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Article

Simple Medical Waste Incinerator Design and Construction

Bayu Wahyudi[1]*, Muhammad Iqbal Maulana[2], Mohammad Rofi'i[3]

[1] Sekolah Tinggi Ilmu Kesehatan Semarang, Indonesia ; e-mail : bayuwahyudi@stikessemarang.ac.id
[2] Sekolah Tinggi Ilmu Kesehatan Semarang, Indonesia
[3] Sekolah Tinggi Ilmu Kesehatan Semarang, Indonesia
* Corresponding Author : Bayu Wahyudi

Abstract: Medical waste management is a major concern in protecting public health and the environment. This study aims to design and test a simple medical waste incinerator controlled by a microcontroller, intended for use in small-scale healthcare facilities. The method used was research and development (R&D), involving need analysis, system design, hardware assembly, and performance testing of the components and waste combustion effectiveness. The results indicate that the system operates stably with voltage error rates below 1% and high temperature sensor accuracy. The incinerator achieved an average combustion effectiveness of 95% across four types of disposable medical waste. The tool can operate automatically based on temperature and time settings, utilizing readily available and energy-efficient electronic components. These findings suggest that the developed incinerator is suitable as an alternative solution for medical waste treatment in clinics or health centers and has potential for further development into an environmentally friendly and sustainable incineration system.

Keywords: incinerator, medical waste, microcontroller, simple device, waste treatment.

1. Introduction

Medical waste management is a serious challenge in the healthcare sector because it can be infectious and contain hazardous chemicals that endanger the environment and public health. According to data from the World Health Organization , around 85% of medical waste is classified as non-hazardous waste, while the remaining 15% consists of high-risk infectious, chemical, and radioactive waste (Zhang et al., 2020) . This type of waste is often generated by hospitals , laboratories, and clinics, and includes items such as masks, bandages, and disposable personal protective equipment.

One of the most effective methods for handling medical waste is incineration, which is the process of burning waste at high temperatures to destroy pathogens and reduce waste volume (Darmawan, 2024) . This process can produce temperatures between 800°C and 1,200°C which can deactivate harmful microorganisms. However, the incinerator used must be carefully designed to be efficient and not cause air pollution due to toxic gas emissions (Olanrewaju & Fasinmirin, 2019) .

Unfortunately, many incinerators available on the market today do not meet the energy efficiency and emission standards set by environmental regulations. Several studies have stated that emissions from non-optimal incinerators can cause air pollution and additional health risks (Green, 1992; Ibrahim et al., 2023) . This indicates the need for a new design of a simpler incinerator that still meets functional and environmentally friendly criteria, especially

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for small-scale needs in primary health care facilities such as clinics or community health centers.

Several previous studies have developed incinerators with various approaches. Lasmana et al. (2021) designed an incinerator fueled by used oil with a waste burning capacity of 15 kg in 20–30 minutes, while Rizki (2021) developed an oil-fueled incineration system for organic waste with a temperature of 748°C. However, most of these designs still rely on conventional fuels and have not integrated an automatic temperature and time control system. (Maulana et al., 2023) .

To answer these needs, this study offers a simple medical waste incinerator design that combines a spiral wire-based heating element with Arduino UNO microcontroller control. In addition, the use of the MAX6675 temperature sensor and automatic control system is expected to improve the stability and operational safety of the tool.

Based on the background and literature studies that have been described, the purpose of this study is to design and test the performance of a simple medical waste incinerator that can process solid medical waste on a small scale with high efficiency and environmentally friendly emissions. This study is expected to provide a real contribution to safe, practical, and sustainable medical waste management practices at the basic health service level.

2. THEORETICAL STUDY

Medical Waste and Environmental Risks

Medical waste is waste from health service activities such as hospitals, laboratories, and clinics, which contain risks of infection and chemical contamination. This waste includes personal protective equipment (PPE), bandages, masks, gloves, and disposable medical devices that are often exposed to patient body fluids (Oroei et al., 2014; Zhang et al., 2020) . Inaccuracy in managing this waste can lead to the spread of infectious diseases such as Hepatitis B and C and HIV, even groundwater and air pollution (Darmawan, 2024; Oroei et al., 2014) .

According to WHO, around 15% of healthcare facility waste is hazardous, including infectious waste and chemical/radioactive waste, while 85% is classified as non-hazardous domestic waste (Zhang et al., 2020) . Therefore, safe waste disposal is an urgent need in the healthcare system.

Incinerator Technology in Medical Waste Treatment

An incinerator is a waste processing device that works on the principle of thermal combustion to reduce volume and destroy hazardous substances in waste. The combustion process occurs at temperatures between 800°C and 1,200°C, allowing for effective destruction of pathogens and chemicals (Darmawan, 2024) . In addition to destroying waste, incinerators also reduce the risk of pollution because waste is converted into ash and gas which are easier to handle (Green, 1992; Ibrahim et al., 2023) .

However, the challenges of conventional incinerators are high emissions and wasteful energy consumption. Therefore, the development of modern incinerators with sensor technology and automatic control is urgently needed (Olanrewaju & Fasinmirin, 2019; Putra & Pratama, 2023) .

Figure 1 Incinerator Tool (SolutionClick , 2023)

Component Technology Supporters

a. Elemen Heater (Spiral Wire)
b. Thermocouple Type K
c. Miniature Circuit Breaker (MCB)
d. Solid State Relay (SSR)
e. Arduino UNO microcontroller
f. Liquid Crystal Display (LCD) 20x4
g. MP1584 Stepdown Module

3. Proposed Method

This study uses a mix method approach, namely a combination of quantitative and qualitative methods, with the aim of developing and testing the performance of a simple microcontroller-based medical waste incinerator. Meanwhile, the qualitative approach is obtained through direct observation, documentation of the assembly process, and expert validation of the performance and technical feasibility of the device. This research is included in the research and development (R&D) category with an applied experimental research approach that took place from January to April 2025 at the STIKES Semarang Electromedical Engineering Laboratory. The research stages include needs analysis, system design, assembly, functional testing, and evaluation of the performance results of the incinerator system. The main devices used in this study include a laptop, solder, tin, digital multimeter, and electronic toolset, while the components consist of Arduino UNO as the main controller, MAX6675 temperature sensor, spiral heating wire as a heating element, 20x4 LCD for user interface, SSR relay as a breaker and power connector, MCB for overcurrent protection, and MP1584 stepdown module and pushbutton as a temperature and combustion time setting unit (Creswell & Creswell, 2018; Lasmana et al., 2021; Rizki, 2021; Shadfar et al., 2021; Sugiyono, 2020) .

System Design

The incinerator system design consists of a power supply subsystem, a heating subsystem, and a microcontroller-based control subsystem. The 220V AC power supply is supplied through a dimmer and stepdown to adjust the voltage of the electronic components. Arduino UNO as a control unit will read the temperature input from the K-type thermocouple sensor (MAX6675) and display the information on a 20x4 LCD. The heater will be activated via an SSR relay if the temperature is below the target and will stop automatically if the temperature is reached (Fuadi et al., 2020; Shadfar et al., 2021)

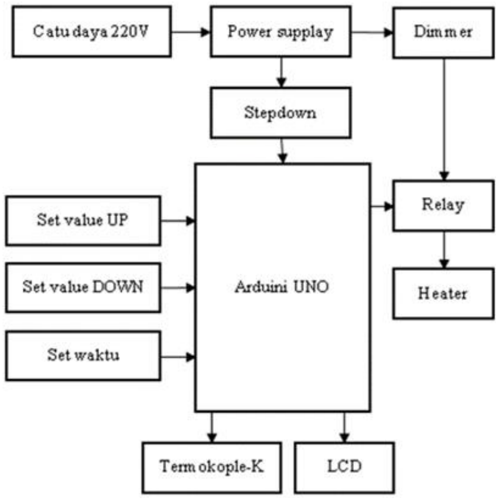

Figure 2 Block diagram

Program Algorithm (Flowchart)

The system is designed to work automatically based on user-set temperature and time input. The flowchart includes: sensor initialization, reading temperature, activating heater, and monitoring temperature until stable.

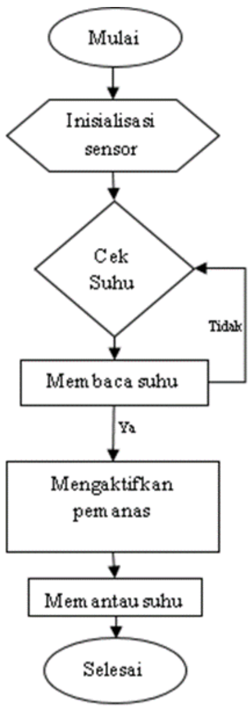

Figure 3 Flowchart channel programming

Electronic Circuit Assembly

The series consists of:

1. Power Supply Circuit :

   Provides 12V and 5V voltage for microcontroller and sensors.

2. MAX6675 Sensor :

   Reads the combustion temperature and sends the data to the Arduino.

3. LCD 20x4 :

   Displays temperature and baking time.

4. 4. Pushbutton :

   Set the temperature value and burning duration.

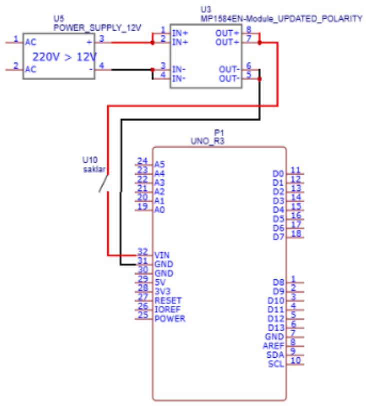

Figure 4 Power supply circuit

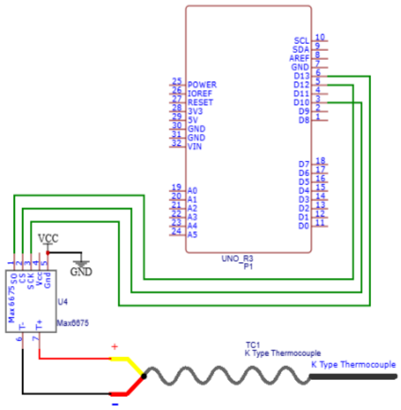

Figure 5 MAX6675 Sensor

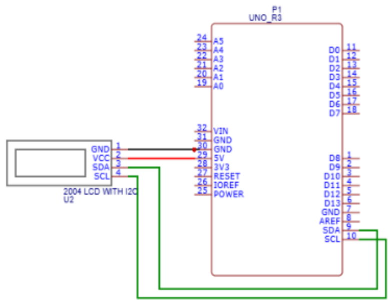

Figure 6 LCD

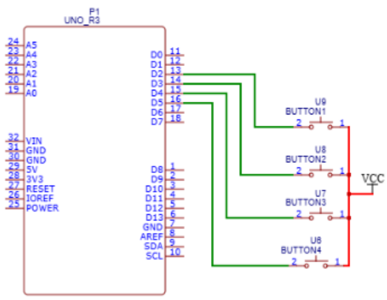

Figure 7 Pushbutton

Overall Circuit and Tool Design

All components are arranged in a closed system using a heat-resistant metal frame. The position of the control buttons, LCD, and heater are arranged ergonomically.

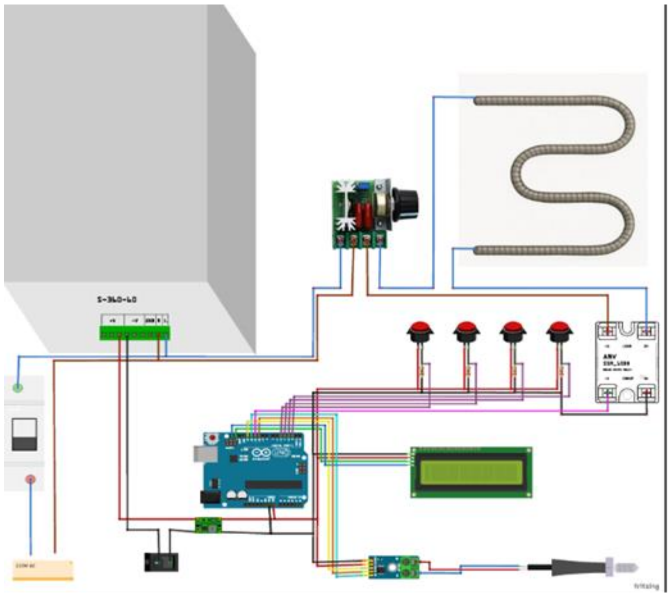

Figure 8 Series Overall

Operating Procedures

Operation begins by connecting the device to a power source, setting the temperature and time via the control buttons, then turning on the heater. The system will work automatically until the combustion process is complete. When the temperature has been reached, the heater will automatically turn off and the system enters standby mode .

Data collection technique

Data is collected through:

1. Voltage and Current Test
   Use a multimeter to measure the input and output voltages of the power supply, stepdown, sensors, and LCD.
2. Temperature Sensor Accuracy Test
   Comparing the readings of the thermocouple sensor with an analog thermometer.
3. Burning Effectiveness Test
   Using medical waste samples (masks, bandages, head coverings, cotton) to measure the percentage of successful combustion (Lasmana et al., 2021; Rizki, 2021).

Data Analysis Techniques

Data were analyzed using quantitative descriptive statistics, namely calculating the percentage of error in each measurement . Qualitative data were obtained from observations of tool functionality and expert validation of the system's suitability to electromedical engineering principles (Winarno et al., 2024).

4. Results and Discussion

For evaluate performance waste incinerator tool medical simple that has been designed , done a series testing to aspect electricity , temperature sensor accuracy , and effectiveness burning waste . Testing This aiming For ensure that all over component Work in accordance with specification technical And standard applicable tolerances , as well For know how far the tool capable process waste medical congested very use in a way efficient . Summary results testing the served on Table 1 below .

Table 1. Recapitulation Results Testing Component And Performance Tool

No	Type Testing	Average Result	Standard Reference	Percentage Error (%)	Information Short
1	Supply input voltage power (TP1)	219.4 V AC	220V AC	0.06%	Stable, consistent tolerance
2	12V power supply output (TP2)	12.4 V DC	12V DC	0.33%	Normal, appropriate need tool
3	voltage (TP3)	5.2 V DC	5V DC	0.04%	Stable, fit for Arduino & LCD
4	MAX6675 (TP4) temperature sensor input	3.43 V DC	3V DC	0.14%	Safe for sensor
5	LCD Input 20x4 (TP5)	5.3 V DC	5V DC	0.06%	Normal and can display data
6	Difference Temperature (Thermocouple vs Analog)	< 1°C	Tolerance ±1°C	—	Accurate sensor
7	Effectiveness burning waste	95% average success rate	Target ≥90%	—	Efficient , only the mask is less than optimal

Results testing show that all over component system electricity tool functioning in range tolerance standard , with stable input and output voltage . The MAX6675 temperature sensor indicates accuracy tall in read temperature burning with difference not enough from 1°C compared to analog thermometer . While that , effectiveness tool in burn waste medical like bandages , cotton , and closing head reach level 100% success , whereas on the mask occurs A little decline effectiveness to 80% due to easy material characteristics stick on element heater . Overall average effectiveness burning is 95%, indicating that tool can reliable For scale small in facilities health.

Discussion

Results testing to tool incinerator waste medical simple show that designed system capable Work in a way functional And efficient in burn waste medical very use in scale small . Testing done through six point measurement main , namely the supply input 220V AC power , 12V DC power supply output, 5V DC stepdown output, MAX6675 temperature sensor input , LCD input, and validation temperature use -K thermocouple compared with analog thermometer . All results measurement show level error is at in limit tolerance maximum 2%, which indicates reliability system electricity tools . Average voltage output is at on stable value And in accordance with component datasheets , such as the MP1584 stepdown which outputs average voltage 5.2V (Digikey, 2022; Fuadi et al., 2020) . Besides that , the result test temperature show accuracy tall between the sensor and tool measuring comparator with average difference less from 1°C, strengthening MAX6675 sensor validity in arrange temperature burning . Test effectiveness burning done to four type sample waste (masks, bandages , covers) head , and cotton), with results success burning reach 100% for three type waste and 80% for masks because character more material easy melt And stick on element heater . In overall , level success burning reached 95%, and system heating Arduino UNO controlled automatic proven can Work in accordance with arrangement temperature And specified time user (Artanto, 2012; Putra & Pratama, 2023) . Network control electronics are also tested in condition variation load , and the result show stability Power And recovery fast after activation burden (Shadfar et al., 2021; Winarno et al., 2024) . With efficiency consumption good energy And control relative emissions clean , tools This rated worthy used in facilities health level First like clinic And health centers , especially For waste medical light that is not contain material chemistry heavy (Green, 1992; Ibrahim et al., 2023; Zhang et al., 2020) . Implications from results This support urgency development device manager waste medical independent based on technology simple However effective , especially in frame support effort Handling waste post- COVID-19 pandemic the volume of waste medical increase drastic (Darmawan, 2024; Zhang et al., 2020) .

5. Conclusions

Based on the design and testing results, it can be concluded that this simple medical waste incinerator tool based on the Arduino UNO microcontroller is able to work functionally and efficiently in processing small-scale solid medical waste such as bandages, masks, head coverings, and cotton. The electrical system of the tool shows voltage stability at each test point with a very small error percentage (<1%), while the MAX6675 temperature sensor is able to read temperatures accurately with a tolerance of less than 1°C. The average combustion effectiveness reaches 95%, indicating that this tool can be relied on to support medical waste management in first-level health care facilities. The advantages of this tool lie in the digitally controlled temperature and combustion time automation system, as well as the use of components that are easily obtained and energy efficient.

Although this device shows good performance, its development still has room for improvement. Further research is needed to integrate the smoke filtration system so that exhaust emissions can be minimized according to stricter environmental standards. In general, this device is worthy of being used as an affordable and applicable alternative solution for medical waste management in clinics or health centers, and can be used as a basis for the development of more sophisticated incinerator technology in the future.

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