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Challenges and Recommendation of the Information Technologies Application in Hazardous Medical Waste Management amidst Pandemic Covid-19

Challenges and Recommendation of the Information Technologies Application in Hazardous Medical Waste Management amidst Pandemic Covid-19

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Abstract. Handling of Covid-19 patients requires more medical equipment than normal conditions, increasing the amount of hazardous medical waste. The management of hazardous medical waste has many challenges; therefore, it needed a strategy to solve it using information technology. Based on a filter of 376 articles, this review adopted a Systematic Literature Review approach to evaluating the recent challenge and recommendation in the field of Hazardous Medical Waste Management amidst Covid-19. Through a four-phase workflow consisting of searching, screening, excluded, and included literature search, this study identified the most influential journals, scholars, and articles that have been influential in the domain of Hazardous Medical Waste Management. These literature review results are four challenges in Hazardous Medical Waste Management, including Regulation, Technology, Financial and Awareness. The other finding is IT application recommendations such as IoT, Big Data, DSS, AI and GIS. By providing the latest research about the challenges and recommendations in the domain of Hazardous Medical Waste Management amidst Covid-19, the paper serves as a preliminary recommendation for practitioners and researchers to link current research to future trends.

1. Introduction

COV-19 pandemic has shattered the world. The total number of infected people has increased from 5 million in March 2020 to more than 53 million in October 2020 and continues to grow, which does not appear to have peaked at its current stage [1]. The COV-19 pandemic has triggered a global crisis and has elevated economic and social concerns that will also overflow into environmental concerns. The impact of COV-19 on hazardous medical waste management consist of changes in waste composition, amount of waste, frequency and timing of disposal (temporal), allocation (spatial) and risk of infection [2]. Waste prevention and adaptation measures in various countries have been summarized by (ACR +, 2020). Dynamic and responsive action is required to overcome challenges. For instance, waste collection and distribution must be corrected due to changes in the amount and composition of waste. Existing waste collection systems, both frequency and route, can be changed by requests for garbage collection at different places and at other times [3]. It is limited to existing processing facilities and capacities, which may or may not be ready to adapt to this sudden change.

The hazardous medical waste produced during the pandemic is not limited to waste produced by hospitals and health centers. It can also be from people with mild symptoms or without symptoms of Covid-19 as well as producing virus-laden waste (masks, gloves, tissues, etc., which is dumped). Since

viruses can persist in cardboard, plastic and metal for hours to days organizing or disposing of the waste indiscriminately can endanger the lives of workers involved in waste management. [4].

The practices of collection, separation, storage, transportation, care and disposal, and important related aspects, including disinfection, protection of personnel, and improper training, can lead to contamination of waste with viruses, which can pose a risk of transmission. Therefore, the safe treating and final demolition of hazardous medical waste are essential in an effective action. However, due to the limited availability of infrastructure and waste management technology in several countries, several alternative technologies were studied to assist waste management by utilizing information technology, such as waste management with big data, IoT and AI.

The concept has currently received limited attention and is not yet widely understood, although its potential is well documented. Therefore, a systematic review is applied in this study to fill the research gap. The mission of this study is to present a literature review on the issues and barriers in hazardous medical waste management and the use of technology that enables more efficient, effective and sustainable waste management. The research also recommends innovative alternative solutions to existing infectious medical waste management challenges.

The main contribution of this research is based on an exploration of literature reviews, namely the barriers to hazardous medical waste management during the Covid-19 pandemic and recommendations for alternative information technology-based waste management solutions. These findings provide insights for all stakeholders, including technology service providers, users, governments, monitoring agencies, industry associations and the public, to overcome these barriers. This paper is divided into five sections and starts with a background on the challenges in hazardous medical waste management and information technology adopted in hazardous medical waste management, followed by reviewing the relevant literature. The following sections describe the data collection methodology and procedures. Section 4 presents the results, analysis and findings of hazardous medical waste management and information technology adopted in hazardous medical waste management. Conclusions and recommendations on how to proceed in the future are presented at the end.

2. Method

This study applies a literature review methodology strategy with Kitchenham's systematic review technique [5][6]. The first step is to identify the purpose of the review, then answer by constructing a research question. After asking questions, a review procedure was developed. There are three stages to selecting relevant articles. First, an initial reference search is carried out, selecting relevant manuscripts with the title and full text. The final stage was compiling filtered references and conducting analysis and interpretation between selected literature collections to answer the research questions. The elaboration of the review process is described in Research Issue.

2.1. Research issue.

This analysis objectives to find the Hazardous Medical Waste Management solution proposed by the initial research on handling the Covid-19 Pandemic. Therefore, we formulate two research questions in this study, as follows:

Table 1. Research Question and Objective

Research Question (RQ)	Objective (Obj)
RQ1: What are the challenges in managing biomedical hazardous waste?	Obj1: To identify the challenges in hazardous medical waste management during the pandemic
RQ2: What are the recommendations in managing hazardous medical waste management during the pandemic?	Obj2: To determine the recommendations in managing hazardous medical waste management during the pandemic

2.2. Schematic Examination

Before selecting the literature to investigate, firstly, this study developed a critical review procedure, including manuscript sources, key phrases, and elimination and inclusion criteria. This analysis process uses six reference material sources such as Scopus, IEEE Xplore, SpringerLink, Emerald Insight, ProQuest, and ScienceDirect. The focus of this analysis is to explore challenges and recommendations regarding the management of hazardous medical waste during the Covid-19 Pandemic. Thus, the question terms practiced in the literature search step were as follows:

> (challenge OR barrier OR problem) AND (opportunity OR innovation OR recommendation) AND (hazardous medical waste management OR hospital hazardous waste management OR health-care hazardous waste management) AND (pandemic OR covid-19)).

Primary search results for the year of publication in the last two years (2019-2020) and include several manuscripts, including papers, journals, and book chapters. This study developed an inclusion and elimination standard for each selection procedure, as shown in Table 2 below.

Table 2. Inclusion and Elimination Criteria

Phase	Initial Phase	Phase 1 (Title and abstract selection)	Phase 2 (Full-text selection)
Inclusion Criteria	- Similar to the enlisted query string	- Associated to challenge, recommendation, hazardous medical waste management, pandemic, Covid-19	- The solution to the research question - Deliver relevant context with the challenge, recommendation, hazardous medical waste management, pandemic, Covid-19
Exclusion Criteria	- Irrelevant domain - Published more than one year ago	- A case study in the hospitals, clinics and labs - Irrelevant with industry domain	- A case study of non-hazardous medical waste management - Unavailable full text - Duplicate manuscript

2.3. Quality Assessment

This study arranged eight requirements to evaluate the chosen literature's quality [7], as shown in Table 3 below.

Table 3. Literature Requirement Checklist

Req	*Requirement* Issue	*Y / N / P*
R1	Does the paper define objectives?	Y / N / P
R2	Does the publication include a relevant literature review, background, and research context?	Y / N / P
R3	Does the manuscript declare an obvious research methodology?	Y / N / P
R4	Does the reference present definite contributions?	Y / N / P
R5	Does the conclusion solve the research issue?	Y / N / P
R6	Does the article recommend future research opportunities?	Y / N / P
R7	Does the finding relate to the biomedical hazardous waste context?	Y / N / P
R8	How is the reputation of the publisher? (Q1/Q2/Q3/Q4/conference	Y / N / P

Particularly article was supplied a statement based on the requirement question. Yes statement concern to the quality of articles, though No and Partially refers to the article's inadequate substantiation to fulfill the criteria.

2.4. Study Selection

From the results of this initial reference analysis, 376 manuscripts were defined based on the keywords specified in the search stage. Since eliminating papers by abstract and title, the number of major studies was decreased to 137. Then after selecting based on the full text and eliminating duplicate manuscripts, 51 papers were included in the analysis stage. The final stage, peer-reviewed author reviews, used the Manuscript Guidelines (see Table 3), which preferred 27 papers. Figure 1 below delivers a specific process based on the inclusion and predefined criteria.

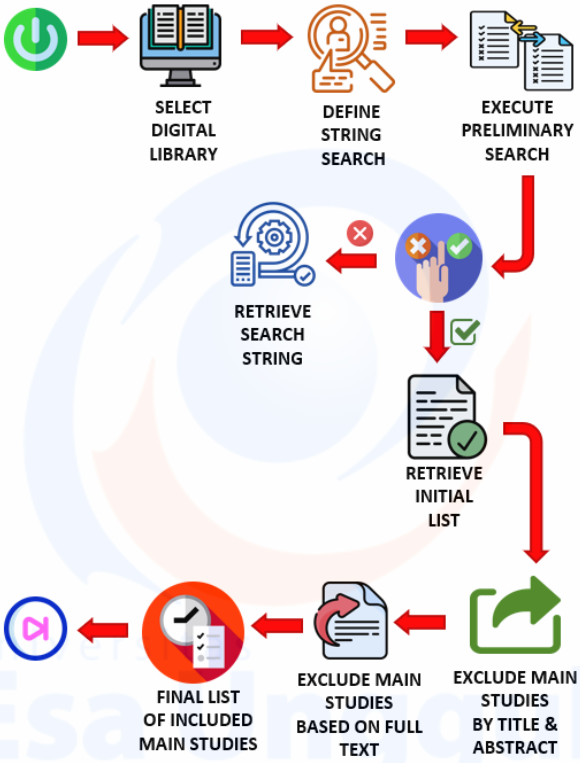

Figure 1. Study Selection Process

2.5. Evaluation of Finding

The analysis process begins by extracting metadata from each manuscript. This research adopts the UNSW pattern to conduct an annotated bibliography to map each article's metadata and remove the matter. The annotated bibliography consist of several components such as citation, title, background, research purposes, methodology, research scope, limitations, conclusions, and reflections. This study also analyzes the topics described in the paper based on the purpose of using IT. The process of synthesis and classification of articles is arranged based on the outcome of the previous process

3. Results and Discussion

3.1. Demography of Selected Studies

Based on the results of the publication demography, it is known that the challenges in managing hazardous medical waste during the pandemic are divided into four categories, it concist of Regulation, Technology, Financial and Awareness. The demographics present that the Technology, Financial and Regulatory categories each received four publications amounting to 26-27%. The rest is owned by the

Awareness category, which has three articles of publication. This result indicates that the three categories of Technology, Financial and Regulation, are very important because they become the resource to encourage the management of hazardous medical waste to be more efficient. However, the awareness category is also important because this factor becomes the basis for changes in the behavior and culture of the community in managing hazardous medical waste.

By the countries of publication producing countries, it can be seen that most publications are dominated by developing countries. There are only four publications from developed countries. This result defines that many developing countries face the problem of hazardous medical waste management due to the limited ability to provide infrastructure, technology and awareness in hazardous waste management. The detail od challenges in hazardous medical waste management is shown on Figure 2.

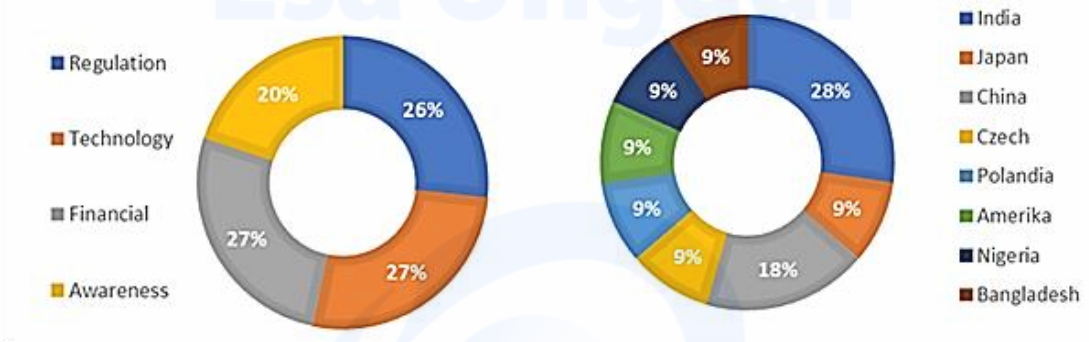

Figure 2. Challenges Demography

The demography analysis of publications on the recommendations for IT applications in waste management during the pandemic, that the IT applications that the IoT and IS / DSS were widely adopted then followed by AI and GIS while Big Data and Blockchain were only discussed in one article. From this data, the IoT technology is the preferred technology in the development of smart cities, in which IoT and GIS technologies are combined to control the amount of hazardous waste and monitor the amount of waste generated during the pandemic; thus, the information can be presented well where waste is positioned and waste management can run efficiently.

From the regions of publication, it can be seen that most of the publications are dominated by developing countries, namely as much as 56%, there are only seven publications from China and Hong Kong. This shows that IT adoption in the management of hazardous medical waste is an essential concern for developing countries. This occurs because the amount of waste that appears during the pandemic period is increasing while the waste processing facilities owned by developing countries are very limited; for this reason, innovation is needed to manage hazardous medical waste in the face of the pandemic. The elaboration of IT recommendation for hazardous medical waste management is shown on Figure 3.

Figure 3. Recommendation Demography

3.2. Challenges in managing hazardous medical waste

The review of the research documented five critical challenges. These challenges were identified most regularly and were defined to be essential. They are defined as follows*:*

3.2.1. Uncertainty of the authority obligations

Restriction in environmental guidelines and law enforcement in the C-19 pandemic have been described as major obstacles. It arises because the constraint of socialization and counseling regarding the regulation of hazardous medical waste and the absence of sanctions violations in the domain of infectious medical waste (vulnerable law enforcement) is a challenge in treating hazardous waste for society and the environment. Due to this lack of regulatory pressure, many organizations do properly manage infectious medical waste. They do not feel obliged to invest in the latest technology to improve the quality of hazardous medical waste management [8], [9]

Lack of authority commitment is a common obstacle for initiatives business process improvement. Countries should be committed to protecting the environment, not only to secure resources but also to re-engineer business processes to manage hazardous medical waste [10], [11]. Law enforcement in infectious medical waste management is also a manifestation of the government in implementing the principles of Good Environmental Governance to raise

It requires a variety of methods for environmental restoration. As a result, the lack of appropriate infectious medical waste management standards is a challenge in treating hazardous waste for society and the environment.

3.2.2. Barrier of awareness about environmental and waste management issues.

The next of the critical barriers to implementing hazardous medical waste management is a lack of awareness about environmental and sustainability issues-particularly in pandemic Covid-19. According to Rume et al [10], [12] for organizations to be more oriented towards sustainability, they must create changes such as environmentally friendly technology, sustainability schemes and provide sustainable products and product-service combinations.

Lack of education and knowledge of the environmental protection culture results in their mindset, habits and behavior often not paying attention to environmental protection. Through accurate information, various types of hazardous waste can be identified efficiently and contribute significantly to the success of hazardous medical waste management practices. Hazardous waste is always generated as part of a structure. Therefore, identification of waste by reference to current information is important [13]

3.2.3. Issues in Information Technologies

The application of the latest technology and its application particularly in infectious medical waste management, has recently begun in several organizations and countries, mainly due to pandemic conditions. Many organizations or nations do not have the proper information or ability to conduct technology-based infectious medical waste management. This obstacle is usually faced by poor and developing nations. Thus, it affected the ignorant on improving infectious medical waste management by applying information technology [14], [15].

Smart technology has large capacities, but its applications pose technological challenges. One of the most common barriers is "difficulties in technology integration" [10]. This difficulty arises when organizations or countries implement multiplatform technologies that are not compatible with each other. Another difficulty arises with technology with rapid model life cycles. Since the agile growth of innovation in the technology domain, it is difficult for many users to catch up. Although, technological developments for the classification and analysis of infectious medical waste are restricted, especially during the pandemic. [11]

Information system support and infrastructure availability are important elements in the management of hazardous waste during a pandemic, where technology is needed that can solve the hazardous medical waste management rapidly, timeless and limitless. Thus, information technology is the right medium to assist the infectious medical waste treatment during the pandemic.

3.2.4. Funding and Collaboration Constraints

Many organizations or countries are having difficulty getting funding to improve hazardous waste management amidst this pandemic. Partly because the investment required in hazardous medical waste management technology is very high for organizations and individuals Implementing information technology in hazardous medical waste management during this pandemic requires a large investment, but reducing the spread of the virus is a top priority implementing technology-based waste management is not possible when organizations only pursue their short-term economic interests. [10], [16]

Many countries are still facing limited funding sources for investment, operations, and maintenance, resulting in minimal management of infectious waste. Infectious medical waste management is not yet a priority, so the budget allocation for waste management is limited. Nevertheless, collaboration with the private sector in the form of investment and Corporate Social Responsibility has been carried out in several countries, such as infrastructure assistance (trash bins, transportation equipment, and waste management training for the community). Hazardous medical waste reduction projects change the standard to assist the recovery of hazardous waste materials, which are costly [17], [18]. Thus, the lack of sufficient funding to support technology initiatives aimed at helping hazardous waste treatment becomes a barrier.

3.3. Recommendations for the of information technologies in hazardous medical waste management

Currently, no country has prepared to amidst the Cov-19 pandemic. The strategy in overcoming the gap in Covid-19 is to increase supervision of infectious medical waste management, starting from waste sorting, temporary storage, transportation, and destruction must be carried out thoroughly and continuously. Obstacles in implementing one process chain need to be evaluated immediately. In-fact many countries keep using incinerators in the handling of hazardous medical waste. However, this technology is not environmentally friendly because combustion products that do not meet standards can cause air pollution, worsening the pandemic situation related to air pollution it causes. Therefore, efforts were made to find ways to manage hazardous medical waste. The right step to bring about this change is to present medical waste treatment technology that is environmentally friendly by applying information technology.

The mapping between information technology and its benefits for the treatment of hazardous medical waste as shown in Table 4

Table 4. Information Technology Mapping

Inf Tech	Source(s)	Setting Route	Control Hazardous Waste	Real-Time Waste Inf.	Monitor and Measure the level of container
IoT and realtime GIS	[10], [19]–[24]	✓	✓	✓	✓
BlockChain	[25]	✓			
Cloud Computing and Big Data Analytics	[26]		✓		✓
Information System and Decision Support Systems	[27]–[31][32], [33]	✓	✓	✓	✓
Artificial intelligence, including machine learning and deep learning	[30], [34]		✓		✓

There are four categories of hazardous waste management systems using information technology according to Esmaeilian et al. [35], namely compiling and developing sensor-based data and technology,

communication and data transmission technology, field trial technology, and technology for managing and scheduling waste hauling truck routes. Geographical Information Systems and the Internet of Things can help provide integrated, timely, and sustainable solutions. The technology is embedded into the information system for decision support [27]–[31][32], [33]. The technology helps optimize the routes that garbage disposal vehicles take for waste collection and demolition and automation via sensors in bins to signal that collection is needed because the trash is filled up [10], [19]–[24]

Artificial intelligence algorithms have integrated with big data analytics and cloud computing to analyze many waste data to provide real-time waste information [30], [34]. This technology can also offer treated waste information to provide recommendations regarding the data on the source of waste generation and how many storage and disposal sites are available [26]. The information provided can assist waste transport service providers in planning their logistics operations effectively [11], [21], [22].

A further system is a blockchain that processed infectious medical waste information using smartphones. The system manages central waste storage information in a database server system. Therefore, it can be monitoring incoming waste generation data from hospitals and health services. The flow of data and information on waste management presented transparently. The resulting report can help decision-makers be more optimistic about managing hazardous medical waste [25].

4. Conclusion

This paper draws on the issues of proximity and challenges to global waste management in the context of the current COVID-19 crisis. Although reduced economic activity due to COVID-19 has made the air and air cleaner, the change in biomedical waste generation at the same time poses problems in the management of hazardous medicine. Virus-laden medical waste can pose a health risk to sanitation workers. Therefore, hospital and health center waste need to be designed separately while the waste stream can be managed according to the provisions of regular waste management. However, many obstacles are the implementation of better waste management. These obstacles are difficult to overcome because they are related to one another. The challenges that exist in managing hazardous medical waste during the COVID-19 pandemic are the contribution of this research, as for the obstacles that arise from

Several studies state that an intelligent waste management system can reduce transportation costs by up to 30% and carbon emissions by 60%. The means that a waste management system can help decrease air contamination and have a smaller environmental impact. The synthesize of eliminating the number of hazardous medical waste and increasing environmentally friendly dangerous medical waste treatment technologies is a sustainable solution.

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