation	Chen & Sun (2018); Xiao (2018); Lu et al. (2016); Liu et al. (2015)
	Security	Chen & Sun (2018)
	Treatment effectiveness/capability	Chen & Sun (2018); Hinduja & Pandey (2018); Xiao (2018); Lu et al. (2016); Liu et al. (2015)
	Track record on performance	Hasan & Rahman (2018); Rafiee et al. (2016)

Verification of Green Criteria and Sub-criteria for Pharmaceutical Waste Disposal Practices

The green criteria and sub-criteria determined from the literature review were then verified with experts by using semi-structured interviews and a set of questionnaires. A total of three experts from the Engineering Services Division, Ministry of Health Malaysia were selected as respondents based on their level of expertise in policy making on pharmaceutical waste disposal practices. They are the chief assistant director and two engineers, who had 11 to more than 20 years of work experience in related fields (Table 2).

Table 2 The Profiles of Experts from the Engineering Services Division, Ministry of Health Malaysia.

No.	Position	Years of work experience related to waste management
Expert 1	Chief Assistant Director	11 - 15 years
Expert 2	Engineer (Civil)	Above 20 years
Expert 3	Engineer (Civil)	11 - 15 years

Then, the experts were interviewed to select the criteria and sub-criteria listed and also any criteria that are not listed in Table 1. The unlisted sub-criteria suggested by the experts were public perception on aesthetic impact and waste disposal related policies including societal wellbeings, were classified as social criterion and category of pharmaceutical waste (i.e., Class I, Class II & Class III) and waste-to-energy (WtE) requirements, which grouped in technical criterion as in Table 3.

Table 3 The Shortlisted Criteria and Sub-Criteria from the Experts.

Criteria	Sub-Criteria
Social	Public perception on aesthetic impact
	Waste disposal related policies including societal wellbeings
Technical	Category of pharmaceutical waste (i.e., Class I, Class II & Class III)
	Waste-to-energy (WtE) requirements

Next, the experts were asked to evaluate and validate the four criteria and 39 sub-criteria through a set of questionnaires. The experts had eliminated a total of four sub-criteria from environmental criteria, namely the efficacy of microbial inactivation, energy consumption per kg of waste, material consumption and water consumption per kg of waste, two sub-criteria of social criterion, i.e. technology acceptance and technology acquisition and three sub-criteria of technical criterion, i.e. ability to treat a wide range of infectious waste, reliability/ease of operation and security due to irrelevant and redundant cases with other sub-criteria. The retained and removed criteria dan sub-criteria are in Table 4.

Table 4 The Verified Criteria and Sub-Criteria from the Questionnaire.

Criteria	Sub-Criteria	Result
Economic	Capital cost	Retained
	Disposal cost	Retained
	Installation requirements	Retained
	Net cost per ton	Retained
	Operation and maintenance cost	Retained
Environmental	Emission of air and secondary pollution	Retained
	Efficacy of microbial inactivation	Removed
	Energy consumption per kg of waste	Removed

Criteria	Sub-Criteria	Result
	Extent of use of renewable energy	Retained
	Mass and volume reduction	Retained
	Material consumption	Removed
	Noise	Retained
	Odour	Retained
	Release with health effects	Retained
	Resource recovery capabilities	Retained
	Risk level for communities, workers and environment	Retained
	Space requirement	Retained
	Waste residuals	Retained
	Water consumption per kg of waste	Removed
Social	Acceptance of cost	Retained
	Acceptability of treatment residues by local landfill	Retained
	Extent of necessary resettlement of people	Retained
	Land requirement	Retained
	Policy level	Retained
	Public acceptance	Retained
	Technology acceptance	Removed
	Technology acquisition	Removed
	Visible or aesthetic impact	Retained
Technical	Ability to treat a wide range of infectious waste	Removed
	Adaptable to future situations	Retained
	Availability of spare parts and usage of local materials or manufactured technologies	Retained
	Availability of local expertise/skilled operators	Retained
	Compatibility with existing technology and natural conditions	Retained
	Level of automation/sophistication	Retained
	Occupational hazards	Retained
	Reliability/ease of operation	Removed
	Security	Removed
	Treatment effectiveness/capability	Retained
	Track record on performance	Retained

Determination of the Meaningful Green Criteria and Sub-Criteria for Pharmaceutical Waste Disposal Practices in Malaysia

Based on the extensive review conducted from various literature and the experts, it can be determined that this research has obtained four main green criteria, namely economic, environmental, social, and technical as well as 31 sub-criteria that have been grouped according to each criterion specified for pharmaceutical waste disposal practices in Malaysia. For the economic criterion, there are five sub-criteria that have been identified, which are capital cost, disposal cost, installation requirement, the net cost per ton and operation and maintenance cost. While for environmental criterion, there are 10 sub-criteria such as emission of air and secondary pollution, extent of use of renewable energy, mass and volume reduction, noise, odor, release with health effects, resource recovery capabilities, risk level for communities, workers and environment, space requirement as well as waste residuals.

Next, social criterion have recorded acceptance cost, acceptability of treatment residues by community, extent of necessary resettlement of people, land requirement, public perception on aesthetic impact and waste disposal related policies including the societal wellbeings, which makes six sub-criteria in total for social criterion, whereby technical criterion has stated a total of 10 criteria such as category of pharmaceutical waste (i.e., Class I, Class II & Class III), adaptable to future situations, availability of spare parts and usage of local materials or manufactured

technologies, availability of local expertise/skilled operators, compatibility with existing technology and natural conditions, level of automation/sophistication, occupational hazard, track record on performance, treatment effectiveness/capability and waste-to-energy (WtE) requirement. To simplify, all of the meaningful criteria and sub-criteria designated for pharmaceutical waste disposal practices in Malaysia can be illustrated using hierarchy structure in Fig 2.

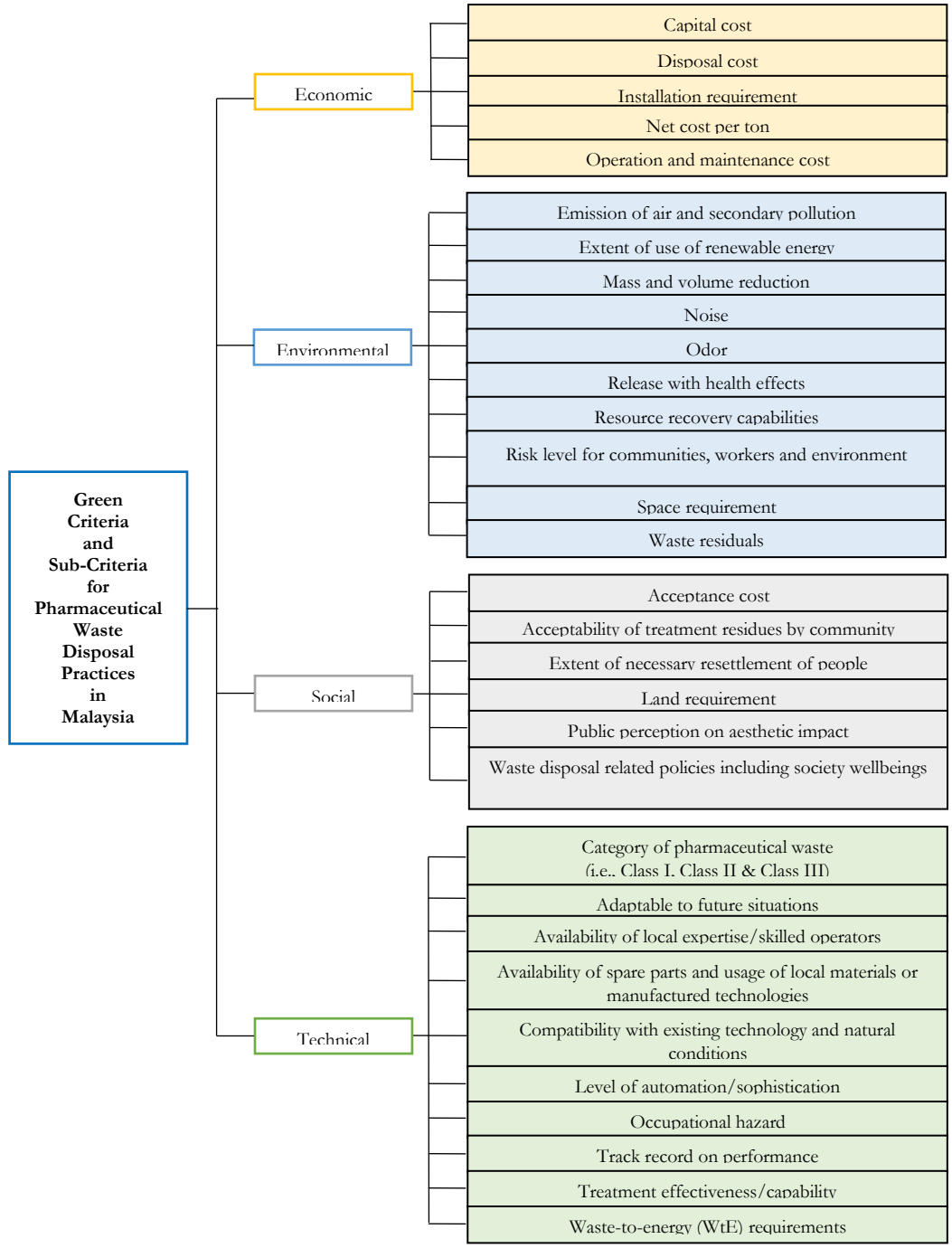

Fig. 2 The Green Criteria and Sub-Criteria for Pharmaceutical Waste Disposal Practices in Malaysia.

Conclusion

This research has reviewed criteria and sub-criteria with green elements for green pharmaceutical waste disposal practice in Malaysia. It is suggested that four main criteria comprising 31 sub-criteria should be taken into consideration in implementing the green practice of pharmaceutical waste disposal. Improper disposal of pharmaceutical waste has the potential to adversely affect the human ecosystems and wildlife. There are various disposal treatments and technologies that can be employed to dispose pharmaceutical waste, but to date their effectiveness and safety for a long-term used has not yet to be determined. Therefore, a safe and green form of practices needs to be implemented in order to prevent more problems due to improper disposal of pharmaceutical waste. The main advantage of this research is that it can provide guidelines for the selection of appropriate pharmaceutical waste disposal practices by considering green criteria and sub-criteria simultaneously, such as economic, environmental, social, technical and 31 other sub-criteria. Therefore, this research has proposed more secure pharmaceutical waste disposal practice as it considers green criteria and sub-criteria compared to previous research.

Nonetheless, there are some drawbacks that have been recognized in this research. This research only uses the opinion of experts from the Engineering Services Division, Ministry of Health Malaysia (MOHM), while policy making on pharmaceutical waste disposal practices in Malaysia involves several organizations indirectly such as the Department of Environment (DOE) and concession companies. Therefore, the obtained criteria and sub-criteria through this research can be less comprehensive. The future research should consider opinions from the abovementioned organizations so that it can be applied holistically, in both public and private sectors in Malaysia. This research uses only a qualitative approach to determine the green criteria and sub-criteria for pharmaceutical waste disposal practices in Malaysia. Nevertheless, the research can be further improved by adopting a quantitative approach, which is to quantify or measure the level of importance of each criterion and sub-criteria based on the opinion of experts. The level of importance for the criteria and sub-criteria will then be measured based on the weightages given by the experts using a multi-criteria decision-making model. Future research on the selection of the best disposal treatment based on the criteria and sub-criteria involved could also be done using several Multicriteria Decision Making (MCDM) technuque, such as the Analytical Hierarchy Process (AHP) and Best-Worst Method (BWM) if each of the criterion and sub-criteria need to be prioritized.

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