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Design and Implementation of Solid Medical Waste Sorting System Based on Inductive Proximity Sensor and Radio Frequency Identification (RFID)

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Abstract – *Medical waste separation is a crucial issue in Indonesia, because of the potential dangers it poses, such as the risk of spreading diseases and environmental pollution. This research aims to make innovations in solid medical waste sorting systems, to sort waste automatically using Inductive Proximity sensors and Radio Frequency Identification RFID. The results of the inductive proximity sensor test are able to accurately detect metal medical waste with an average detection time of 117.5 ms. RFID is also able to read ID cards accurately. The system offers innovative solutions to improve occupational safety and sustainable separation of solid medical waste.*

Keywords*: Solid medical waste, Inductive Proximity Sensor, RFID. Waste sorter*

I. Introduction

The problem of medical waste in Indonesia is an urgent issue, in line with the growth of the number of health facilities and the improvement of medical services[1]. Medical waste is the result of medical activities of health services and treatment of patients in medical activities in various areas, such as polyclinics, treatment rooms, surgery, obstetrics, autopsies, and laboratories[2]

Waste from hospitals requires special attention in its management, especially solid medical waste which can be a medium for the spread of advanced diseases due to its dangerous content [3]. Starting from pathogens, genotoxic, chemicals, and radioactive[4]. Each of these ingredients can trigger infectious bacterial infections, respiratory and skin diseases, genetic disorders, and even death[5]

Based on data from the Ministry of Health, the amount of medical waste produced in Indonesia reaches thousands of tons every year, and the handling is still far from optimal[6]. Solid medical waste management can be well organized if medical waste separation is carried out properly and according to procedures[7]. Solid medical waste sorting has a very significant role, namely the prevention of disease transmission that can occur due to contact with contaminated medical waste[8]

Inadequate management of medical waste can lead to the spread of disease, environmental pollution, and health risks for workers who handle such waste[9]. Solid medical waste includes sharp objects such as syringes, used plastic objects, and the remains of laboratory materials that can contain pathogens[10]

Conventional medical waste management methods are often ineffective and require close supervision and adequate infrastructure[11]. Solid medical waste sorting is not an easy task to do manually. According to Government Regulation No. 22 of 2021 concerning the Implementation of Environmental Protection and Management, the medical waste management process consists of storage, collection, transportation, utilization, processing and stockpiling[7]. Accuracy and caution are needed so that there is no pollution or danger for the officers involved[2]

To answer these problems, innovations are needed in medical waste management technology that can increase the efficiency and effectiveness of the solid medical waste sorting and handling process. One of the solutions that can be applied is the use of a solid medical waste sorting system based on

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Inductive Proximity sensors and Radio-Frequency Identification (RFID)[12]

The Inductive Proximity Sensor is capable of detecting waste and distinguishing between solid metallic and non-metallic medical waste. RFID technology is used to provide identity to medical waste disposals, so that this system can record the identity data of the disposal[13]. This system can monitor waste disposal activities more accurately and responsibly, be it individuals, communities, or other related parties. Thus, the system not only separates metallic and non-metallic waste faster and more accurately, but also ensures that each type of waste is handled according to safe and environmentally friendly procedures and can be traced back to the source[14]

The use of this medical waste sorting system is expected to improve work safety, reduce the risk of environmental pollution, and support more sustainable medical waste management. This research focuses on the design and implementation of a solid medical waste separation system using Inductive Proximity and RFID sensors, so that it can be an innovative solution in overcoming the problem of medical waste in Indonesia.

II. Research Method

The research method used in this study is an experimental approach that begins with the study of literature as a reference in designing tools and writing. Furthermore, hardware design and programming-based software design are carried out. After completing the design, the device will be manufactured and tested. The components of the tools and materials required in the design and implementation of the solid medical waste separation system are shown in table 1.

Table 1 Tools and materials

Tool and material names	Function	Sum
Arduino One	Microcontrollers to control systems and data processing[15]	1
Sensor Inductive proximity	Detecting the presence of metal objects[16]	1
Ultrasonic Sensor	Measuring distances and detecting objects	1
Sensor infrared	Detecting the presence of objects using infrared rays[17]	1
RFID tag	Identification tag for each Medical Waste disposer[18]	3
Rfid reader	Reading data from RFID tags	1
Motor servo	Drive system parts for waste separation	2
Buzzer	Provides sound signals for indication	1
LCD I2c	Displays the discarder's identity name	1

II.1. Wiring System

The design of a solid medical waste separation system includes the planning and arrangement of hardware and software components. Figure 1 is the design of the tool's component set[19]

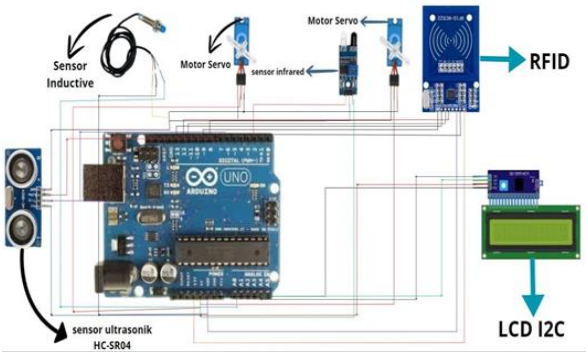


Figure 1 Component Network

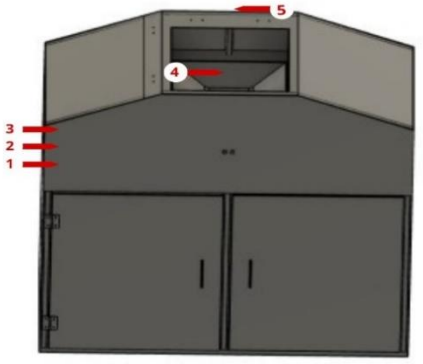
The design of this medical waste sorting system has several main components used, including an adapter power source, LCD with I2C to display identity information, and an Arduino Uno as a control microcontroller. The system is equipped with an inductive proximity sensor that functions to detect the presence of metal waste and an RFID sensor that is used to identify the identity of the waste disposer. When metal waste is detected by an inductive proximity sensor, a buzzer will sound as an indication that the waste is metal. The servo motor then directs the waste to the appropriate medical waste container whether metallic or non-metallic. Table 2 describes the components and cable connection paths to the arduino

Table 2 Component connections

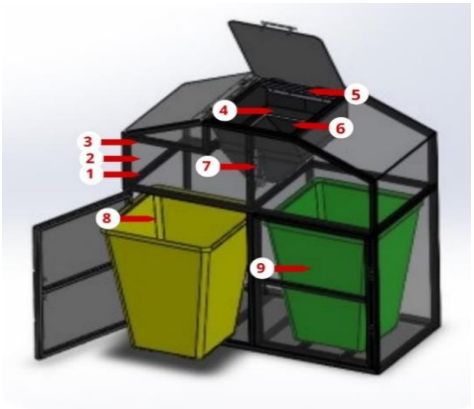
Component Name	Pin Components	Connection to Arduino
Inductive Proximity Sensor	VCC	5V
	GND	GND
	Signal Output	D2
RFID Reader (RC522)	VCC	3.3V
	GND	GND
	SDA	D10
	SCK	D13
	MOSI	D11
	MISO	D12
	RST	D9
Infrared Sensor	VCC	5V
	GND	GND
	Signal Output	D3
Ultrasonic Sensor	VCC	5V
	GND	GND
	Trig	D5
	Echo	D4
Motor Servo	VCC	5V
	GND	GND
	Signal Output	D6
Buzzer	VCC	5V
	GND	GND
	Signal Output	D7
LCD I2c	VCC	5V
	GND	GND
	SDA	A4
	SCL	A5

II.2. Device Design

The design design of the solid medical waste sorting system is shown in figure 2 with the grouping of metal and non-metal medical waste types.



(a)



(b)

Figure 2 (a) The 3-dimensional design of the medical waste sorting system is seen from the outside. (b) the design appears from the inside.

The 3-dimensional design of the medical waste sorting system was made using the fusion 360 application with the overall size of the skeleton, namely, 50 cm wide, 70 cm high, and 40 cm front-rear dimensions. The size of the top bin lid is, 20 cm long and 15 cm wide. Medical waste disposal with metal and non-metal types has the same size, namely, a capacity of 20 liters, a length of 32 cm, a width of 29 cm, and a height of 40 cm. Table 3 describes the components of the tools and materials that will be installed in the medical waste sorting system according to the design in figure 2.

Table 3 Tool part number on the system

Number	Components of tools and materials
1	RFID Reader
2	Sensor Infrared
3	LCD I2C
4	Sensor Inductive Proximity
5	Motor Servo 1
6	Ultrasonic Sensor
7	Motor Servo 2
8	Metal medical waste bin
9	Non-metallic medical waste disposal

II.3. Flowchart System

Figure 3 shows the stages of the system workflow according to programming.

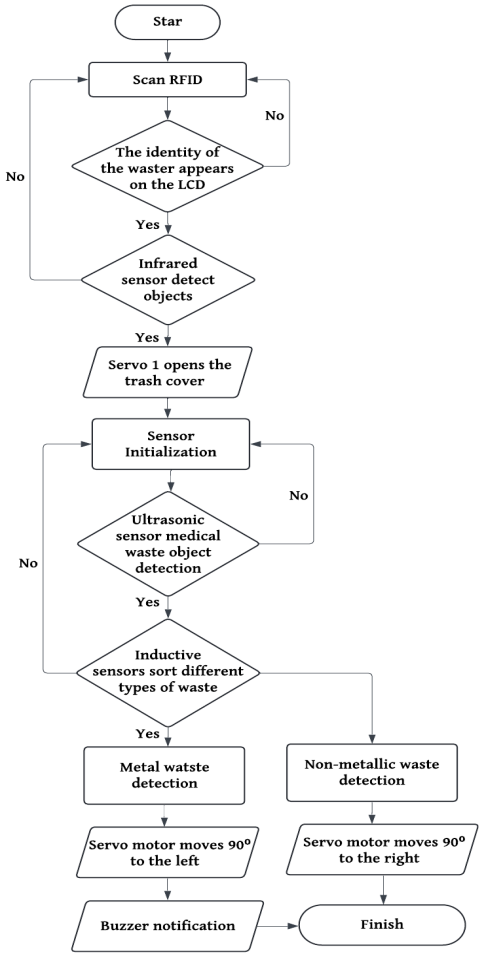


Figure 3 System working flowchart

III. Results and Discussion

III.1. Inductive proximity sensor testing

Figure 3 shows a set of tools for testing inductive proximity sensors in detecting medical waste with buzzer and servo motor outputs.

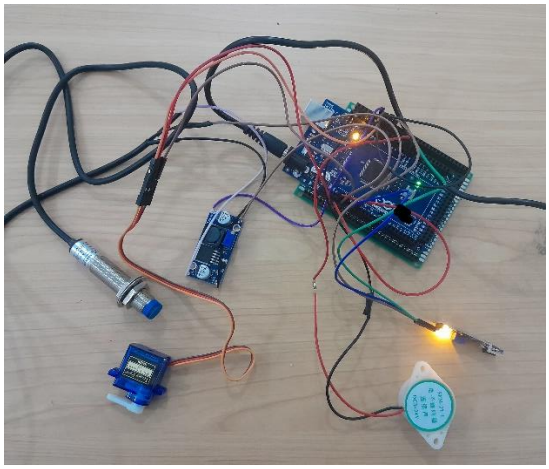


Figure 3 Component range of inductive proximity sensor

The inductive proximity sensor detection test to detect the type of solid medical waste was carried out using several samples, namely in table 4.

Table 4 Types of medical waste

Medical waste	Type of material
Syringe	Metal
Knife	Metal
Scissors	Metal
Eyedropper	Metal
Mask	Non-metallic
Bandage	Non-metallic
Glove	Non-metallic
Infusion bottles	Non-metallic

When the sensor successfully detects the difference in the type of material in the medical waste, it automatically directs the metal waste to the correct disposal site with the help of a servo motor, as well as the type of non-metallic medical waste. This can increase the risk of contamination directly and improve safety in health facilities.

Table 5 is an inductive proximity sensor test, by calculating the sensor detection time of various types of medical waste and the description of the detection results.

Table 5 Inductive proximity sensor testing

Types of medical waste	Detection time (ms)	Information
Syringe	120	Detection
Knife	110	Detection
Scissors	115	Detection
Eyedropper	125	Detection
Mask	-	Undetected
Bandage	-	Undetected
Glove	-	Undetected
Infusion bottles	-	Undetected

Detection time states the time it takes for the sensor to detect medical waste in milliseconds (ms). This time is measured from the moment the waste approaches the sensor until detection is made. The inductive proximity sensor showed good performance in detecting metals, as all metal samples were detected 100% with an average detection time of 117.5 ms in equation 1.

$$\frac{120+110+115+125}{4} = 117.5\ ms \quad (1)$$

When the test was carried out no non-metallic waste was detected by the sensor, indicating that this sensor works according to specifications to detect only metallic materials. Thus producing useful features in the context of solid medical waste management.

III.2. RFID testing and reading

The next test is on the RFID readout to ensure whether the RFID reader can read the RFID tag and display the user's identity information on the I2C LCD. Figure 4 is a series of RFID readers and 3 RFID tags as identity cards for medical waste disposal, using an arduino.

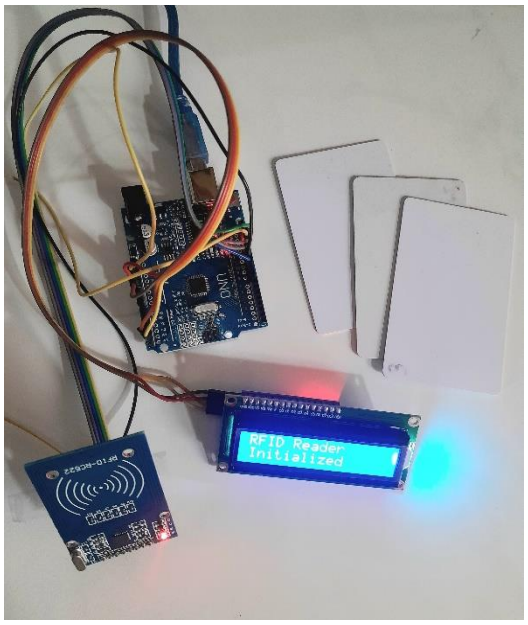
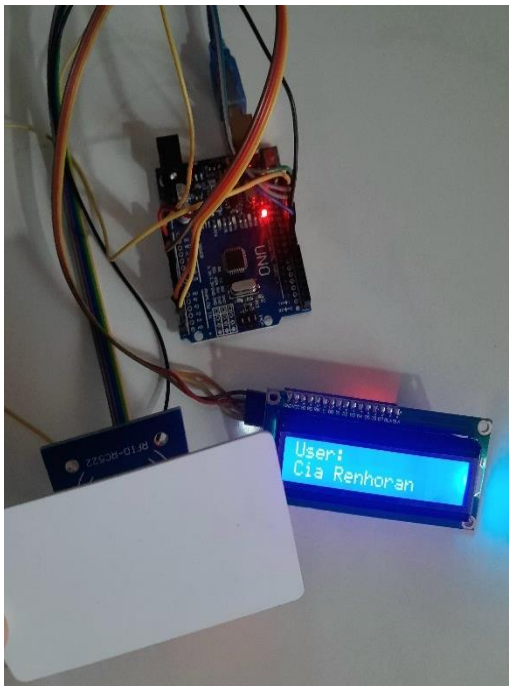
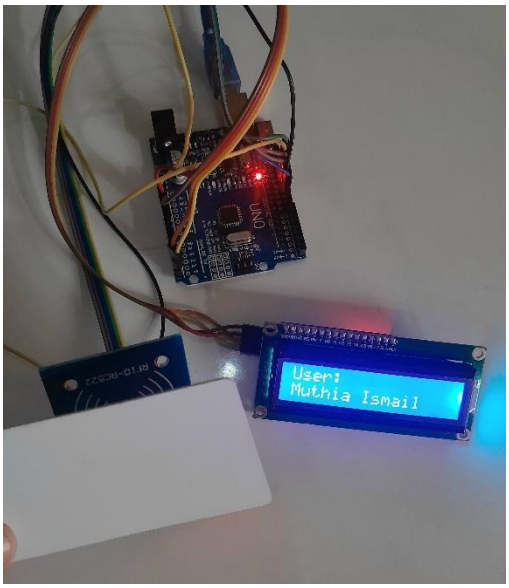


Figure 4 RFID reading network

RFID tags have been programmed to be medical waste disposal identity cards, so when a person disposes of medical waste, it must attach each tag to the RFID reader in turn, and the name will appear on the I2C LCD screen. Figure 5 shows the readings from RFID.



(a)



(b)

(c)

Figure 5 (a) RFID Tag 1, (b) RFID Tag 2, (c) RFID Tag 3

Table 6 displays the reading results on RFID by displaying the user ID along with information on whether the ID card was read successfully or not.

Table 6 RFID test results

RFID Tag	User ID	Information
Tag 1	Cia Renhoran	Succeed
Tag 2	Muthia Ismail	Succeed
Tag 3	Ajeng Ayu	Succeed

Tag 1 system reads RFID tags and displays the

name "Cia Renhoran" on the LCD, tag 2 systems read RFID tags and displays the name "Muthia Ismail" on the LCD, and so does tag 3 systems read RFID tags and displays the username "Ajeng Ayu" on the LCD. The test results prove that RFID readers can read each tag accurately and display the user's information that has been registered correctly.

IV. Conclusion

The Inductive Proximity sensor used in this system has proven to be effective in detecting and distinguishing between metallic and non-metallic waste. The tests carried out showed that the sensor was able to accurately detect medical metal waste with an average detection time of 117.5 ms. In the RFID test applied, it successfully read the RFID tag and display the user's identity information well on the I2C LCD screen. Overall, the system provides an innovative approach to addressing the challenges of sorting and managing solid medical waste in a sustainable manner. By continuing to develop and integrate this system, it is hoped that it can contribute significantly in the future.

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