ASEAN Journal of Science and Engineering

Journal homepage: http://ejournal.upi.edu/index.php/AJSE/

Digital Educational Media for Hospital Waste Management: Addressing Waste Types, Illegal Disposal, and Environmental Impact

Muhammad Dwian Rahadi [1], R. Susanti [2], Yuni Wijayanti [3], M. Maspiyah [1], Novia Restu Windayani [1], Faisal Ibnu [1]

[1] Universitas Negeri Semarang, Indonesia
[2] Universitas Negeri Surabaya, Indonesia
[3] Universitas Bina Sehat PPNI Mojokerto, Indonesia
*Correspondence: E-mail: noviawindayani@unesa.ac.id

ABSTRACT

This study examined the effectiveness of digital educational media in improving hospital waste management and reducing nosocomial infections. We developed the WM Health Solutions mobile application to provide real-time waste management education, hygiene reminders, and compliance tracking in hospitals. This can patch improper waste disposal poses health and environmental risks. We used the Analysis, Design, Development, Implementation, Evaluation (ADDIE) model. The study assessed the impact of digital learning on hospital waste practices. Because nosocomial infections are linked to poor waste handling, implementing WM Health Solutions in three hospitals led to a notable reduction in infection rates. Qualitative analysis showed that participants found digital education engaging and accessible, making waste management training more effective. Because traditional methods may not suit busy healthcare settings, mobile-based learning ensures continuous access to vital hygiene protocols. This study confirms that digital education can enhance hospital waste management, ensuring safer environments and better compliance with waste disposal regulations.

ARTICLE INFO

Article History:
Submitted/Received 25 Nov 2024
First revised 26 Dec 2024
Accepted 23 Feb 2025
First available online 24 Feb 2025
Publication date 01 Mar 2025

Keyword:
Development,
Digital media,
Education,
Environmental health,
Hospital,
Nosocomial infection.

1. INTRODUCTION

A clean and contamination-free hospital environment is an absolute requirement to prevent healthcare-related infections (Healthcare Associated Infections / HAIs) which is one of the main challenges in global health services [1]. Mobile apps for hand hygiene education in hospitals increase adherence to proper hygiene practices among medical personnel. The app provides instructional videos and daily reminders. The Waste Management Health Solutions application is a mobile or web-based software designed to assist hospitals and other healthcare facilities in managing medical waste effectively and safely. Waste management in hospitals is very important because the waste can be in the form of hazardous, infectious, and chemical materials that require special handling so as not to pollute the environment or endanger human health. In today's digital era, the use of digital media as a means of education has shown its effectiveness in various health fields.

Digital media allows for the delivery of information that is more interactive and interesting and can be accessed anytime and anywhere. Several studies have shown that digital media-based education can improve knowledge and behaviors [2-11]. Specifically, it related to hand hygiene, the use of personal protective equipment, and other hygiene procedures in hospital settings. Therefore, the application of hospital environmental health education through digital media can be an effective strategy to prevent nosocomial infections and maintain the cleanliness of the hospital environment.

Digital media allows for the delivery of information that is more interactive and interesting and can be accessed anytime and anywhere. Several studies have shown that digital media-based education can improve knowledge and behaviors related to hand hygiene, the use of personal protective equipment, and other hygiene procedures in hospital settings. Therefore, the application of hospital environmental health education through digital media can be an effective strategy to prevent nosocomial infections and maintain the cleanliness of the hospital environment.

2. LITERATURE REVIEW

2.1. Sources of Hospital Waste

Waste produced by hospitals can endanger public health, namely waste in the form of viruses and germs that originate from the Virology and Microbiology Laboratory and are difficult to detect. Liquid waste and solid waste from hospitals can function as a medium for the spread of disorders or diseases for officers, sufferers, and the community (see **Table 1**).

Liquid waste and solid waste from hospitals and health centers can serve as a medium for the spread of disorders or diseases for officers, sufferers, and the community [12]. Waste syringes and other waste can be a risk factor for the transmission of various diseases such as diseases due to nosocomial infections, HIV/AIDS, Hepatitis B and C, and other diseases transmitted through blood. The source of hospital waste comes from various activity units in the hospital area, such as outpatient/polyclinic units, inpatients, intensive care, emergency care, hemodialysis, central surgery, and mortuary (see **Table 2**).

DOI: https://doi.org/10.17509/ajse.v5i1.80941
p- ISSN 2776-6098 e- ISSN 2776-5938

Table 1. Hospital waste sources.

Waste Sources	Types of Waste Produced
Hospital Patient Care	Infectious waste (bandages, plasters, gloves)
	Sharp objects (syringes, scalpels)
	Pathological waste (body tissue, blood)
Laboratory	Chemical waste
	Biological waste (blood samples, muscle tissue)
	Sharp waste (syringes, glass tubes)
Surgical Installation	Pathological waste (body tissue)
	Infectious waste (contaminated surgical equipment)
Radiology and Nuclear	Radioactive waste (used X-ray film, radioactive isotopes)
Maintenance and Cleanliness	Chemical Waste (cleaners, disinfectants)

Table 2. Research on hospital waste sources.

No	Research Title	Ref
1	Decentralized systems for the treatment of antimicrobial compounds released from hospital aquatic wastes	[13]
2	Healthcare waste in Bangladesh: Current status, the impact of COVID-19 and sustainable management with life cycle and circular economy framework	[14]
3	Antimicrobial resistance bacteria and genes detected in hospital sewage provide valuable information in predicting clinical antimicrobial resistance.	[15]
4	Multidrug antibiotic resistance in hospital wastewater as a reflection of antibiotic prescription and infection cases	[16]
5	Microbial diversity and potential health risks of household municipal solid waste in China: A case study in winter during the outbreak of COVID-19	[17]

2.2. Types of Waste

Hospital waste is waste produced from hospital activities in solid, liquid, and gaseous form. Hospitals as a means of health services as a gathering place for sick and healthy people can be a source of disease transmission and allow environmental pollution and health problems, as well as produce waste that can transmit diseases [18]. Hospital waste is hazardous to the health of the environment and to the community in the hospital environment and its surroundings. Hospital waste, if not managed properly and according to the rules, can pollute the environment. To avoid these risks, waste management in hospitals is needed (see **Figure 1**).

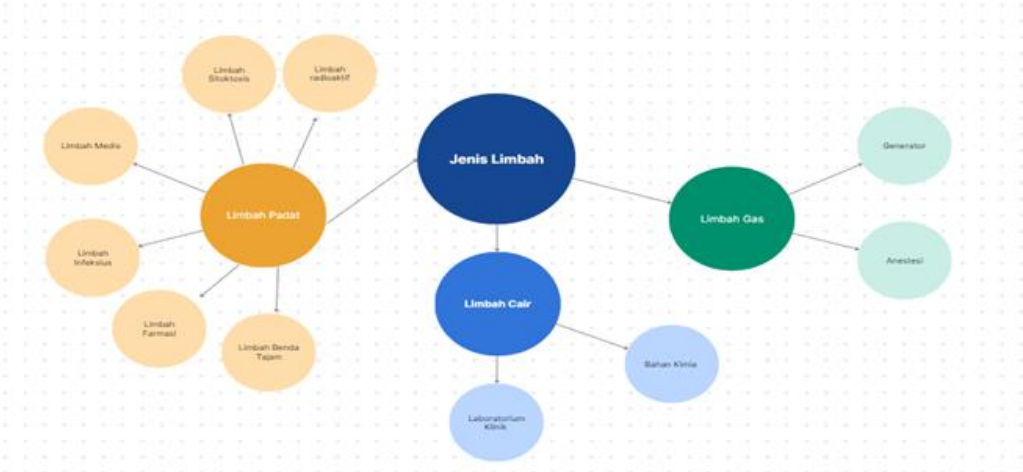

Figure 1. Flow chart of waste type.

DOI: https://doi.org/10.17509/ajse.v5i1.80941
p- ISSN 2776-6098 e- ISSN 2776-5938

Hospital solid waste, better known as hospital waste, is something that is not used, disliked, or something that must be disposed of which generally comes from activities carried out by humans, and is generally solid. Hospital waste in solid form due to hospital activities consisting of solid and non-medical waste, namely:

(i) Non-medical waste is solid waste generated from non-medical activities that come from kitchens, offices, parks, and yards that can be reused if there is technology [19]. It is stored in a black plastic trash can.

(ii) Solid medical waste is solid waste consisting of:
   a. Infectious waste and pathological waste, waste suspected of containing pathogenic material (bacteria, viruses, parasites, or fungi) in concentrations or quantities sufficient to cause disease in susceptible hosts.
   b. pharmaceutical waste (expired drugs), chemical additives; Pharmaceutical waste includes pharmaceutical products, medicines, vaccines, and serums that have expired, are not used, spilled, or disposed of appropriately.
   c. Cytotoxic waste is waste derived from the rest of the chemotherapy service drugs [20]. materials that are contaminated or may be contaminated with cytotoxic drugs during compounding, transportation, or cytotoxic therapeutic actions. The handling of this waste requires proper absorbent and the cleaning agent must always be available in the compounding room. It is stored in a purple plastic trash can.
   d. Sharp solid medical waste such as glass shards, syringes, pipettes, and other medical devices. Store it in a safety box/container.
   e. Radioactive waste is waste derived from medical use or research in the laboratory [21] related to radioactive substances. It is stored in a red plastic trash can. This waste can originate from nuclear medicine actions, radiological examinations, radioimmunoassays, and bacteriological can be in solid, liquid, or gaseous form, among others.

(iii) Hospital liquid waste is all wastewater including feces that come from hospital activities, which may contain microorganisms, toxic materials, radioactivity, and blood that are harmful to health. The handling is through WWTP (Wastewater Treatment Plant). Hospital wastewater is all liquid waste that comes from the results of the process of all hospital activities, which includes: domestic liquid waste, which is waste from hospitals that may contain microorganisms, toxic chemicals, and radioactivity. Infectious liquid waste comes from the patient's toilet service activities (Bath, Wash, Toilet) in the form of liquid waste in the bathroom and washing of the equipment used, clinical laboratories in the form of wastewater from washing laboratory equipment and the like, treatment or clinical care mainly comes from kidney dialysis activities and washing of operating room equipment, laundry and cleaning of infection rooms, emergency, and radiology.

(iv) Gas waste, all waste that comes from incineration activities in hospitals, such as incinerators, kitchens, generator equipment, anesthesia, and the manufacture of cytotoxic drugs [22]. Cytotoxic waste is waste produced from contaminated materials and preparations for cancer chemotherapy that can grow living cells.

Table 3 show types of hospital waste and their characteristics.

DOI: https://doi.org/10.17509/ajse.v5i1.80941
p- ISSN 2776-6098 e- ISSN 2776-5938

Table 3. Types of hospital waste and their characteristics.

Types of Waste	Information	Feature
Infectious Medical Waste	Waste that can transmit disease or infection.	a. Contains dangerous pathogens. b. Requires special handling.
Hazardous Waste	Waste containing hazardous or toxic chemicals.	a. Contains chemicals such as pharmaceutical ingredients, and laboratory chemicals. b. Requires special handling and disposal.
Pathological Waste	Waste originating from discarded body tissue or biological remains.	a. Contains body tissue or organs that have been removed. b. Requires special care to prevent infection.
Pharmaceutical Waste	Expired pharmaceutical waste or remaining pharmaceuticals.	a. Contains drugs or pharmaceutical ingredients. b. Requires special disposal methods.

2.3. How to Treat Hospital Waste

In general, medical waste is divided into solid, liquid, and gas. Meanwhile, the category of solid medical waste consists of sharp objects, infectious waste, pathological waste, cytotoxic waste, pressurized tube waste, genotoxic waste, pharmaceutical waste, waste with heavy metal content, chemical waste, and radioactive waste.

(i) Medical waste; Waste contaminated with blood and body fluids is put in a yellow plastic bag. Examples: laboratory samples, pathological waste (tissues, organs, body parts, autopsies, body fluids, blood products consisting of serum, plasma, platelets, and others), diapers are considered infectious waste when used in patients with gastrointestinal infections, menstruation and patients with infections transmitted through blood or other body fluids. The destruction of medical waste must be done by using the method of incineration, it is necessary to maintain the integrity of the packaging when the waste is handled. Combustion or incineration systems that use mechanical equipment. However, try to treat medical waste following applicable regulations and environmentally friendly treatment [23]. Medical waste is not allowed to be disposed of directly into a domestic waste landfill before it is safe for health. The method and technology of processing or destroying medical waste is adjusted to the capacity of the hospital and the type of medical waste that exists, by heating using autoclaves or by burning using incinerators. Medical waste treatment can be done internally or externally. Medical waste treatment is more often using the incineration method using an incinerator with a temperature of 1000 – 1200 oC. One of them is the waste of sharp objects; Waste that has a sharp surface put in a puncture-proof container and water. Examples: needles, syringes, IV tips, objects with sharp surfaces (see **Figure 2**).

(ii) Liquid Waste, Pollutants contained in liquid waste are a serious threat to environmental sustainability because in addition to pollutants that are toxic to aquatic biota, pollutants also have an impact on the physical, chemical, and biological properties of the aquatic environment. Liquid Waste Treatment is aimed at removing materials that can interfere with the process or treatment units. Preliminary processing is very important as the basis for the success or failure of the subsequent processing process:

a. Bar Screen Functions to filter coarse objects contained in wastewater. Bar screens are generally made of iron or steel bars that are installed in parallel to form a strong frame.

DOI: https://doi.org/10.17509/ajse.v5i1.80941
p- ISSN 2776-6098 e- ISSN 2776-5938

The grating is installed transversely on the channel before the next processing unit, forming an angle of 30o to 60o to the flat plane of the channel.

b. Equalization Equalization is used to address operational problems caused by discharge variations, to improve the performance of subsequent processes, and to minimize the size and cost reduction of facilities. The 16 important design parameters in initialization are the dwell time of the 16 important design parameters in initialization.

Figure 2. Medical waste treatment flow chart.

(iii) Second Stage Treatment The second stage of treatment in principle aims to remove dissolved organic substances and suspended solids in liquid waste (see **Figure 3**). The following is the second level of treatment that is commonly used in liquid waste treatment systems:

a. Sedimentation Sedimentation can be rectangular or circular. At the time the wastewater flow is very calm to settle. The criteria needed to determine the size of the sedimentation basin are surface loading, tank depth, and residence time.

b. A bioreactor also known as a fermenter is a system that can provide a biological environment that can support the occurrence of biochemical reactions from raw materials to desired materials. Biochemical reactions that occur inside a bioreactor involve an organism or active biochemical component (enzyme) derived from a specific organism, either aerobically or anaerobically. Meanwhile, the biological agents used can be in a suspended or mobilized state. The main components of a bioreactor consist of a tank, sparger, impeller, fine sieve or baffle, and sensors to control parameters.

c. Activated Sludge The biological wastewater treatment process with a suspended culture system has been widely used worldwide for domestic wastewater treatment. This process is essentially an aerobic process in which organic compounds are oxidized into CO2 and H2O, NH4, and new biomass cells. For oxygen supply, it is usually by exhaling air mechanically. The most common and widely used wastewater treatment system with suspended cultures is the treatment process with activated sludge processes.

DOI: https://doi.org/10.17509/ajse.v5i1.80941
p- ISSN 2776-6098 e- ISSN 2776-5938

d. Liquid waste shall be collected in containers (containers) that follow the characteristics of the chemical and radiology, volume, and procedures for handling and storing them.

a) Sewage drains must use a closed, watertight duct system, and waste must flow smoothly, as well as be separate from rainwater drains.
b) The hospital must have a liquid waste treatment plant on its own or together with the surrounding buildings by the requirements.
c) It is necessary to install a liquid waste discharge meter to determine the surprising discharge of the waste produced.
d) Wastewater from the kitchen should be equipped with a fat catcher and the wastewater drain should be equipped/covered with a grill.
e) Wastewater originating from laboratories and other medical installations (e.g. hemodialysis, operating rooms) that produce search waste must be treated at a Wastewater Treatment Plant (WWTP), by applicable regulations.
f) The frequency of inspection of effluent liquid waste is carried out once a month for swapantau and at least once every 3 months for a sampling test by applicable regulations.

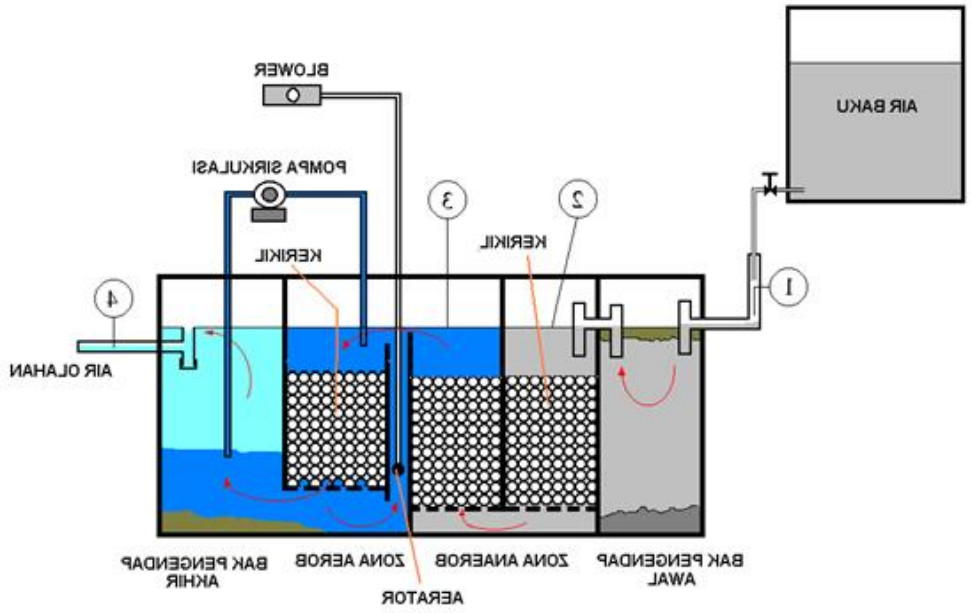

Figure 3. Hospital waste treatment.

(iv) Gas Waste, Gas Waste Security is an effort to handle gas waste which consists of the selection, maintenance, and repair of hospital utilities based on appropriate gas emissions and waste inspections to reduce the risk of health and environmental problems caused. Hospital operations and utilities produce exhaust and particulate emissions that have an impact on air pollution and public health problems. The dominant source of exhaust emissions from hospitals comes from emissions from parking vehicles, incinerator chimneys, generator chimneys, and boiler chimneys. Thus, it is necessary to carry out management to maintain the ambient air quality of the hospital environment well. Each hospital must conduct laboratory examinations of exhaust gas emissions and outdoor ambient air with the following frequency provisions: exhaust and outdoor ambient air with the following frequency provisions:

DOI: https://doi.org/10.17509/ajse.v5i1.80941
p- ISSN 2776-6098 e- ISSN 2776-5938

a. Test exhaust gas emissions from incinerator chimneys at least every 1 (once) time per 6 months.
b. Test the exhaust gas emissions from the chimney of the boiler engine, at least every 1 (one) time per 6 months.
c. Flue gas emission test from the generator chimney (Capacity <1000 Kva), every 1 (one) time a year.
d. Test exhaust emissions from the chimney of operational vehicles at a minimum, every 1 (one) time a year.
e. Ambient air test in the courtyard outside the hospital, at least once every 1 (one) time.

2.4. Illegal Opportunities

Medical waste management is part of environmental sanitation in hospitals which aims to protect the community from the dangers of environmental pollution sourced from hospital waste and efforts to control the spread of diseases. The negative impact of medical waste on the community and the environment occurs due to poor management. The impact that occurs from medical waste can cause pathogens that can have adverse effects on humans and the environment.

Based on this, Law Number 36 of 2009 concerning Health (hereinafter referred to as the "Health Law") was issued in Articles 4 and 5 which states that everyone has the same right to obtain the degree of health of individuals, families, and their environment.

Article 1 paragraph (3) of the 1945 Constitution (hereinafter referred to as the 1945 Constitution) states that the State of Indonesia is a state of law. Through the elaboration of the 1945 Constitution, it is emphasized that Indonesia is a country of law that attaches great importance to law enforcement in all areas of the social, political, and economic life of its population; This includes the fact that Indonesia is a country of law. Everyone in Indonesia is obliged to obey the law, which was created to ensure that everyone is treated fairly, to maintain order, and to prevent anarchy. Law Number 44 of 2009 PpArticle 1 concerning Hospital Hospitals (Hospital Law), a hospital is defined as an entity that, among other things, provides related medical services, "providing inpatient, outpatient, and emergency medical care to patients in need." Plenary services include health care, which may be curative, rehabilitative, preventive, or promotional.

Based on data from the Indonesian Anti-Counterfeiting Society (MIAP), regarding the spread of fake health products which can reach a figure of up to 40%, according to the Director of Medical Device Supervision of the Ministry of Health of the Republic of Indonesia, Eka Purnamasari, this medical device has been regulated in Law Number 17 of 2023 concerning Health (see **Table 4**).

Table 4. List of illegal hospital waste recycling.

Types of Waste	Illegal Reasons to Recycle	Potential Risks
Infectious Waste	Can transmit infectious diseases (eg HIV, Hepatitis)	Spread of infection and health risks
Sharp Waste	Potential for serious injury	Physical injury and risk of infection
Hazardous Waste	Contains toxic and radioactive materials	Soil and water contamination, health risks

DOI: https://doi.org/10.17509/ajse.v5i1.80941
p- ISSN 2776-6098 e- ISSN 2776-5938

2.5. Diseases Caused to the Hospital Community

Diseases caused by the presence of hospital waste have several factors (see **Table 5**), including:

(i) Infection: Infection is a major risk associated with hospital waste. Pathogens contained in infectious waste can cause different types of infections, ranging from skin infections to serious systemic infections.
(ii) Infectious diseases: Some infectious diseases such as hepatitis B, hepatitis C, HIV/AIDS, and tuberculosis can be transmitted through contact with contaminated medical waste.
(iii) Poisoning: Exposure to hazardous chemicals contained in chemical waste can cause acute and chronic poisoning.
(iv) Cancer: Some chemicals in medical waste, such as cytotoxic drugs, are carcinogenic and can increase the risk of cancer.
(v) Skin diseases: Direct contact with medical waste can cause skin irritation, dermatitis, and even wounds that are difficult to heal.

Table 5. Hospital waste disease

No	Types of Diseases	Types of Diseases
1	Infection	**Respiratory tract infections:** Breathing air contaminated by particles from medical waste can cause upper respiratory tract infections such as flu or lower respiratory tract infections such as pneumonia. **Gastrointestinal tract infections:** Swallowing food or drink contaminated by medical waste can cause diarrhea, vomiting, and other gastrointestinal infections.
2	Hepatitis B	Hepatitis B virus infection can cause severe liver damage and even liver cancer.
3	Hepatitis C	Hepatitis C virus infection can also cause chronic liver damage and cirrhosis of the liver.
4	HIV/AIDS	HIV attacks the immune system and can lead to AIDS, a condition in which the body becomes extremely susceptible to infection.
5	Tuberculosis	An infectious disease that attacks the lungs and can spread to other organs of the body.
6	Urinary tract infection	It often occurs in patients who use catheters.
7	Pneumonia	Lung infections are common in patients on ventilators.

2.6. Types of Waste Treatment Education

The hospital has implemented several things that have been done in connection with the hospital management program:

(i) Orientation Education, which is understood at the beginning of employees to find out the basic understanding of the types of waste. This is also about the handling of medical waste, and the use of PPE to protect yourself from exposure to hazardous materials contained in medical waste.
(ii) Workshops or seminars, are from outside parties who are resource persons in the management of medical waste, liquid waste, or gas waste and there are interactive discussions.
(iii) Certification Program, the hospital encourages staff to follow a nationally or internationally recognized certification program. This certification guarantees the competence of staff in medical waste management.

DOI: https://doi.org/10.17509/ajse.v5i1.80941
p- ISSN 2776-6098 e- ISSN 2776-5938

3. METHODS

This research uses a development model or in English it is called Research and Development (R&D). Development research is a research method used to produce a certain product and to test the effectiveness of the product. This development research uses the ADDIE model. The ADDIE model consists of five stages, including analysis, Design, Development, Implementation, and Evaluation.

Based on this description, it can be concluded that the ADDIE model is a simple set for designing learning where the process can be applied in various settings due to its common structure. This can be seen from the steps that will be taken, always referring to the previous steps that have gone through the process of improvement or revision. Thus. interesting learning media products can be obtained that will create effective learning. **Figure 4** is a picture of media development using the ADDIE model.

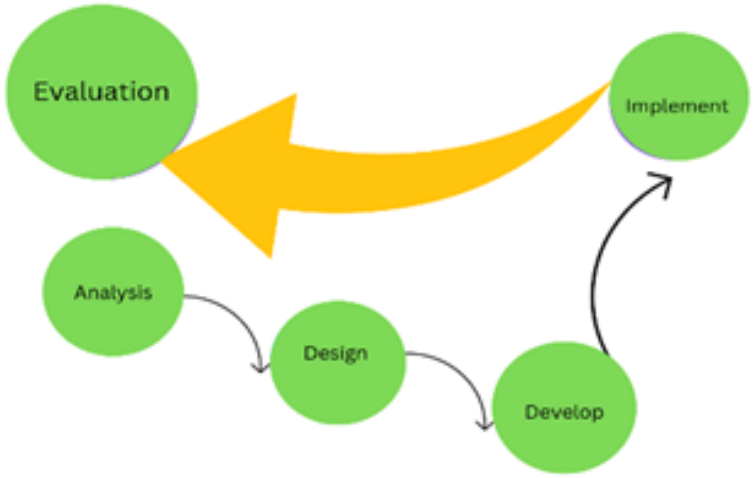

Figure 4. Media development using the ADDIE Model.

The stages carried out in developing hospital waste education media are as follows:

3.1. Analysis

Data about this stage, the aim is to collect information about what is needed to develop a learning media. Thus. the media can later support the learning process activities. The development of the learning media began with the discovery of hospital waste education problems which made it a problem for hospital employees and the community, including hospital patients. Thus, to keep up with the times, the media developed in this study is in the form of educational media in the form of an android application that can be used by hospital employees and all hospital visitors, patients, and the public using smartphones or laptops/computers. The media is expected to support the understanding of materials from Hospital Waste due to the existence of various diseases that can be transmitted.

At this stage, the use of actions will be analyzed what has been done by the hospital about hospital waste education. Based on the observations that have been made at the Islamic Hospital, Ahmad Yani stated that this hospital waste has not been educated much. Thus, the knowledge of the causes and processing carried out has not been implemented, only by throwing it in the garbage but cannot be sure that the syringe, for example, will be returned or not. Thus, the material that will be developed is Educational Media regarding various types of hospital waste, types of waste, how to manage and whether it is illegal or not. Thus, some of the things above have shown that the development of digital educational media is very

DOI: https://doi.org/10.17509/ajse.v5i1.80941
p- ISSN 2776-6098 e- ISSN 2776-5938

suitable to be developed to support process activities or hospital waste material to decollate it.

3.2. Design

The activities carried out at this stage are designing educational media. The plan includes: The first page of educational media contains the logo of the learning media and the title of the material to be presented (see **Figure 5**).

Figure 5. Logo of hospital waste education media.

3.3. Development

The development stage is a form of implementation of the design stage or design that has been prepared. At this stage, a product will be produced in the form of learning media in the form of an application. The steps that will be taken during the development process of educational media include the collection of educational materials needed in the development of digital educational media, the collection and creation of supporting aspects of the development of learning media such as images and animations, the creation of educational media designs, converting media in the form of applications, and trial applications on androids and laptops/computers.

Product testing is a stage that must be carried out in development research because at this stage we can see and know the feasibility or validity and practicality of a product. Therefore, this stage is very important to do. The steps in the trial phase of this product include:

3.3.1. Trial design

3.3.1.1. Expert validation test

The expert validation test in question is a product test carried out by competent experts. These experts include material expert validators and media expert validators. The validity test was carried out by competent validators, namely 2 media expert validators and 2 material expert validators. Thus, in this study, there are 4 material expert validators and media expert validators, consisting of 2 material expert validators, namely 1 environmental health academic, 1 hospital employee in the environmental field, and 1 media validator, namely 1 IT in the hospital department.

3.3.1.2. Test subject

The subjects of the trial in the development of this educational media are 2 hospitals in the Surabaya-Sidoarjo area, the product practicality test uses a sample of 1 hospital, while the effectiveness test is carried out with a sample of two hospitals. The object of this study is the development of hospital waste digital educational media that has been created to help educate hospital employees and the community. Thus. they are not exposed to various effects

DOI: https://doi.org/10.17509/ajse.v5i1.80941
p- ISSN 2776-6098 e- ISSN 2776-5938

of hospital waste management and increase effectiveness for the community environment by providing knowledge and resources about hospital waste.

3.3.1.3. Effectiveness data instrument

The activeness instrument sheet was used to obtain data in determining the percentage of success of the effectiveness of educational media used by hospital employees, and the general public after the implementation of digital educational media.

3.3.2. Types of data

In this development research, the data used are quantitative data and qualitative data. The following is an explanation of the data that will be obtained:

(i) Quantitative Data Quantitative data is obtained from the results of questionnaire assessments in the form of validity percentages by material experts, media experts, and practicality obtained from 2 hospitals.

(ii) Qualitative Data is obtained from a questionnaire containing the results of comments and suggestions assessed by material validators, media validators, and language validators for product validation development and later the results from the validators will be used in product improvement. Then to find out the effectiveness of the product, it will be obtained from the results of the questionnaire response of hospital employees regarding the product developed.

3.3.3. Analysis techniques

Data analysis techniques are carried out after the data is obtained. In this case, the valid and practical scale of the development products that have been produced will be calculated. Data acquisition at the qualitative data analysis stage from the results of comments from several media experts and material experts was used to make improvements. Meanwhile, the data acquisition at the quantitative data analysis stage will be used to calculate the valid and practical scale of the development products produced. The data analysis techniques in this study include:

(i) Analysis techniques. The percentage of data on product validation can be calculated with the equation (1). The validity criteria of the resulting product can be expressed in the **Table 6**. If the validation results obtained show more than 60%, the product meets the feasible category. Thus. it can be said that the product is valid.

$$Presentase = \frac{the\ number\ of\ scores\ given\ by\ the\ validator}{Total\ of\ score\ maximal} \times 100\% \quad (1)$$

Table 6. Product validity criteria.

Weight of Value	Category	Evaluation (%)
5	Very Worth It	80 – 100
4	Worthy	60-80
3	Less Worthy	40-60
2	Not feasible	20-40
1	Totally Unworthy	0-20

(ii) Product effectiveness analysis. With the same formula, if the results of the students' response show more than 60%, the product can be said to be effective. The criteria for product effectiveness can be expressed in the following **Table 7**. If the results of the

DOI: https://doi.org/10.17509/ajse.v5i1.80941
p- ISSN 2776-6098 e- ISSN 2776-5938

practicality obtained show more than 60%, the product meets the effective category. Thus. it can be said that the product is effective.

Table 7. Criteria for effectiveness of educational media.

Weight of Value	Category	Evaluation (%)
5	Very Effective	80 – 100
4	Effective	60-80
3	Less Effective	40-60
2	Ineffective	20-40
1	Very Ineffective	0-20

3.3.4. Evaluate

Evaluate or evaluation is a stage where the development products that have been tested will be evaluated. This stage is carried out to assess the products that have been successfully developed. The evaluation can be carried out in accordance with the assessment of the validation questionnaire by material and media experts and the effectiveness questionnaire by hospital employees.

Mixed Techniques This research uses qualitative and quantitative methodologies. This method examines the application of hospital waste for environmental health. This study examines hospitals in five major cities in Surabaya using digital applications. Method. First, Literature Studies Collecting scientific articles, industry reports, regulatory guidelines, and other relevant documents. Combining information from multiple sources to identify trends, current technologies, and best practices. Second, Case Study Selecting several hospitals that implemented innovative waste management solutions. Detailed information on the successes and challenges of implementing waste management solutions in specific locations. Third, Surveys and Questionnaires Prepare a questionnaire that includes questions about waste management practices, challenges, and needs. Quantitative and qualitative data describing waste management practices and challenges in various hospitals. Fourth, determine the area that.

Case Study: Choose 3-5 representative hospitals of different sizes and types (e.g., general hospitals, specialty hospitals). Surveys and Questionnaires: If possible, target 20-30 hospitals to get more representative and diverse data. Observation and Live Experiments: Conduct observations or experiments in multiple hospitals (e.g., 3-5) to obtain in-depth and detailed data. A larger number of hospitals will provide more representative and generalizable results, but may require more resources and time.

4. RESULTS AND DISCUSSION

The research conducted is an R&D (Research and Development) research with the ADDIE approach that produces a digital educational media product for hospital waste. This digital educational media was created using the Sony Vegas Pro 11 application. The results of the research obtained are as follows:

4.1. Analysis

In this study, an interview was conducted at the Surabaya Islamic Hospital, where there are problems regarding hospital waste management and knowledge for hospital employees or the community. The problem is that there is no education to hospital employees about how to manage it, and what factors can be done with hospital waste contained in solid, liquid and gas waste.

DOI: https://doi.org/10.17509/ajse.v5i1.80941
p- ISSN 2776-6098 e- ISSN 2776-5938

4.2. Design

Design is the stage of preparing the design of the educational media to be made. At this stage, it consists of three steps, namely: compiling educational media on the application, designing the display design of hospital waste education media and compiling an instrument to assess the effectiveness of hospital waste education media. Effectively applied waste management technologies and methods can improve efficiency, reduce waste volume, and reduce environmental and health impacts. The integration of advanced technology and staff training proved to be key in achieving positive results in hospital waste management, demonstrating that advanced incineration and sterilization technologies can reduce the environmental impact of medical and infectious waste, supporting our results in reducing environmental and health impacts (see **Figure 6**).

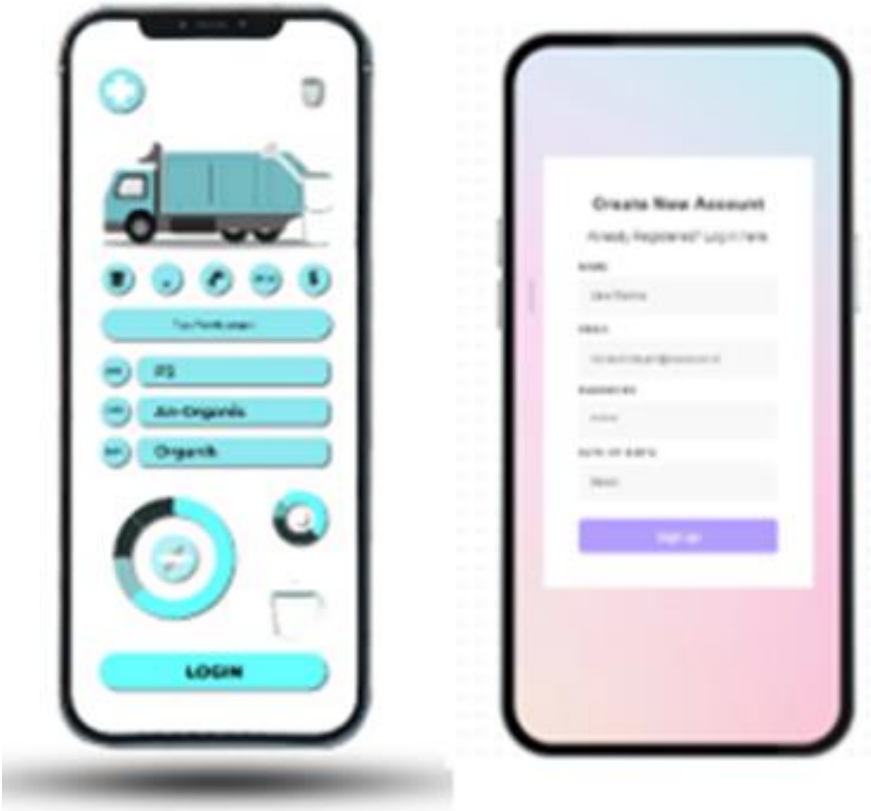

Figure 6. Hospital waste educational media design.

The following is an example of a health waste management application display. The main features illustrated include:

a. Waste Classification: Different colors for different types of medical waste such as infectious waste, pharmaceuticals, and sharp objects.
b. Management Tracking: A display that shows the stage of the trace from source to culling.
c. Automatic Scheduling: Notifications that help with automatic scheduling of waste pickups.
d. Compliance reports: Automated reports related to regulatory compliance.
e. Education and Training: An educational module for staff training on safe waste management.
f. Preparation of Instruments

Assessment of the Effectiveness of Educational Media Instrument The assessment is submitted to material experts, media experts, and hospital employees (see **Table 8**).

DOI: https://doi.org/10.17509/ajse.v5i1.80941
p- ISSN 2776-6098 e- ISSN 2776-5938

Table 8. Validation of material expert instruments

No	Revision	The Next Step
1	Adding indicators to the graphical aspect of the media expert questionnaire	Addition of indicators to the graphical aspect in the media expert questionnaire
2	Adding the garnish principle aspect to the subject matter expert questionnaire	Addition of aspects as directed by the validator

4.3. Development

This stage of development is adjusted to the design at the design stage. The steps include:

4.3.1. There is a video on how to treat hospital waste

Everything planned at the pre-production stage is applied at this stage of production. After the video capture is complete, the video enters the editing stage carried out by the editor. In this study, Sony Vegas Pro 11.0 software is needed for editing. Thus, the software first needs to be installed, then the editor does the editing according to the digital education media (see **Figure 7**).

Figure 8. Medical waste management video.

4.3.2. Validation

The educational media has been developed and the assessment instrument has been validated. Thus, the next step is to validate the educational media to media experts and material experts to find out the effectiveness of the learning media. The effectiveness of the content contains 6 indicators, the language has 4 indicators, and the presentation has 4 indicators. The results of the recapitulation of the questionnaire assessment by material experts were 85%. Thus, it was declared effective (see **Figure 9**).

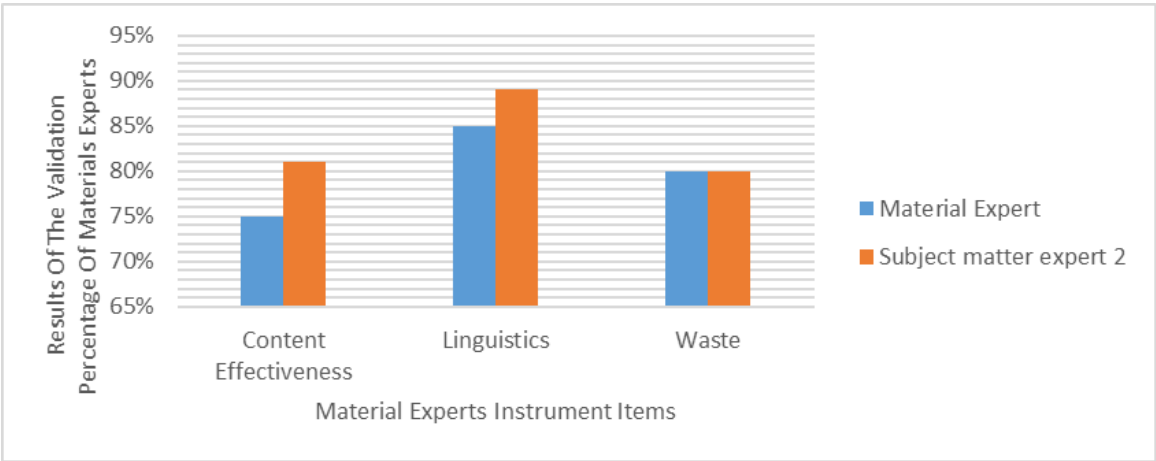

Figure 9. Results of the assessment of the material expert questionnaire.

DOI: https://doi.org/10.17509/ajse.v5i1.80941
p- ISSN 2776-6098 e- ISSN 2776-5938

The effectiveness of hospital waste digital education media based on media aspects was assessed by media experts from IT experts, namely Mr. Hirnanda Dimas Prandana, M.Pd. The assessment questionnaire has a multi-level scale with a score range of 1 for the lowest score and 5 for the highest score. The assessment includes 3 aspects, namely the feasibility of content, presentation, and graphics. The effectiveness of the content has 6 indicators, the presentation has 4 indicators and the graphics have 10 indicators. In this case, it has a value of 81% stated as "very effective" and can be used as a digital educational media for hospital waste for hospital employees and the general public (see **Figure 10**).

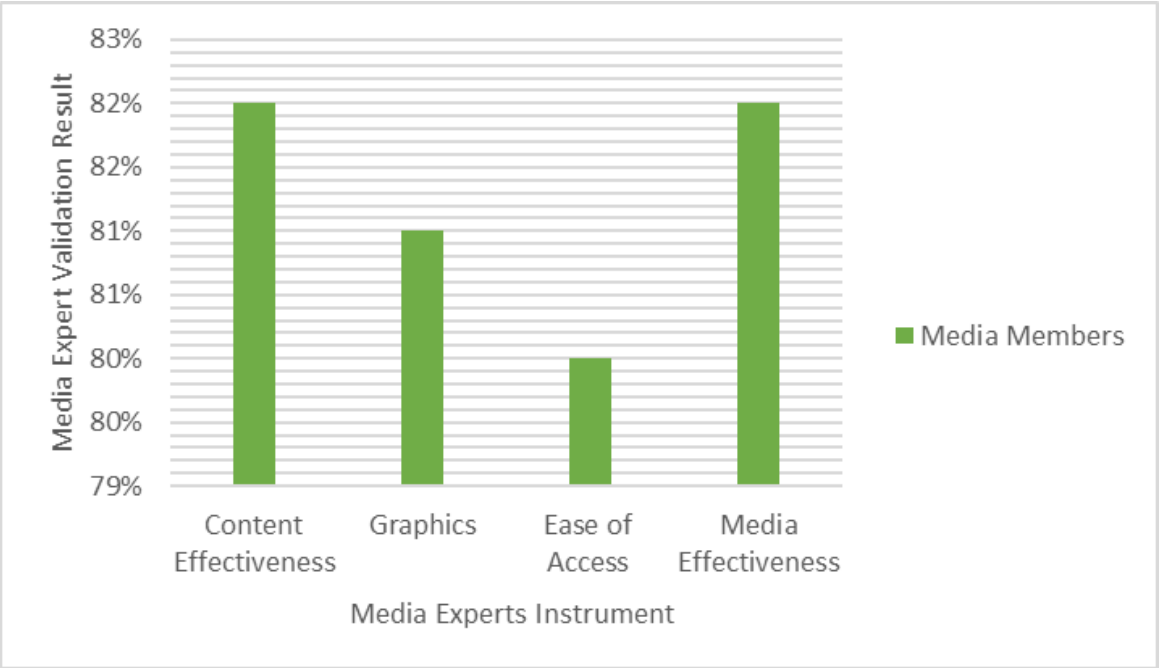

Figure 10. Results of the media expert questionnaire assessment.

Have a significant positive impact on waste management in health facilities. The use of this application increases the efficiency of waste management by up to 25%. Hospital waste management applications have been successful in improving waste management efficiency, regulatory compliance, and reducing operational costs. With improvements in data management and response to problems, these applications have a significant positive impact on waste management in healthcare facilities.

4.3.3. Final product results

From the results of the validation, learning videos were improved following comments/suggestions from material experts and media experts. **Figure 11** is the display of digital educational media after the revision.

Main Dashboard: Provides an overview of waste status and important data that is easily accessible. Waste Container Monitoring: Allows users to visually view the status of containers through interactive maps. Waste Tracking and Management: Simplify the management of waste container data and status with workflow forms and graphs. Training and Education Modules: Provide necessary training materials for staff with evaluation features. Analytics and Reports: Presents detailed analysis data and reports for performance evaluation. Notification and Alert System: Manage and respond to notifications to ensure prompt action on waste issues. The results of the waste management application show an increase in efficiency in hospital waste management. By using app features such as container monitoring, waste data

DOI: https://doi.org/10.17509/ajse.v5i1.80941
p- ISSN 2776-6098 e- ISSN 2776-5938

tracking, and training modules, hospitals can manage waste more effectively and be more compliant with regulations. Analysis and reports point.

Figure 11. Medical applications of hospital waste**.**

4.3.3.1. Effectiveness test

Data obtained from 23 Hospital Employees were obtained as a result of the effectiveness of media use Digital Education on Waste Management Reviewed from the aspect of independent learning for hospital employees. This digital educational media will make it easier for the general public as well as regarding dangerous hospital waste. Thus, they are more concerned (see **Table 9**).

Table 9. Results of the effectiveness of hospital waste digital education media.

Criteria	Presented	Comments
Content Relevance	82%	Most staff found the content relevant to their daily tasks.
Engagement Level	89%	High engagement due to interactive elements.
Ease of Use	75%	Generally user-friendly, but some have minor navigation issues.
Clarity of Information	90%	Clear information, effective use of visuals
Impact on Knowledge	78%	The majority reported an improved understanding of waste management
Applicability	85%	Many felt they could apply the knowledge immediately.
Overall Satisfaction	80%	Positive feedback, with suggestions for more topics.
Average Score		82.71%

The results of the media effectiveness analysis Digital education of hospital waste based on effectiveness questionnaire filled out by hospital employees. The results of the effectiveness analysis obtained were 82.71% with the category of very effective.

5. CONCLUSION

Research shows that hospital waste management applications offer an effective solution to improve efficiency, compliance, and data management in waste management. With proper

DOI: https://doi.org/10.17509/ajse.v5i1.80941
p- ISSN 2776-6098 e- ISSN 2776-5938

implementation and adequate training support, this application can have a significant positive impact on waste management in healthcare facilities. The use of this application increases the efficiency of waste management by up to 82.71%. Hospital waste management applications have been successful in improving waste management efficiency, regulatory compliance, and reducing operational costs. With improvements in data management and response to problems, these applications have a significant positive impact on waste management in healthcare facilities.

6. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. Authors confirmed that the paper was free of plagiarism.

7. REFERENCES

[1] Adu, R. O., Gyasi, S. F., Essumang, D. K., and Otabil, K. B. (2020). Medical waste-sorting and management practices in five hospitals in Ghana. *Journal of Environmental and Public Health*, *2020*(1), 2934296.

[2] Imaniyati, N., Ramdhany, M.A., Rasto, R., Nurjanah, S., Solihah, P.A., and Susilawati, A. (2024). Neuroscience intervention for implementing digital transformation and organizational health completed with literature review, bibliometrics, and experiments. *Indonesian Journal of Science and Technology*, *9*(2), 287-336.

[3] Luckyardi, S., Karin, J., Rosmaladewi, R., Hufad, A., and Haristiani, N. (2024). Chatbots as digital language tutors: revolutionizing education through AI. *Indonesian Journal of Science and Technology, 9*(3), 885-908

[4] Restianty, A., Sumartias, S., Hadisiwi, P., and Hafiar, H. (2024). Digital applications as assistive technology for students with disabilities. *ASEAN Journal of Science and Engineering*, *4*(3), 445-470.

[5] Nuhu, K.M., Abdulfatai, D.A., and Onojah, A.O. (2021). Undergraduate awareness and perception on the use of digital collaborative tools in facilitating learning in selected universities within the Ilorin metropolis. *Indonesian Journal of Educational Research and Technology, 1*(3), 95-104.

[6] Muktiarni, M. and Widiaty, I. (2023). Bibliometric analysis of the integration of digital tools in marine conservation education. *Indonesian Journal of Educational Research and Technology*, *3*(3), 305-314.

[7] Muhabbat, H., Mukhiddin, K., Jalil, H., Dustnazar, K., Farxod, T., Shavkat, M., Khulkar, K., and Jakhongir, S. (2024). The digital frontier: AI-enabled transformations in higher education management. *Indonesian Journal of Educational Research and Technology*, *4*(1), 71-88.

[8] Tarisayi, K.S. (2024). Memetized learning: How humor-infused stories can engage geography students in the digital age. *Indonesian Journal of Educational Research and Technology*, *4*(2), 113-120.

[9] Babalola, E.O., Boor, C.H.M., Aladesusi, G.A., and Shomoye, M.A. (2021). Development and validation of digital photo series for the teaching of BT in Ilorin, Nigeria. *Indonesian Journal of Educational Research and Technology, 1*(3), 105-116.

DOI: https://doi.org/10.17509/ajse.v5i1.80941
p- ISSN 2776-6098 e- ISSN 2776-5938

[10] Maulid, M.N., and Sakti, A.W. (2022). The effectiveness of learning videos as a source of digital literacy on poster learning in elementary schools. *Indonesian Journal of Multidiciplinary Research, 2(*1), 51-56.

[11] Anh, D.H.M. (2022). Factors affecting satisfaction on online education on students digital teaching page in Ho Chi Minh City, Vietnam. *Indonesian Journal of Multidiciplinary Research, 2(*1), 179-186.

[12] Salman, N., Aryanti, D., and Taqwa, F. M. L. (2021). Evaluasi Pengelolaan Limbah Rumah Sakit (Studi Kasus: Rumah Sakit X di Kab. Tasikmalaya). *Jurnal Komposit: Jurnal Ilmu-Ilmu Teknik Sipil*, *5*(1), 7-16.

[13] Sharma, M., Yadav, A., Dubey, K. K., Tipple, J., and Das, D. B. (2022). Decentralized systems for the treatment of antimicrobial compounds released from hospital aquatic wastes. *Science of the Total Environment*, *840*, 156569.

[14] Dihan, M. R., Nayeem, S. A., Roy, H., Islam, M. S., Islam, A., Alsukaibi, A. K., and Awual, M. R. (2023). Healthcare waste in Bangladesh: Current status, the impact of Covid-19 and sustainable management with life cycle and circular economy framework. *Science of The Total Environment*, *871*, 162083.

[15] Cai, L., Sun, J., Yao, F., Yuan, Y., Zeng, M., Zhang, Q., Shio, X., Wang, S., Wang, Z., and Jiao, X. (2021). Antimicrobial resistance bacteria and genes detected in hospital sewage provide valuable information in predicting clinical antimicrobial resistance. *Science of The Total Environment*, *795*, 148815.

[16] Siri, Y., Bumyut, A., Precha, N., Sirikanchana, K., Haramoto, E., and Makkaew, P. (2024). Multidrug antibiotic resistance in hospital wastewater as a reflection of antibiotic prescription and infection cases. *Science of the Total Environment*, *908*, 168453.

[17] Liu, Y., Li, S., Zheng, Z., Zheng, X., Ajmal, M., Zhao, M., and Lu, W. (2023). Microbial diversity and potential health risks of household municipal solid waste in China: A case study in winter during outbreak of COVID-19. *Science of The Total Environment*, *904*, 166672.

[18] Wulandari, A., Nusantara, R. W., and Anwari, M. S. (2020). Effectiveness of artificial wetland system in processing liquid waste of hospital-x. *Journal of Man and Environment, 27*(2), 39-49.

[19] Chotijah, S., Muryati, D. T., and Mukyani, T. (2019). Implementation of hospital waste management policies at the Sultan Agung Islamic Hospital, Semarang City. *Humanities (Law and Civil Society), 7*(3), 223-236.

[20] Arlinda, V. P., Windraswara, R., and Azinar, M. (2022). Analysis of medical waste management. *Indonesian Journal of Public Health Research and Development, 3*(1), 52-61.

[21] Himayati, N., Joko, T., and Dangiran, H. L. (2018). Evaluasi pengelolaan limbah medis padat bahan berbahaya dan beracun (b3) di rumah sakit tk. ii 04.05. 01 dr. soedjono magelang. *Jurnal Kesehatan Masyarakat*, *6*(4), 485-495.

[22] Tumewu, K. S., Mangangka, I. R., and Legrans, R. R. (2023). Evaluation of the performance of the anaerobic-aerobic biofilter wastewater treatment plant (WWTP) of the North Sulawesi Provincial Hospital. *TEKNO, 21*(85), 901-911.

DOI: https://doi.org/10.17509/ajse.v5i1.80941
p- ISSN 2776-6098 e- ISSN 2776-5938

[23] Sirait, A. A. F. D., Mulyadi, A., and Nazriati, E. (2015). Analysis of medical waste management at the gunungtua regional general hospital (RSUD), North Padang Lawas Regency, North Sumatra Province. *Journal of Environmental Sciences, 9*(2), 183-192.

DOI: https://doi.org/10.17509/ajse.v5i1.80941
p- ISSN 2776-6098 e- ISSN 2776-5938