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Towards digitalization of Malaysian Medical Facilities Waste Management

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Abstract

Medical waste is produced in huge quantities daily, and the increasing amount of it is a worldwide issue that makes managing medical waste more and more crucial. Leakage or improper use of medical waste can be harmful, risking the environment and human lives. The pandemic COVID-19 has challenged current practices with the increasing number of waste and the possibility of transferring the virus from one person to another. In Malaysia, waste management predominantly remains a manual endeavor. where data is usually keyed in either by waste generators, transport contractors, or process occupiers. Digitalization of this setup can be a way to manage waste management effectively as it could be tracked and monitored in real-time. This paper discusses the applicability of exponential technologies, such as Internet of Things and Blockchain, to communicate real-time data to all stakeholders. It presents a framework that can be used to improve the overall waste management process by improving tracking and tractability of waste. Such technology is expected to have an impact across the whole waste management cycle including segregation, storage, transport, and disposal process, and at the same time, help with documentation and administration arrangement.

Keywords: medical waste, Malaysia, waste management

1. Introduction

Malaysia, a developing country, has one of the best healthcare facilities in the world. According to an article in Malaysia Today, in 2020, Malaysia ranked first in healthcare services with advanced technologies and fluent English-speaking doctors [1]. However, this rank does not reflect the technology and systems utilized in managing medical waste. World Health Organization (WHO), through its guidelines, has defined the classification of medical waste that exists in hospitals, clinics, and other medical facilities (Table 1). Medical waste in Malaysia is controlled by the Environmental Quality Act under the category of Scheduled Waste, grouped as SW403, SW404, SW421, and SW405 since 2005. This act is regulated under Malaysian Environment Quality Act 1974 (EQA 1974).

With the presence of 144 public and 240 private hospitals, Malaysia produced 33,000 metric tonnes (Mt) in the year 2022 [2]. This number was reported to increase by 27% due to pandemic outbreaks and is expected to keep increasing. Malaysia works for the best to take advice from WHO, even though they come with different terms for handling their healthcare wastes. Malaysia segregates medical waste into six major groups. The terminology of the waste category used by Malaysian hospitals and clinics can be seen in Table 1.

Medical waste can be a potent source of diseases such as HIV, Hepatitis B, and Hepatitis C [3]. Covid-19 viruses, a worldwide issue, can be transferred easily with improper handling. These diseases can cause serious threats to human lives; therefore, it needs appropriate attention [4].

Waste management in the medical industry is not only involved disposal. It starts from segregation and collection, storage facilities, transportation, and finally, the disposal process. The primary objective of waste management is to ensure no infectious, hazardous materials, diseases, viruses, or other bacterial contamination affects humans and the environment.

Until today, Malaysian medical waste management is more focused on documentation and administration [5], [6]. Malaysia served medical waste by attending to the weight of the waste, storage, and transportation companies involved and the date of waste has been processed. With the presence of website technology, Malaysia is moving to manage waste electronically. However, tracking by administrating is perhaps not enough. In developed countries, waste management is tracked using high-technology integrated systems, including CCTV, Wi-Fi, and RFID. For example, the usage of RFID bags, stickers, waste weighing systems, transporting lorries, and landfill areas has been introduced in Korea as early as the SUDOKWON project started [7]. The following research questions are investigated:

1. What are the limitations of the current approaches used for medical waste management in Malaysia?
2. How an actionable framework can be designed to address the issues of medical waste management?
3. How to gain stakeholder confidence to use the recommended system?

Implementation of waste management using IoT can be one of the best choices to not only monitor the waste process but to assist the administration's work. As medical waste continues to increase, the violation possibilities can be increasing together. IoT systems with the usage of sensors and RFID readers may work together to enhance the quality of waste management. A system with an embed of sensors and RFID tagging is planned to manage the stages of waste management focus parameter (Table 2). This tagging can be connected to a blockchain network in the loop of all identities involved in waste management from manufacturers to the users (hospitals) to the storage and transportation contractors and treatment occupiers.

2. Medical Waste Management in Malaysia

2.1. Segregation and Collection

Segregation of medical waste in Malaysia is divided into general, human blood and body fluid, infectious and pharmaceutical waste. The utilization of colour coding has been raised by WHO and proven as a good segregation approach in the medical industry. Malaysian hospitals and clinics segregated their waste by using colour code bins to ease the steps of the storage and sterilization process, which can easily be referred to in Table 2. WHO guides colour bin segregation using yellow, brown, and black bins, with the function of hazard and biohazard labels. All yellow biohazard plastic will need to be collected and transferred from clinical

Table 1: Medical waste definition and terminology [9], [10]

Definition	**World Health Organization (WHO)**	**Malaysia**
Terminology	Healthcare waste	Clinical Waste
Sharps	Sharps	Sharps
Body parts and organic including blood bags and blood preserves	Pathological waste	Blood and Body fluid waste
Waste is subject to the special requirement to prevent infectiously	Infectious waste	Infectious waste
Waste is not subject to any special requirement	General waste	General waste
Chemicals consisting of dangerous substances	Chemical waste	Infectious waste
Medicines and control drugs	Pharmaceutical & Cytotoxic waste	Pharmaceutical & Cytotoxic Pharmaceutical waste

Table 2: Medical waste management procedures in Malaysian medical facilities [8], [10].

Waste category		**Colour of container/bin**	**Procedure**
Sharps		Yellow bin with label 'SHARP'	• Date the starting day of use • Layer with yellow biohazard plastics Empty the bin at least once a week or when it is ¾ full.
Blood and body fluid		Yellow	
Infectious	Stool specimen, body liquid, excrement	Light blue	• Light blue bag to be sent to Autoclave, change to the yellow bag before sending to incineration.
	Expired blood, blood components, surgical tissue, culture plate	Yellow	• Date with the day of waste produced.
Pharmaceutical & Cytotoxic Pharmaceutical	Pharmaceuticals that pose no hazard during collection such as chamomile tea, cough syrup	Black	Manage to join the municipal waste
	Pharmaceuticals that pose a hazard when used improperly	Yellow	
	Heavy metal, contains unidentifiable pharmaceuticals	Yellow	
Reusable linen	Used and non-infectious	White	Wash with detergent and dry
	Used and infected	Red	Soak in sodium hypochlorite 0.5% for 30 minutes before rinsing with water and dry.

areas to storage facilities daily [8]. All waste bags are compulsory to have clear labels and dates of production before transfer to any eleven off-site facilities licensed by the Ministry of Environment to handle medical wastes in Malaysia.

2.2 Storage

Malaysian hospitals approach two types of storage facilities; temporary storage and off-site central waste storage. This interim storage facility must be enclosed and separate from any medical supply room and food preparation areas [9]. Storage facilities should be well-maintained, adequately lit, ventilated, and free from all pests. Spillage and leakage to the surroundings can be dangerous to the environment and allow the misapplication of waste. In the central waste storage facilities in Malaysia, the storage areas are designed to limit accumulated storage. They are not more than 20 metric tonnes and do not exceed 24 - 48 hours of storage, depending on the waste type [8], [10]. Refrigeration between 4- 6 °C is required if a large amount of waste is planned to be stored in any storage facility.

2.3 Transportation

Waste facilities use a wheeled cart to carry all waste. Trolleys and wheelie bins are used mostly in Malaysian waste internally within medical centers and storage facilities. Transporting medical wastes on the road to the off-site facilities will require dedicated vehicles and must avoid populated areas, the water catchment, and other environmentally sensitive areas. The government licenses only seven treatment facilities to handle medical waste disposal in the whole of Malaysia [11]. In the Republic of Korea, waste is limited to travel up to a maximum of 350 km and four hours of traveling time [12]. The transportation is also completed with refrigeration facilities to take care of the waste condition during traveling.

2.4 Process.

Treatment and disposal are aimed to reduce the potential of infection, contamination, or virus spread to humans and the environment. Incineration has been confirmed as a preferred method of any medical waste disposal handler since 2005 [12]. This method is useful for the destruction of pathogenically hazardous organic matter in medical waste. Because of this advantage, incineration is an expensive method that may produce many toxic emissions such as Dioxin and Furan [12], [13]. There are also five other treatment processes that can be used as a method in treating and disposing of waste. Low-heat thermal process, which is done without the presence of oxygen, could destroy the microorganism. This process is operated between 100°C to 180°C to treat medical waste even if it is not sufficient to cause combustion [9]. Mechanical processes such as shredding, grinding, and mixing may help reduce waste volume and improve heat transfer rate. Besides, enzymes can be utilized to speed up the destruction process of waste-containing pathogens. Chemical treatment is usually used as a medium of disinfection. Malaysia chooses to do incineration as a preferable disposal method to handle medical waste.

Incineration is usually operating at high temperatures and under controlled conditions. The temperature can be as high as 1100°C to 1600°C. Before incineration, the autoclave is done on infectious waste for sanitization. The flow of waste processes can be easily seen in Fig. 1.

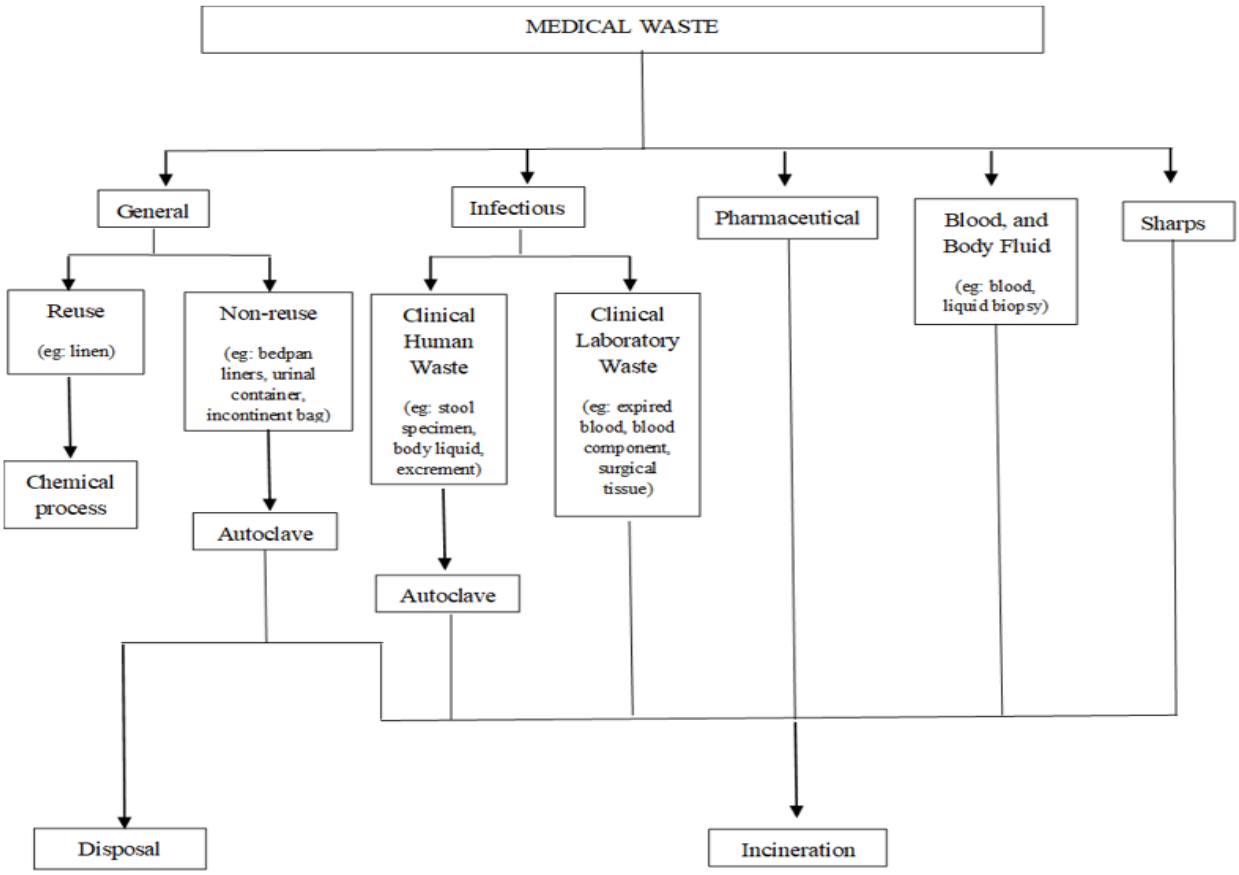

Fig.1. Treatment and Disposal Method of Medical Waste from Malaysian Hospital

3. Challenge of Malaysian Medical Waste Management

The Malaysian citizen, after the announcement of MCO, is subjected to the rule of being fined not more than RM1000 or jailed for not more than six months or both to anyone who abides by it [14]. During the MCO, all Malaysian citizens must wear face masks in public spaces to stem the coronavirus infection. With the regulation of mandatory wearing of PPE and the high number of active cases, Malaysians will produce more and more hazardous waste every day. With the current technology and manual human work, the situation can bring the issue of:

1. Increasing the number of medical wastes to be taken care of that are produced by the medical staff and patients. The waste includes all the PPE, linens, medication, excretion, and food.
2. Violation of waste in municipal waste that will mostly be brought to incineration or landfilling centres. Workers need to check the violation manually and can be poisoned by the virus during working, or pollution of land, air, and water could happen due to the violation.
3. Too many manufacturers produce PPE for Malaysians without taking responsibility for tracking medical waste management and proper disposal.
4. Administration and records of medical centres in purchasing PPE and waste generation are being supervised separately.

4. Internet of Things

The Internet of things (IoT) is an inventive technology that integrates with various sensors or actuators in both wired and mostly wireless networks. IoT connects physical objects digitally to sense, monitor, and interact with the users [15]. IoT can be a significant modern technology that offers better administration and monitoring strategies for waste management by connecting the RFID and sensors to the integration of advanced technologies [16]. In other words, IoT can give the experience of monitoring systems by providing the actual status of the waste.

The IoT is a three-layers architecture network that includes the perception layer, network layer, and application layer. The perception layer plays a role in connecting to the sensors and actuators. The network layer is usually represented as Wi-Fi or Bluetooth, enabling the transmission and processing of data to the cloud. Cloud is a server or promising technology where data can be stored safely. The application layer provides application services to visualize the situation in any remote location. The flow of the three layers network is shown in Fig. 2.

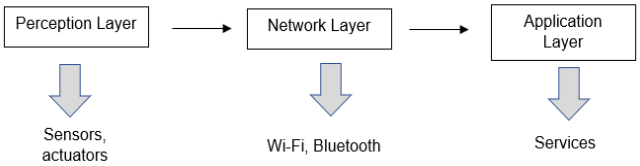

Fig. 2. Architecture of three-layer network in IoT [16].

Sensors are the most crucial parts for IoT to function [16]. Generally, most of the sensors embedded in previous research are to focus on monitoring the bin level by using ultrasonic sensors [16] – [21]. The development of IoT is not new to medical industry. Back in 2017, IoT with the help of cloud computing has been introduced to the medical industry and affected better healthcare services. Many body sensor machines, wearable devices, and medical equipment are connected to IoT networks to allow patient monitoring in medical services [22]. The medical industry also faces enormous challenges to save generated data of documentation for both medical and management.

This growing volume of IoT devices has opened opportunities for high-technology services that benefit not only medical providers but also patients. Sleep patterns, cardio fitness levels, and heartbeat readings can be easily monitored by using smartwatches and smartphones. Not only that but the deep neural network of the AI revolution is also used in diagnosing diseases like cancer [23].

In medical waste management, IoT is proposed for managing smart bins. The bins, with the approach of colour codes, will be monitored waste levels and weighing capacities. Research has proposed the utilization of IoT as a way of connecting the bins' status to waste contractors [24]. Monitoring the weight of medical waste is also proposed by using Blockchain technology in 2022 [25].

All data and information collected will be transferred and stored in the cloud. Wi-Fi and Bluetooth are examples of the network used to connect data to the server and be used to provide services. In this case, the IoT system is expected to provide a service in waste management.

5. Radio-Frequency Identification (RFID)

RFID is an electromagnetic tracking tag that can be attached to any object. In Malaysia, RFID is widely used in tracking cars for highway tolls payment. In waste management, RFID can work as a medium with the alert of other censors to allocate information to the government along the waste management processes. Rapid Frequency Identification (RFID) is a recommended medium used as a medium for classifying, identifying, or tracking works in segregating and labeling waste [26].

The medical industry has introduced RFID technology with the approach of iMedBox. Through this proposal, patients can get their medicine from the box by touching the RFID tags to the medicine box. All medicine prescriptions are inserted by the doctors during the consultation [27]. Recently, RFID is also proposed to be used in sensing glucose concentration [28].

RFID is not new in waste management. In developed countries, the residents are compulsory to throw their waste by only using RFID bags [29]. In the medical waste management, RFID is not only proposed to be used in smart bin lids and with sensors to monitor waste levels but to track the location of the waste [16] – [21], [30].

6. Blockchain Technology

Blockchain is a network technology that will be giving notification updates to all individuals that are connected in the loop. These individuals are called stakeholders. Each of the stakeholder who are registered in this smart contract, will receive evidence of any transaction or payment peer to peer and encrypted using public-key cryptography [15], [31]. Blockchain technology is popular since the existence of

Bitcoin. This technology is viewed as working independently with centralized authorization.

Waste management stakeholders include the waste occupiers, waste storage and transport contractors, and the treatment and process occupiers. Blockchain can be a medium of communication for these clients to be updated on the status and condition of the waste. The technology can be programmed to record and track data from the purchasing status to waste segregation to storage and transportation, and lastly the process involved in the supervised waste.

The medical industry adopted blockchain technology recently. This has been presented by research on waste management. In monitoring waste weights, data will be presented to the loop of waste generators, transport contractors, and treatment occupiers.

7. Proposed Methodology

Malaysia has improvised the management systems for medical waste. Usage of the eSWIS portal helps to track waste inventories and administration [6], [32]. This portal can be expected to improve the information for the transportation and disposal process. This can be useful to the Malaysian government in tracking waste information.

In resolving the challenges faced by Malaysians, RFID controls can associate with medical waste management services. Current waste management is too dependent on hard-copy documentation and manual work. IoT with the technology of blockchain and RFID can be useful to bridge the gap. Table 3 shows the focus parameters of every stage of waste management processes.

Table 3: Focal of each stage of medical waste management and proposal methodology

Procedure	Focus Parameter	Proposed Methodology
Segregation	- Type of waste. This focus is to ensure the no violation of waste in every bin collected from hospitals.	- Bin RFID reader
Storage	- Storage durative. Medical waste is limited storage for between 24 – 48 hours. - Humidify of storage area. The humidity control is used to ensure the waste condition has been cared for. The refrigeration temperature of storage should be between 3°C - 8°C.	- Durative sensor - Humidity sensor
Transportation	- Transport information. This is to ensure the transportation is done at the correct time, with the exact responsible company	- Transport RFID reader
Process	- Process facility information to ensure accurate process plant and process suitability for every type of waste.	- Facility RFID reader - Temperature sensor

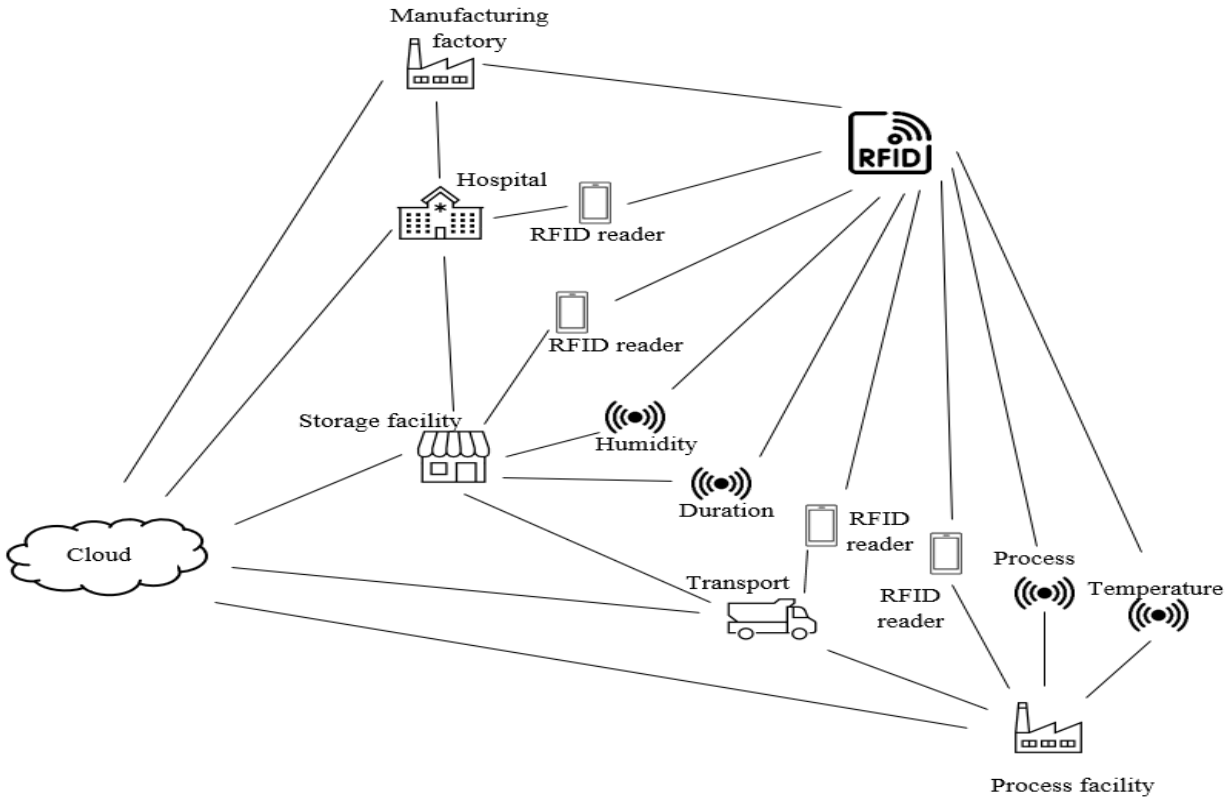

Fig. 3. Proposed methodology of medical waste tracking by using the Internet of Things.

Monitoring medical waste will start from the manufacturing of medical items. All medical PPE, tools, or instruments are designed to be installed with RFID from the manufacturing company. This RFID is expected to come with specific codes to represent the type groups of the items. This can be useful to alert staff on the violation of the waste in the waste bins. Durative sensors can be helpful to allow users to track the duration of waste being stored. These methods are planned to build with alarm systems to give notifications on waste conditions to the waste producers and storage contractors.

A humidity sensor can be used as a control method to control the condition of the waste storage. Uncontrolled humidity can cause moisture that speeds up bacterial reactions and welcomes pests. Transportation and Process RFID readers are utilized as administration medium to record responsible waste-handling trucks, location waste is forwarded, and process used for waste disposal. On locating the waste, RFID usually works by connecting to the GPS and Global packet for radio service (GPRS). This feature is famously implemented in waste collection trucks [15].

The temperature sensor is an additional piece of gear mantled to confirm the temperature used during the process is suitable for the type of waste. All this information is planned to be connected directly to user devices and the administration webpage for documentation purposes. The arrangement of sensor flows is as in Fig. 3.

Blockchain technology will be used as a communication medium for each medical waste stakeholders. As the manufacturing company produced a set of medical tools tagging will be jotted to the buyer hospital. This network loop will involve the company, the hospital, the future waste storage will be stored, transportation companies, and the process occupier. All stakeholders will be notified by the status of each of the medical items from manufacturing until they are processed to disposal. For example, if there is any case of waste violation happens in a hospital's ward, the waste generator will get notified and other stakeholders aware about this issue until it is settled.

All data collection will be stored in the cloud and can easily be used for documentation and administration works.

Conclusion

Waste management is an important quality indicator in the healthcare industry. Improper or mishandling of medical waste can allow the spread of viruses and bacterial diseases. While Malaysia has a stable administration of medical waste handling flows and the current waste management is reliable, the digitalization of the current system can further enhance the administration and documentation processes. In digitalization of systems to manage medical waste, utilization of the IoT and RFID can give a lot of advantages, e.g., the violation of waste segregation can be avoided, and waste can be tracked easily. The blockchain can also help with authorities with any data security issues.

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