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Sensors and Transducers for Lava Flood Detection: Systematic Literature Review

Iswanto Suwarno[1*], John Minto[2], Esraa Abdellatif Hammouda[3], Mohamed Yusuf Hassan[4], Abdikani Yusuf Abdulle[5],
[1] Departement of Electrical Engineering, Universitas Muhammadiyah Yogyakarta, Yogyakarta, Indonesia
[2] University of the West of Scotland, Paisley, United Kingdom
[3] Clinical Research Department, El-Raml Pediatric Hospital, MoHP, Alexandria, Egypt
[4] Faculty of Medicine and Surgery, Benadir University, Mogadishu, Somalia
[5] Economics Management, School of Social Science, University Sains Malaysia, Penang, 11800, Malaysia
* Corresponding Author

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ABSTRACT

Disasters always come suddenly, becoming a natural phenomenon that humans face. One of the natural disasters is a lava flood, which is a collection of lava released by a volcano and reaches the lower surface with the help or encouragement of rainwater. The impact of lava floods has a high risk because the material it carries can cause damage and has the potential to cause death, injury, illness, life at risk, loss of security, displacement, damage or loss of property, and disruption of community activities, so an early warning system is needed. can provide accurate data about the time of the disaster. To overcome digital sophistication, tools have been created in the form of sensors and transducers for lava flood detection. The aim of this research is to examine sensors and transducers for lahar flood detection. This research uses a systematic literature review using Preferred Reporting Items for Systematic Reviews (PRISMA). The results of article screening and selection found 77 potential articles that met the inclusion criteria. The results of the research show that the development of sensors and transducers has begun to create a lot of lahar flood detection tools through artificial intelligence based on the internet of thought which uses sensors and transducers inside and optimization of sensors and transducers for lahar flood detection must be done by setting the point of detection tools for use in various flood-prone locations. lava, so that detection of lava floods can be known before a disaster occurs.

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1. INTRODUCTION

The lava flood phenomenon is a disaster characterized by heavy volcanic material. So when it erupts, most of the volcanic material is not spread throughout the place but accumulates due to its heavy mass. Lava floods always threaten areas along rivers where volcanic material flows [1]; [2]. So the river basin is an area that is prone to lava flood disasters [3]. Data from the Meteorology, Climatology and Geophysics Agency shows that the speed of cold lava flows reaches more than 65 kilometers per hour and is capable of flowing as far as 80 kilometers [4]; [5]. With the previous incident, namely the Merapi eruption in 2010, it spewed 140 million cubic meters of lava, resulting in the loss of 367 lives, more than 2,300 houses damaged, more

than 400,000 people evacuated and thousands of hectares of agricultural land damaged, with losses and damage estimated at IDR 3.5 trillion. Merapi is only one of many active volcanoes in Indonesia [6]; [7]; [8].

There is a potential danger after a volcanic eruption, namely cold lava floods, which are formed from ash and volcanic rock ejected by the mountain during the eruption mixed with rainwater. Cold lava can be a threat to local communities because cold lava has the shape and texture of a sand-stone mixture like cement. wet [9]; [10]. Seeing this phenomenon, an internet of things-based cold lava flood early warning detection system was created after the volcanic eruption, integrated with loudspeakers in places of worship, in order to convey danger information to potentially affected communities as soon as possible, so that people can immediately evacuate to a safer place and minimize loss of life. In relation to electronic systems, sensors and transducers are basically used as lava flood detection tools [11]; [12]; [13]; [14]. A device or device whose function is to convert a physical quantity into an electrical quantity, so that the output can be processed using an electrical circuit or digital system [15]. Due to the extraordinary development of technology, almost all modern equipment has sensors in it [16]; [17]; [18]. One web-based early warning system utilizes results from IQRF sensors [19]; [20]; [21]. The function of the sensor is to scan the energy entering the transducer [22].

In general, transducers are also often referred to as sensors [23]; [24]. It is called that because both are tools that have the same function of converting a quantity of energy into another form of energy. Although at first glance sensors and transducers have almost the same function and role. However, they are actually two different tools [25]. If a transducer is a device that functions to convert energy into another form of energy [26]; [27]. So this sensor is a component that is the input part of the transducer [28]; [15]. Then help him convert this energy into other amounts of energy as needed. In everyday life, transducers are often used for various electronic circuits. Where the function and ability of the tool to change the amount of energy can be adjusted depending on the tool used. Because different types of devices are installed with transducers, their functions and ways of working will also be different [29]. For example, on a mic or earphone, this transducer will function to convert electrical energy into sound energy. Meanwhile, in incandescent lamps, electrical energy is converted into lighting. Likewise if the transducer is installed on another electronic device. Then the function and way of working will adapt to the function and use of the electronic device [30].

Previous research has studied the prediction of cold lava floods on the slopes of Merapi using rainfall data from satellites [31], an early warning system for cold lava floods using sound signal indicators and water level [32]; [33]. Based on previous research, it appears that there has been no systematic literature review that specifically reviews Lahar Flood Detection Sensors and Transducers. The aim of this research is to examine sensors and transducers for lava flood detection.

2. METHODS

This research uses a systematic literature review method using Preferred Reporting Items for Systematic Reviews (PRISMA). Research was carried out systematically through appropriate research stages. The data provided is comprehensive, balanced and aims to synthesize relevant research results. The stages of systematic literature review research include writing the background, research objectives, formulating research questions, literature search, screening and selecting relevant articles, filtering and selecting appropriate research articles, then analyzing, synthesizing qualitative findings, and creating a research report.

3. RESULTS AND DISCUSSION

RESULTS

Systematic literature review is a research method that aims to identify, analyze, evaluate all previous research results. The research results that have been obtained are in accordance with the research stages that have been carried out.

3.1. Formulate research questions

The results of the formulation of research questions related to sensors and transducers for systematic literature review lava flood detection can be seen in Table 1.

Code	Research question	Motivation
RQ1	How are sensors and transducers related to lava flood detection?	Identify articles related to the relationship between sensors and transducers for lava flood detection
RQ2	How to optimize sensors and transducers for lava	Identify articles related to sensor and transducer

flood detection? optimization for lava flood detection

3.2. Literature Search

A literature search was carried out on relevant articles using keywords, namely sensors, transducers, detection, lava floods. Articles are collected from various databases, such as Scopus, Web of Science, and Researchgate. The strategy used to search for articles is predetermined inclusion and exclusion criteria. This aims to ensure certainty in finding the article you are looking for.

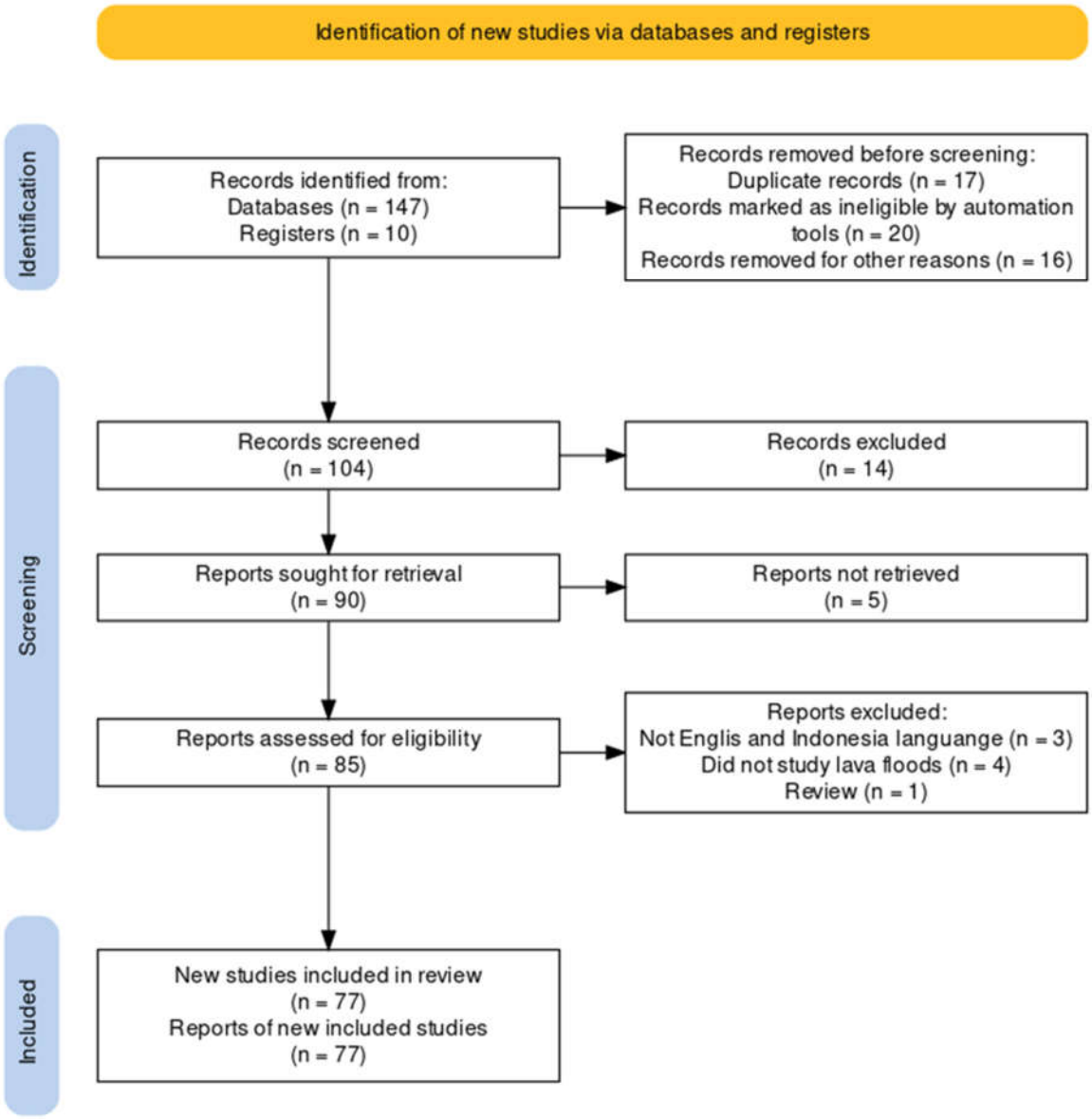

Fig. 1. PRISMA Method

3.3. Article Screening and Selection

Screening and selection of articles uses inclusion criteria to direct the search and selection of English language research articles, complete articles published in international journals from 2013-2023, which are indexed in a database, and have the theme Artificial Intelligence Algorithms for Diabetes Detection. The results of screening and selection of articles using the PRISMA chart obtained 157 articles from three databases, Pubmed, Web of Science, and Scopus (Figure 1). All articles (n= 157) were logged to Mendeley Desktop version 1.19.8, and articles that were duplicates, ineligible by the automation tool, and removed.

Sequentially, 80 articles were excluded for the reasons mentioned in Figure 1. Ultimately, 77 articles were proposed for review in the article manuscript. The resource persons tasked with conducting the assessment are two reviewers who work independently.

3.4. Data extraction, primary study quality testing, and synthesis

Data extraction aims to collect data in order to answer predetermined research questions. Research quality testing plays a role in determining the interpretation of the synthesis of findings and compiling the conclusions explained. Data synthesis aims to collect evidence from selected studies to answer research questions.

DISCUSSION

A search for articles in three databases was successfully carried out and 157 articles were obtained. The results of article screening and selection obtained 77 potential articles that met the inclusion criteria. The theme "Sensors and Transducers for Lahar Flood Detection" was used as the theme of the new statement from the meta-analysis in 77 articles. In this theme the author discusses the development of sensors and transducers for lahar flood detection and optimization of sensors and transducers for lahar flood detection. Starting with studying lava floods. Lava floods are the result of the removal of volcanic material that has not yet undergone consolidation. Materials such as volcanic ash and pyroclastics that have not been consolidated when mixed with water will produce debris flow, namely mass flow. Basically, lava is divided into two types, cold lava or rain lava and hot lava resulting from eruptions. Both types of lava are certainly dangerous, but cold lava is more dangerous because it is difficult to anticipate. In contrast to hot lava, there are several types of water that can mix with unconsolidated material.

In general, lava flows through river channels and valleys [34]. In a short time, this lava is able to completely fill deep river valleys and become full of pyroclastic material which has the potential to cause lava floods downstream [3]; [35]. By shallowing the river channel due to the accumulation of sedimentary lava deposits, in certain sections of the river such as river bends, changes in river gradient from dry to flat, narrowing river width, and shallow river beds can cause lava to overflow beyond the embankments to the left and right. river channels and flooding the area around the river. When lava flows through river channels and valleys, the temperature quickly cools because it mixes with water. As a result, it produces mud that moves quickly and hits anything in its path. Lahar has high destructive power because it carries large stones in rivers, and damages lava-bearing buildings such as gabions, lava control dams, residential areas and agricultural land which can be covered by deposits of lava material for some time, so they cannot function. as agricultural land and others [36].

Thus, it is necessary to carry out lava disaster mitigation efforts, namely to reduce the risk of environmental damage [37]; [38]; [39] . These mitigation methods are carried out as prevention efforts so that as far as possible the lava disaster can be avoided. These actions can involve preparedness measures both from the aspect of disaster control infrastructure and from the aspect of the community's ability to face disasters. Another thing that is more important is to carry out lava flood detection by using namely creating an Internet of Things (IoT) based lava flood detection system [40]; [41]. By using a float mechanical sensor which is more durable than the ultrasonic sensors in existing equipment. The following is an illustration of the Internet of Things (IoT) Illustration.

Fig. 2. Illustration of the Internet of Things (IoT)

The definition of a sensor is an electronic component whose function is to convert mechanical, magnetic, heat, light and chemical quantities into electrical quantities in the form of voltage, resistance and electric current [42]. Sensors are often used for detection when carrying out measurements or control [43]; [44]. Sensors cannot be directly connected to recording, monitoring or signal processing devices [45]; [46]; [47]. This is because the signals are too weak. Therefore, the signal from the sensor must be amplified. The following are the types of sensors and their functions:

Table 1. Types of sensors and their functions

Types of Sensors	Function
Thermal sensors	Thermal sensors are used to detect symptoms of changes in heat or temperature in a particular object dimension or space dimension [48]; [49]
Optical sensors Mechanical sensors	Optical sensors are used to detect changes in light from light sources, reflected light, or refracted light hitting objects or rooms [50]; [51]

The characteristics of the sensor are as follows: a. Linearity : There are many sensors that produce output signals that change continuously in response to continuously changing inputs [53]; [54]. For example, a heat sensor can produce a voltage according to the heat it senses. The difference between linear and nonlinear responses is shown in Figure 1.

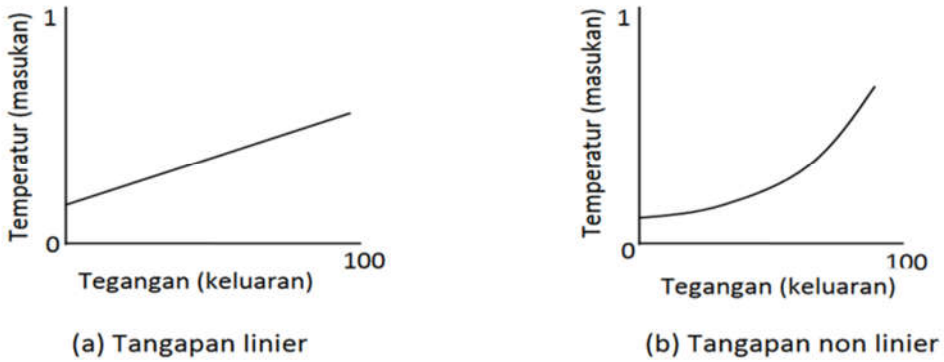

Fig. 3. Sensor output (a) linear response (b) non-linear response

b. Sensitivity: shows how sensitive the sensor is to the quantity being measured [55]; [56]; [57]. Sensitivity is often also expressed as a number that shows the change in output compared to the unit change in input. Sensor linearity also affects the sensitivity of the sensor. If the response is linear, then the sensitivity will also be the same over the entire measurement range. Sensitivity can be expressed in a linear transfer function, for example as in equation (2-1). Linear transfer function: S= a+bs…….. (2-1) with: S: sensor output a: (intercept) sensor output when input is 0, b: (slope) sensor sensitivity. The transfer function determines the relationship between the output S produced by the sensor and: S = f (s) with the sensor stimulus (input), while the non-linear function depends on the mathematical model of the transfer function. The logarithmic transfer function can be shown in equation (2-2). Logarithmic transfer function: S= a+b In s…….. (2-2). Sensitivity with a non-linear transfer function does not have a fixed value. The sensitivity of the sensor at each input point is expressed by equation (2-3): b =ds ds(S0)/ds..... .....(2-3) with: ds ds(S0)/ds : function derivative transfer to s, So= certain input value, c. Response time;

The time required for the sensor to recognize the detected substance or object. The faster the sensor time required, the better the sensor performance [58], as shown in Figure 2.

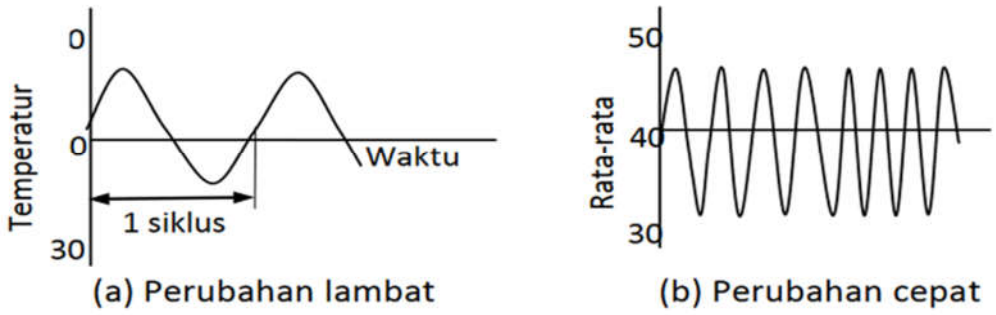

Fig. 4. Sensor response time (a) slow change (b) fast change

d. Repeatability or Precision: the ability of a measurement system to provide the same value for measurements carried out repeatedly on the same variable value [59]. The lack of precision in a measurement system or sensor is influenced by random environmental fluctuations. Structure and Working Principles The structure and working principles of organic optical sensors are explained in reference to DSSC (Dye-sensitized Solar Cell). DSSC consists of several layers. The top is coated with TCO (Transparent Conducting Oxide) glass which functions as an electrode and counter-electrode. In TCO the counter-electrode is coated with a catalyst to accelerate the electron transfer reaction with the electrolyte. The electrode surface is coated with a thin layer of TiO2 where the dye is adsorbed on the TiO2 layer as in Figure 3.

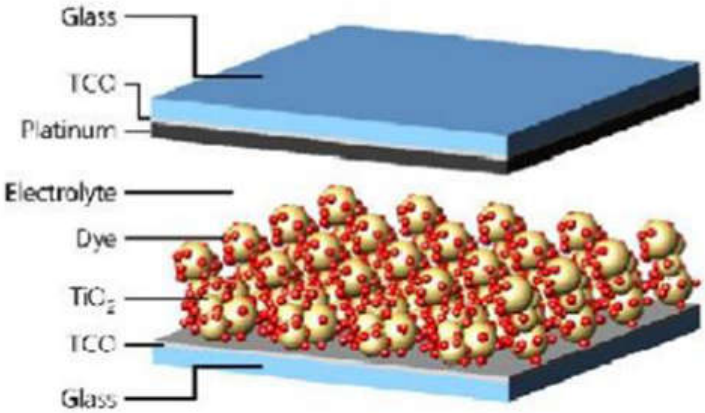

Fig. 5. Struktur DSSC

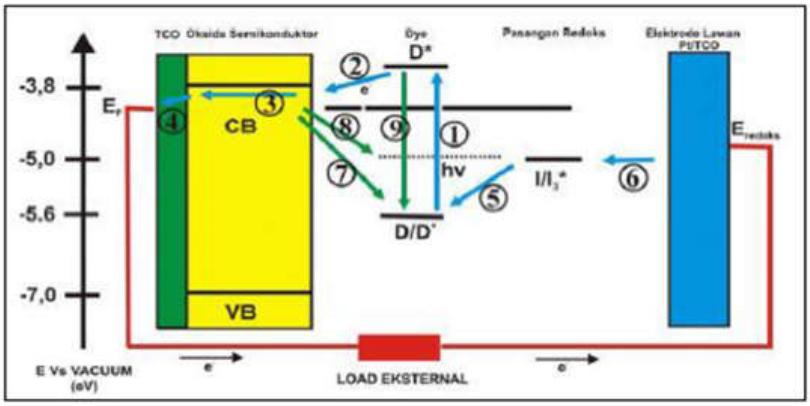

Fig. 6. Skema Kerja DSSC

Basically the working principle of organic optical sensors is a reaction of electron transfer [60]; [61]. The first process begins with the excitation of electrons in the dye molecule due to photon absorption.

Electrons are excited from the ground state (D) to the excited state (D*). D + hv → D* …(2-9).In this unstable condition, electrons are released and injected into the conduction band (CB) of the semiconductor oxide to produce dye molecules and are oxidized. Electrons injected in the semiconductor conduction band will be transferred through TiO2 to the counter electrode via an external circuit [62]; [63] . The presence of an electron donor by the electrolyte (I-) means the dye molecule returns to its initial state (ground state) and prevents the recapture of electrons by the oxidized dye. Apart from sensors, what will be discussed next is transducers.

A transducer is a device that can be given input from a physical quantity to be converted into another physical quantity and after changing this quantity it will be transmitted to another instrument, which can be in the form of a measurement or control system [64]. The types of transducers are as follows: Electrical transducers that convert physical, mechanical or optical quantities directly into electrical quantities in the form of voltage or current proportional to the quantity being measured. Advantages of electrical transducers [65]: [66]: [67]; [68]; [69] : a. Electrical output can be strengthened according to needs, b. The output can be viewed and recorded remotely, besides being able to be read/viewed, several transducers can also be processed together, c. The output can be changed depending on the need for demonstration or controlling other devices. The magnitude of the signal can be expressed in terms of voltage or current. Analog signal information can be converted into frequency or pulse information. The same output can be converted into digital format for display, print-out or on-line computation. Because the output can be modified, modified or amplified, the output signal can be recorded on a multi-channel recording oscillograph, for example, which comes from many electrical transducers simultaneously, d. The signal can be conditioned or mixed to get a combination of similar outputs and transducers, as for example on a computer. air data, or on adaptive control systems. Specific examples such as measuring the Mach number use two quantities to be measured, e. The size and shape of the transducer can be adjusted to the design of the tool to obtain the optimum weight and volume, f. The dimensions and shape of the design can be chosen so as not to interfere with the properties being measured, for example in current turbulence measurements, the size of the transducer can be made very small, this will increase the natural frequency and be better. For example, in miniature piezoelectric transducers. Which is used to measure vibrations. Despite the advantages mentioned above, there are also disadvantages to electrical sensors/feelers, namely that they cause problems in precision measurements [70]. Generally, devices are less reliable than mechanical types because the age and drift of the active components used can affect the electrical quantity. Sensor elements and signal conditioners are relatively expensive, in some cases the accuracy and resolution are not as high as mechanical devices which can have an accuracy of up to 0.01%. [71], But now with the improvement of technology and circuits, the accuracy and stability have increased. The classification of the transducer itself is:

Table 2. Transducer Classification

Transducer Classification	Information
Self generating transducer	Transducers that only require one energy source. Examples: piezo electric, thermocouple, photovoltatic, thermistor, etc. The characteristic of this transducer is that it produces electrical energy directly from the transducer. In this case the transducer acts as a voltage source [72]; [73]; [74].
External power transducer	

Before applying the transducer to the device, ensure that the following requirements are met:

- The transducer must have the ability to produce symmetrical input and output (linearity) [80].
- The tool should also have good sensitivity to the object to be measured.
- The transducer should have the ability to respond and respond quickly to input that occurs on the component.
- Transducers can produce outputs of the same value. Especially if measurements are carried out repeatedly on the same object and measuring quantity.
- The transducer should not be affected by various external factors present in the environment [81].

- Minimum error in measurement because the tool is stable and has a high level of reliability.
- The transducer has the ability to protect if the device is overloaded.
- Components generally have satisfactory instrumentation and low noise.

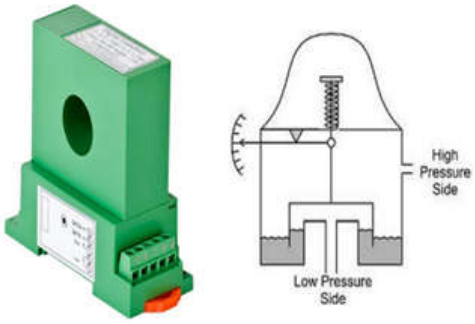

Fig. 7. Tranduser Pembangkit Sendiri

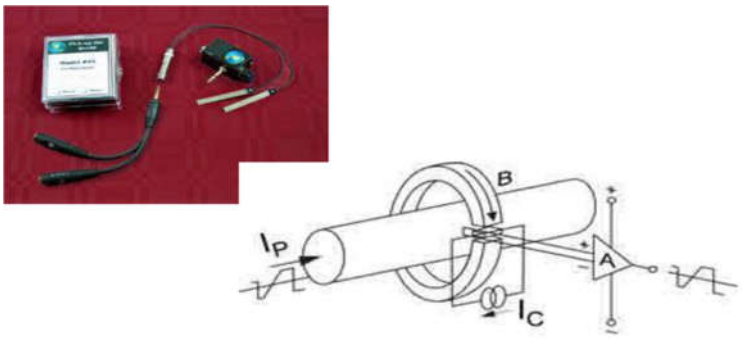

Fig. 8. External power tranduser

The development of sensors and transducers for lava flood detection can be seen to continue to develop following current developments with Atrifial intelligence [82]; [83]. Such as using buoy mechanical sensors which are more durable than ultrasonic sensors in existing tools, using loudspeakers in places of worship with the aim of speeding up information about the dangers of cold lava floods while creating cheap and efficient tools so that they can be reached by various segments of society. Apart from that, by being based on the Internet of Things, this cold lava flood early warning tool will be easily connected to mobile devices and computers via the internet network which will create data interconnection [84]; [85]. This interconnection will make it faster and easier to disseminate early warning information for cold lava floods and make it easier for the public to monitor the latest conditions, weather data and river conditions prone to cold lava floods [86]; [87]. This device is also equipped with solar panels as its main power source [88]; [89]. So apart from being fast and accurate, this tool is also energy efficient and environmentally friendly, as well as allowing this tool to be installed at points that are not reached by the PLN electricity network. The tools needed include soldering iron as the main tool for connecting various electronic components, a multimeter for checking and working relationships between electronic components, a tool set for assembling each component of this system, while other handtools for assembling the mechanical system.

The materials that will be used are buoy mechanical sensors to detect the height of the river water level which suddenly rises. It is also equipped with a 0.5 mm steel sling wire to detect if an avalanche of eruption residue occurs which has the potential to enter the river flow and cause cold lava floods. Then the GSM SIM900A module functions to send river water level data and messages about the condition of landslides left over by the latest eruption in the form of SMS (Short Message Service) to the client side to trigger loudspeakers on the server side to sound and provide an early warning for the public to be alert. How the tool works This is where there are two sides to the tool, the side that acts as a client to retrieve data and a server to convey information on potential cold lava floods resulting from processed data. The client side will be

installed at several points along the river to ensure the ebb and flow of river water around the volcano by utilizing steel slings connected to the rotary encoder. If a ground shift occurs, the rotary encoder will automatically rotate and detect the ground shift to an accuracy of 1 cm. The buoy mechanical sensor functions to detect changes in water level. If an avalanche is detected and the height is above the specified threshold, it will trigger the client side to send a message via the GSM module to the server side. The server will collaborate data from the client with weather forecast data from BMKG which can be accessed generally. Every minute the client side will take a data sample to be sent to the server, then the server will send it to the database to be stored and processed, then the data can be accessed via Android-based applications and websites by the public. Data that can be monitored by the public is monitoring weather status, rainfall and the latest information on river water levels. This information disclosure is to support information transparency to the community and it is hoped that the community can be ready to respond to disasters early.

Optimization of sensors and transducers for lava flood detection and a number of main factors that can influence sensor reliability [90]; [91]; [92]. Electroacoustic transducers that transmit sound pulses and receive return echoes are the most important components in ultrasonic sensors [93]; [94]; [95]. Transducer design expertise and transducer quality can drastically influence the performance and reliability of the sensors used [96]; [97], because substandard transducers are filtered out long before they are marketed. There are two main areas to consider that influence transducer reliability, the first is ensuring that the transducer has the correct mechanical and electroacoustic design for each application, the second is how the transducer is constructed [98]; [99]; [100]. Because one thing influences the other, acoustic and mechanical design are interrelated in many ways. Thus, for correct transducer design, a solid understanding of both is essential [101]; [102]; [103]. There are also some clear differences between the two. This means that the transducer must be made with appropriate materials so that it can withstand the environment without compromising the acoustic performance of the transducer and be made to withstand sound attenuation problems [104]; [105].

Reliable transducer design must begin with a proper characterization of the conditions to which the sensor will be exposed and required to operate [106]. To optimize performance and durability, possible mechanical challenges and the acoustic properties of the environment must also be understood [107]. This applies to transducers and ultrasonic and sonar systems. To achieve the desired operation in an environment, the material must work well with the acoustics, and the material and the acoustics must be designed. The quality of the transducers within them greatly improves the quality and reliability of the sensors manufactured or used and an understanding of materials and acoustics can provide an edge to the user [108]; [109]; [110].

4. CONCLUSION

Lava flood detection must be carried out so that the lava flood disaster phenomenon can be recognized and avoided by the surrounding community. With the help of artificial intelligence based on the internet of thought which uses sensors and transducers which are electronic components. The application of this component in a device is also very crucial. The more knowledge a sensor and transducer designer has regarding an application, the better the sensor and transducer will be at ensuring its performance.

DECLARATION

Author Contribution

This research uses a systematic literature review method using Preferred Reporting Items for Systematic Reviews (PRISMA).

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Conflict of Interest

Declare conflicts of interest or state “The authors declare no conflict of interest.”

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