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Early Warning Design for Environmental Radioactivity Using Unmanned Aircraft in a Radiation Monitoring System as an Effort to Maintain Public Health

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***Abstract*—Radiation monitoring using unmanned aircraft detection systems can reduce the impact of radioactive element activity and contamination. The design of an early warning system using unmanned aircraft and real-time and visual monitoring is a crucial step towards achieving national security by providing an early warning of the dangers of radioactivity that cannot be measured in the environment and can be a health threat. Unmanned aircraft are equipped with detectors and other supporting devices to obtain data: date, time, coordinates, altitude, radiation value, temperature, humidity, battery status, and pressure. The data is managed in the phpMyAdmin database by adjusting the table structure. The receiving device is equipped with the MIT App Inventor application, which was previously designed. The MIT App Inventor display design was prepared by inserting a user interface with labels, text boxes, layout settings, and connectivity to the IP server. Meanwhile, the programming is saved in the installed XAMPP folder. The information data is then processed to obtain radiation level monitoring results in visual form and integrated with databases and servers. The results of developing this technology not only facilitate data analysis in knowing the location and level of radiation when monitoring the environment or solving problems in affected areas but also pave the way for further advancements in radiation monitoring systems.**

***Keywords*— Unmanned aircraft; radiation values; MIT App Inventor; MySQL.**

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I. INTRODUCTION

Currently, environmental monitoring devices are widely implemented. Water monitoring with sediment surfaces is an environmental monitoring application using particle movement [1]. Environmental monitoring of chemicals has also used advances on the Internet of Things to detect chemicals in the epidermis or textile layers. However, research is still developing, so it can have real-time communication capabilities in the future [2]. In the environment, potential dangers can be caused by various things, including potential chemical or chemical hazards that risk affecting workers' health, such as poisoning and even cancer [3]. Preventive efforts in the form of a disaster mitigation system have been carried out for environmental security systems using critical rain threshold charts as a warning before a flood disaster occurs [4]. Detection of sensors has been used in environmental monitoring and control processes, especially in safety-related industries in dangerous chemicals and radioactive detection [5]. Indoor radiation monitoring systems have also been carried out using readings and an LCD screen when measuring radiation [6]. Research on the use of IoT technology has also been carried out in applying nuclear leak detection to avoid casualties [7]. Radiation monitoring systems play a role in maintaining human safety, so this system has significant consequences and is considered a safety-critical system [8].

Historically, early warnings initially contained discussions about an event or conflict that occurred [9]. The data obtained from the results of environmental monitoring can be used for further analysis regarding disasters, outbreaks, or threats that are likely to occur and affect the quality of public health. In emergency conditions, one of which is a nuclear emergency, it is necessary to analyze the situation and identify the incident correctly [10]. In the long term, environmental monitoring can be used as an early warning or as an emergency response when a disaster occurs, especially in this research focuses on public safety against the threat of environmental radiation.

Environmental drone monitoring has been carried out for several elements that support security. Monitoring air humidity and knowing the level of air pollution caused by CO (Carbon Monoxide) is carried out using a quadcopter [11]. Unmanned aircraft are also used in fire monitoring and detection [12]. Monitoring carried out using unmanned aircraft can be a reason because its coverage area is wide, so it is more effective. The use of unmanned aircraft has also been applied in the plantation sector as the primary support for logistics area detection systems [13].

Using unmanned aircraft has the advantage of operating remotely, supported by the latest firmware system development [14]. Using drones also makes it easier to map certain information, such as mapping and identifying land in forest areas [15]. Digital mapping in the agricultural sector for the development of irrigation areas has been carried out using drones to support mapping with aerial photography [16]. To ensure comfort and safety regarding power outages due to kites getting caught in the power grid, it is made easier by using drone technology to detect the problem's coordinates and developments in deep learning algorithm analysis technology to find faster and more efficient results [17]. The Search and Rescue team has also identified objects in disaster areas to identify objects through the operation of unmanned aircraft [18]. Research into monitoring disaster areas has also been conducted using unmanned aircraft equipped with thermal sensors to find victims and facilitate post-disaster evacuation [19]. Apart from that, research has also been carried out to compare algorithms for quadcopters' landing and take-off capabilities [20], thus supporting the use of unmanned aircraft in detection and rescue operations in various circumstances.

Environmental monitoring has been carried out regarding water, soil conditions, critical thresholds for rain, air humidity, and air pollution. Monitoring of plantation logistics areas, identification of forest areas, irrigation mapping, and object identification have been done. In previous research, remote sensing technology was only carried out to monitor armed conflicts or conventional attacks, and monitoring was not carried out regarding attacks using radioactive or nuclear substances [21]. UAVs have also been used in land condition mapping activities to identify vulnerable land areas [22] and monitor geological natural disasters [23]. Monitoring is also carried out in other matters, namely monitoring in nuclear power plant facilities to monitor conditions and the surrounding area [24]. Previous research also used technology to monitor real-time disaster [23].

However, no research has used methods to read data in real-time, using databases, servers, and MIT App Inventor to monitor air levels of radiation. The choice of using MIT App Inventor in this research was based on its ease of operation for creating application projects for Android users [25], and the system is free to use, open source, accessible in real-time in operation [26], and easy to understand [27]. In presenting data, choosing visualization in the form of a dashboard is said to be able to display data informatively [28], and analyzing the dual use of nuclear technology requires mitigating risks carefully and effectively [29]. Previous research also used visualization results in displaying mapping of natural disasters such as floods [30]. Environmental radiation levels need to be monitored to achieve national security as an early warning of the dangers of radioactivity that cannot be measured in the environment and can be a health threat. Radiation exposure and radiological effects on humans and the environment are monitoring issues in nuclear facilities or nuclear power plants [31]. Making Indonesia "Zero from Danger" means ensuring state security and avoiding all threats, including health threats. As stated in Law No. 17 of 2011 concerning State Intelligence, State Intelligence has the role of carrying out efforts, work, activities, and actions for early detection and early warning in the context of preventing, deterring, and overcoming any threat that may arise and threaten national interests and security.

For this reason, to obtain the results of environmental monitoring of radiation levels quickly, easily accessible, and meeting standards for analysis, an early warning system design is needed by utilizing data storage via a database, the use of a web server, and an integrated system application visualization display that can be accessed in real-time. Visualization is carried out by presenting changes in events over time based on data [32] and displayed as a distribution in a graph [33]. In this design, planning, database management, programming, and use of supporting software are carried out. Utilizing a database by integrating data systematically and presenting it with a web interface that is easy to operate will help operators analyze data according to specific needs they want to understand more deeply [34]. By developing this design plan, it is hoped that the results of monitoring environmental radiation levels through the air using unmanned aircraft can be used to maintain public health and ecological safety, thereby realizing national security.

II. Materials and Method

A. Model Development Concept for Unmanned Aircraft

Unmanned aircraft are being developed into nuclear security systems, providing information for waste transportation, radiation, and environmental protection. System configuration for radiation detection using drones and specifications for the type of radiation detector depends on the load capacity the drone can carry. The altitude and height of the drone affect the resolution and sensitivity of monitoring results. The area and object influence the dose rate reading and identification of radionuclides [35]. The use of remote sensing using drone technology equipped with sensors and communications plays a role in obtaining large-scale data. Cost savings in drone operations, data retrieval capabilities, and flying capabilities with flexible maneuvers make drones an effective technology for use as a conventional remote sensing technique [36]. The drone flight system is equipped with a flight control system connected to the processor through power distribution to the motors that stabilize the drone's flight. Drones usually have a magnetometer, barometer, and GPS (Global Positioning System) [37].

On the data receiving side, operators use MIT App Inventor to read radiation monitoring data and utilize RDBMS (Relational DBMS), which contains data in interconnected tables, namely MySQL (My Structured Query Language). MySQL has become the database of choice for many software and application developers on online and desktop platforms because of its reliability, speed, and ease of use. Individuals and small businesses aren't the only ones using MySQL;

Yahoo!, Alcatel-Lucent, Google, Nokia, YouTube, WordPress, and Facebook are all MySQL users [38]. Radiation monitoring data is managed in a database developed in MySQL and managed by phpMyAdmin and can be accessed using a URL in a web browser [39]. In the research, the output data was processed via a microcontroller and then stored in a MySQL database on a web server managed by phpMyAdmin to store voltage, current, and other data. PhpMyAdmin is a tool that supports the administration process of databases and visual platforms in the form of browsers as users [40]. MIT App Inventor is an intuitive visual programming tool that can create functional apps for Android phones, iPhones, and Android/iOS tablets. MIT App Inventor application research was led by Professor Hal Abelson, whose block-based coding program inspired intellectual and creative empowerment [41]. The use of MIT App Inventor in the industrial world is still rarely done, even though this application can help increase reliability and connectivity with specific indicators so that they can be used for decision-making [42].

B. Characteristics of Models Developed for Environmental Radioactivity Monitoring

Early warning system design using MIT App Inventor, as shown in Fig. 1, begins by building from the beginning of a project.

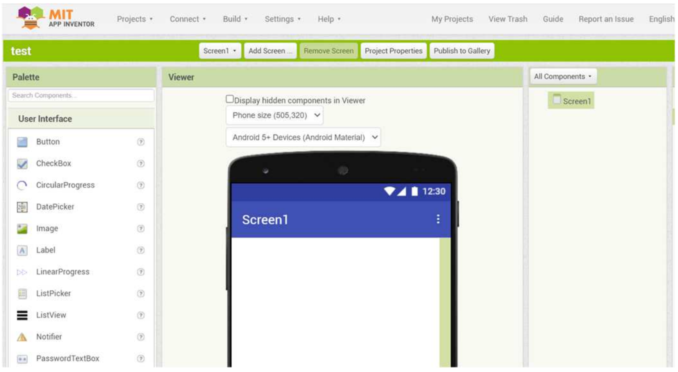

Fig. 1 MIT app inventor view

The results shown in MIT App Inventor will display radiation levels in real-time. Radiation levels can be categorized as a threat if the body absorbs exposure to radiation released by radioactive elements and causes a decrease in health quality in the short and long term.

Radiation can interact with biological material, occurring in DNA, chromosomes, and cells. The interaction of radiation with DNA causes mutations or changes in DNA properties due to cell DNA failing to repair. On chromosomes, radiation causes chromosomal aberrations or changes in the number and structure of chromosomes, which are influenced by the radiation dose level. Too many dead cells in an organ will affect the function of that organ, causing complaints or illnesses in someone exposed to radiation. Cells that change their properties will cause stochastic effects, and cells that die will cause deterministic effects.

Dynamic monitoring is carried out by unmanned aircraft or drones equipped with detectors to read radiation levels. Utilizing this technology with remote control can be used to monitor radiation in areas that are difficult to reach and pass through and are influenced by high or low terrain [43]. Early warning is a way of detecting threats that will occur and allows these situations to threaten public health. Radioactive exposure to the environment or contamination that occurs if left for a long time will significantly impact public health, considering that public health plays a vital role in supporting the implementation of national security.

C. Model Design

Indonesia's plain areas have diverse geographical conditions requiring dynamic radioactive measurements. Dynamic measurements are expected to make it easier for operators to track or monitor radiation levels. In previous research, nerve agents were detected using a portable sensor kit that was easy to use, reliable, and fast for environmental monitoring [44]. In other words, mobile sensing has several advantages over traditional sensing [45]. Unmanned aircraft or drones can move, monitor radiation, and store monitoring data, which can then be read and analyzed using MIT App Inventor.

Fig. 2 explains the architecture of the early warning design system. The drone is operated and obtains environmental monitoring results regarding radiation exposure and the coordinates traversed. The operator prepares the open-source software XAMPP [46] and the phpMyAdmin database for the data transfer; programming contains reading commands, radiation values, and other values linked to MIT App Inventor.

Fig. 2 Early warning design system architecture

This study uses the research and development (R&D) method in developing nuclear technology. Research and development in the nuclear field can be supported by all parts of a country and can be a priority [47]. Model development starts from understanding radiation sources, utilizing technology, and finally producing products to support the development of future nuclear technology [48].

This research used an example of an area where a radioactive source had been placed to read the radiation level at a certain height using an unmanned aircraft or drone. The drone will dynamically detect radiation levels in the area with specific path settings. Then, create a database and design a table structure according to the data type of radiation monitoring results, prepare a program containing commands to read radiation monitoring results, and design the appearance of MIT App Inventor. The MIT App Inventor was innovated so that radiation monitoring results can be read using a smartphone equipped with this application, considering that currently, many people use smartphones to use mobile products for environmental sensing [49]. The MIT App Inventor project display that has been created ensures it can display the radiation level value as read by the detector on the drone in real-time and flexibly.

This research presents the results of measured data carried out as an effort for an early detection system or early warning design, which can be utilized by monitoring operators to analyze environmental radioactivity levels with work steps, as shown in Fig. 3.

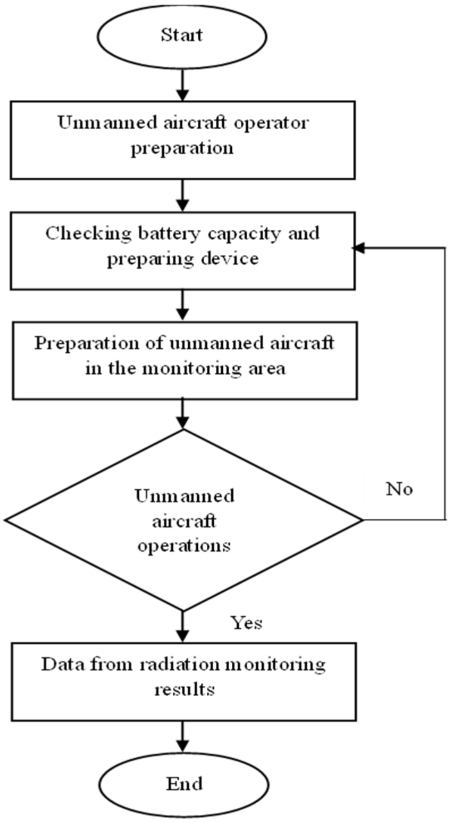

Fig. 3 Radiation monitoring flow diagram using an unmanned aircraft

III. RESULT AND DISCUSSION

A. Model Development Results

This research and development began with a literature study on unmanned aircraft, radiation detection, MIT App Inventor, and phpMyAdmin. Before starting testing, the drone is equipped with a data acquisition device, Geiger Muller detector, and other communication tools to connect to the database as a Tx (Transmit) device or data sending device. Next, the Rx (Receive) or data recipient devices, namely smartphones and server computers, are equipped with MIT App Inventor, MySQL web server, and phpMyAdmin database. Database preparation is followed by creating a table structure corresponding to the radiation monitoring data. After preparations are complete, testing can be carried out in an open area that allows drones to pass through, and then the web server computer and smartphone are connected to the same network. After obtaining the radiation monitoring results, these results can be analyzed using a formula to calculate the dose rate to ensure a safe distance for officers in removal and decontamination if some areas are contaminated.

In Fig. 4, it is explained that the radiation monitoring process begins by completing a table structure with integer, date, time, float, and decimal types that adjust the input data. The connectivity of the sending device on the unmanned aircraft with the database is expected to be running and then displayed. Preparing the application to be built can be done by managing designs and blocks in MIT App Inventor, which can be accessed via http://ai2.appinventor.mit.edu/, fully explained in Fig. 6. The web server computer is certainly equipped with XAMPP as a web server. It activates the Apache and MySQL modules during operation. Activating XAMPP, My SQL, and Apache is a step in utilizing the open-source platform, which is carried out wirelessly or remotely [50]. Wireless smartphone communication utilizes cellular networks to transfer or send and receive data to servers in long-distance communications [51]. When all the devices are ready, drone operation flights to monitor radiation can be carried out. In the data processing process, the following stages are carried out:

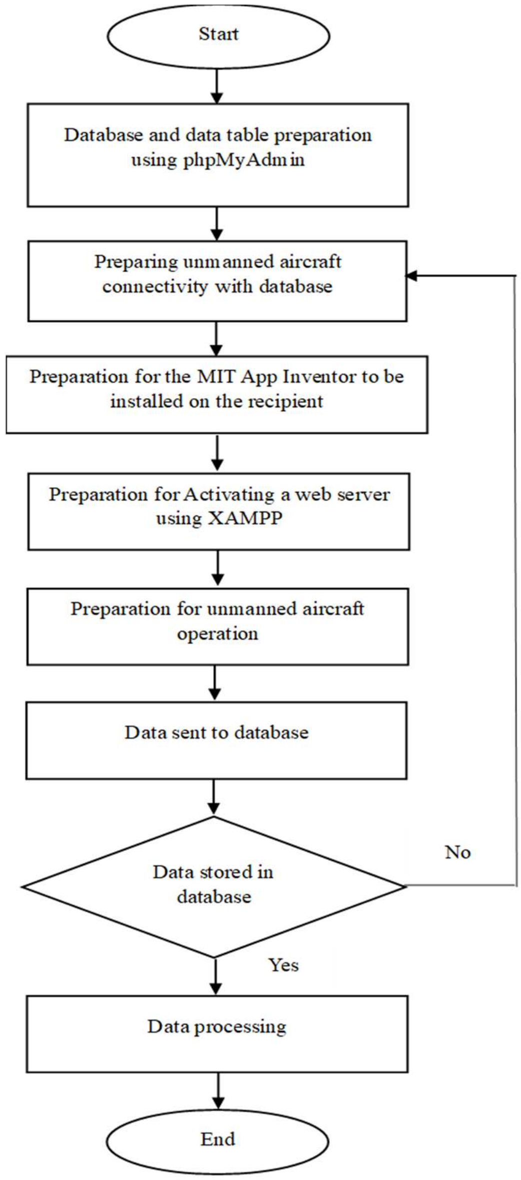

Fig. 4 Radiation monitoring process flow diagram

Fig. 5 explains the radiation data processing process up to the data analysis stage resulting from radiation monitoring. The IP (Internet Protocol) server settings by XAMPP [50] used in this development research can be adjusted to ensure data security. The Server IP can be adjusted to the IP address used during radiation monitoring. Server IP can be seen in the IPv4 network address settings. The smartphone is connected to the IP database server, which is also connected to the web server computer. For security reasons, it is hoped that the IP will only be known by operators, interested persons, and officers involved in radiation monitoring activities so that the security and integrity of the radiation monitoring data is maintained.

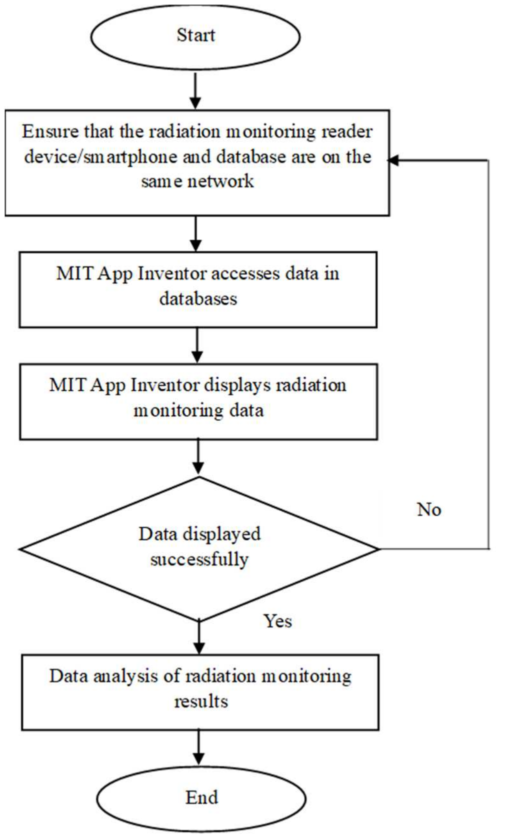

Fig. 5 Flow diagram of the radiation data processing process

Meanwhile, application projects built at MIT App Inventor can be accessed on other devices that permit the download of the application. This application project accesses data from a database containing environmental radiation monitoring results. The data displayed makes it easier to analyze, which is useful for the following safety stage. In MIT App Inventor, two displays (2 screens) are created. The first screen displays a logo and a button to read the radiation monitoring results. On the second screen, there is connectivity with a display of monitoring results using a web viewer.

On the first screen, the block has a command stating that the radiation monitoring reading will start when the button is pressed. The block has a web viewer on the second screen, and the homeURL column is filled in according to the database address. The following process is carried out when managing designs and blocks in MIT App Inventor.

Fig. 6 explains the simple design of creating a radiation monitoring application connected to a database using MIT App Inventor using two display models that the user can access. After that, the radiation monitoring early warning design project using MIT App Inventor was ready for use in operations.

Table I explains the guidelines for filling in the parameters on screen 1 and screen 2. The screen size parameter settings are set by default according to the specified size, and image and button sizes are filled in according to research needs. The Master of Applied Medical Intelligence (MTIM) logo is on screen 1 and screen 2. For the homeURL Web viewer, fill in the URL with IPv4 (Internet Protocol version 4) according to the hotspot used.

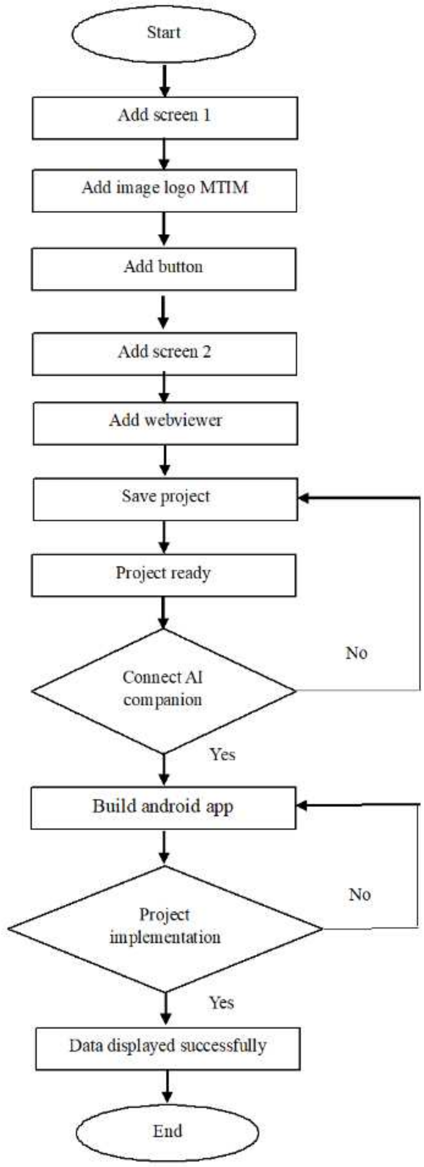

Fig. 6 Flow diagram of the MIT app inventor management process

TABLE I
GUIDE TO FILLING IN MIT APP INVENTOR PARAMETERS

Parameter	Arrangement
Screen	default
Image Height	100 pixels
Image Width	320 pixels
Picture	MTIM Logo
Button Width	Fill parent
Web viewer homeURL	http://IPserver/folder/index.php

From a health perspective, the environmental radiation monitoring analysis results are linked to the dose rate received by a person or radiation officer near the location and receiving radiation exposure. Depending on how large or small the level of radiation the body receives impacts long-term health and direct cell damage. So, we get the equations below.

$$H = \Sigma (D \times Wr) \quad (1)$$

$$E = \Sigma\,(Wt \times H) \tag{2}$$

$$\dot{X} = \Gamma \frac{A}{r2} \tag{3}$$

B. First Model Development

The first draft model displays the design of the MIT App Inventor project by applying parameters suitable for use in radiation monitoring research.

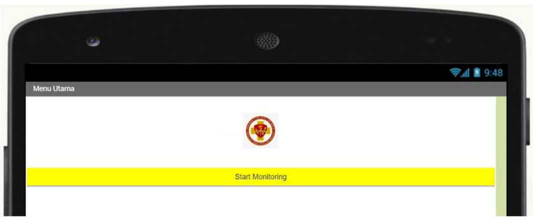

Fig. 7 Screen display 1 MIT app inventor

Fig. 7 shows Screen 1 of the MIT App Inventor project, which consists of the MTIM Study Program Logo and a button to start monitoring, which will link to Screen 2.

Fig. 8 Display of image and button parameters in MIT app inventor

In Fig. 8 displays filling in parameters to set the image size and button details to be displayed. Filling parameters can be adjusted according to table I which was explained previously.

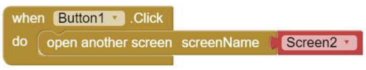

Fig. 9 Design screen display 1

The command created is when Button1 clicks to open another screen screenName Screen 2, which means that if the button is pressed, it will be connected to screen 2. This screen will display monitoring results in the form of graphs of radiation levels according to the radiation monitoring data recorded in the database. The design of screen 1 is shown in Fig. 9.

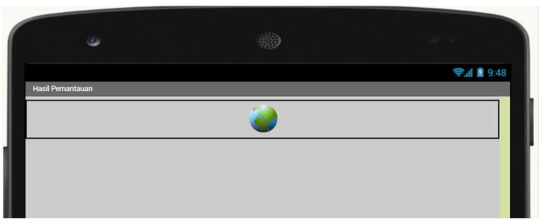

Fig. 10 Screen display 2 MIT app inventor

Fig. 10 shows Screen 2 of the MIT App Inventor project which contains WebViewer1 to display the radiation monitoring results web page by accessing the homeURL.

Fig. 11 MIT app inventor web viewer parameter display

Fig. 11 displays the parameters equipped to carry out the web Viewer function. One important parameter is that the homeURL parameter must match the IP of the Server connected to the database. Manage database data by manually inputting, importing data, or writing commands for database input in the browser column. The data is in the form of device, date, time, latitude, longitude, altitude, radiation, temperature, humidity, battery, pressure, altitude ground, and count data. Then, proceed with checking the success of the database input; experiments can be carried out on a computer connected to the IP server. After the data has been successfully added to the database table, the next step is to connect the server computer to MIT App Inventor using the available features, namely AI Companion.

Further model development involves testing using monitoring data sent by the sending device to the database when testing in the field. The materials prepared include a data-sending device, a data-receiving device, one server computer unit, and three smartphone devices. The first smartphone was used to display raw data from radiation monitoring results. The second smartphone is used as a mobile hotspot or IP server. The third smartphone is used to monitor radiation levels using the results of the MIT App Inventor project's early warning design, which is designed to display real-time radiation monitoring graphs. The radioactive source used during testing was Am-241 or Americium-241. In line with updated data in the database, the dose rate on the radiation monitoring graph shows a peak or spike, which indicates high radiation levels. This condition shows a significant difference from the background radiation value.

System testing continues by using the radioactive isotopes Cobalt-60, Cesium-137, and Americium-241 at 5 cm, 10 cm, 15 cm, and 20 cm to produce varied radiation level readings. The database has been updated, as shown in Fig. 12.

ID	Date	Time	Latitude	Longitude	Altitude	Radiation	Tempe rature	Data_ Count	Radioactive Substances
732	10/8/2023	11:43:49	-6.349235	106.664467	106.3	0.8	37.98	686	Co-60
747	10/8/2023	11:44:20	-6.349211	106.664391	110.1	0.76	38.09	701	
779	10/8/2023	11:45:26	-6.349224	106.664528	105.3	0.68	38.31	734	
833	10/8/2023	11:47:16	-6.34923	106.664207	108.5	1.32	38.63	789	
848	10/8/2023	11:47:47	-6.349212	106.664391	109	1.8	38.75	804	Cs-137
858	10/8/2023	11:48:07	-6.349208	106.664413	109.7	2.24	38.8	814	
912	10/8/2023	11:49:57	-6.349267	106.664452	108.5	0.68	39.02	864	
968	10/8/2023	11:51:53	-6.349246	106.664688	107.2	0.52	39.49	922	
1039	10/8/2023	11:54:31	-6.349246	106.664375	109.1	23.54	40.04	1000	Am-241
1089	10/8/2023	11:56:14	-6.349257	106.664909	78.9	12.55	40.53	1051	
1106	10/8/2023	11:56:48	-6.3493	106.664673	62.8	7.95	40.65	1067	

Fig. 12 Data from radiation monitoring results in the database

The results of testing the early warning design using MIT App Inventor, developed using a smartphone application, can create a low-cost analysis tool [52] and an easy-to-access tool. Smartphone monitoring can also develop rapidly with adjustments to its application potential [53]. In this research, the MIT App Inventor application that was built successfully accessed data from the database, as shown in Fig. 13, Fig. 14, and Fig. 15.

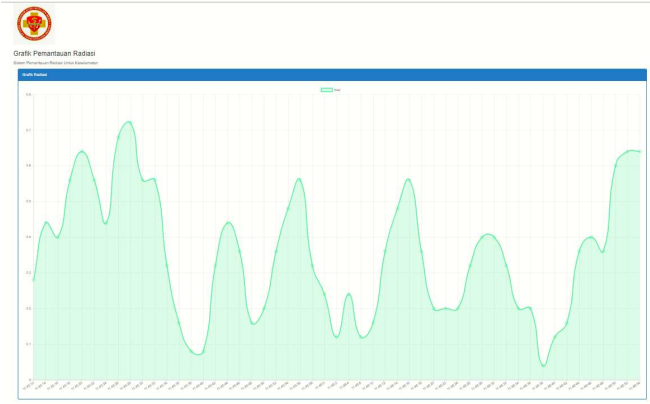

Fig. 13 Early warning design graphics Co-60 dose rate distance 5 cm

Fig. 14 Early warning design graphic Cs-137 dose rate distance 5 cm

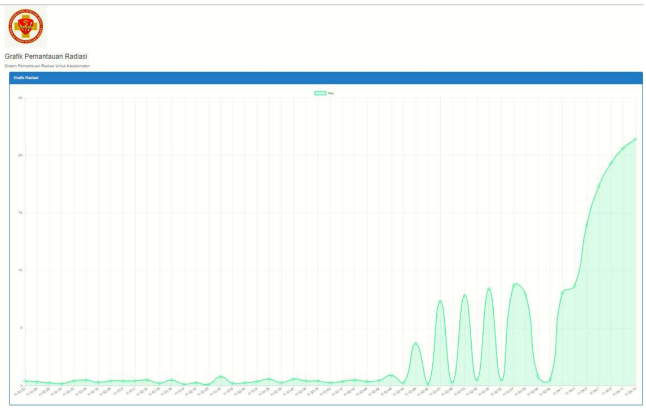

Fig. 15 Early warning design graphic Am-241 dose rate distance 5 cm

Previous research by [55] reported that environmental monitoring was also carried out when the earthquake occurred in Fukushima, thus causing most radioactive materials to pollute the environment. In this condition, it is essential to know the dose rate in real time to immediately identify a safe area for evacuation if a disaster occurs. Apart from these situations, dose rate measurements can also be carried out around the reactor to prevent unplanned emissions [54]. So, it is essential to monitor using a wirelessly connected radiation detector [55].

According to [56], the radiation monitoring system is used to control radioactive pollution and monitor radiation in emergencies or Emergency Radiation Monitoring (ERM), in which case This could result from the operation of Nuclear Power Plants (PLTN) as a Radioactive Pollution Control effort. In comparison, research by [57] stated that the results obtained in air monitoring are good coverage and can make surveys. Air traffic is effective in characterizing contamination over large areas. The considerable flight line distance will increase the potential for misclassification of the contaminated regions.

TABLE II
SUMMARY OF PREVIOUS RESEARCH RELATED TO AIRBORNE RADIATION MONITORING SYSTEMS

Research Result	Contributors/Year
Measurement data (cps) from radiation sensing and signal processing components and background radiation data.	Kim et al. [55]
The airborne implementation of ERM systems (using UAVs) is exciting and efficient. Remote detectors can monitor far from the disaster site so that equipment and personnel are protected from high levels of radiation resulting from the disaster that occurs. Geiger Muller Detector: Maximum Detection Distance Limit (50 m) and Integration Time (2s).	Kumar et al. [56]
Misclassification of flight line distance.	Masoudi et al. [57]

Table II contains some of the results of previous research regarding airborne radiation monitoring, namely the radiation monitoring data, which displays the results of radiation intensity measurements in the form of cps or counts per second. In contrast, in this study, the radiation levels have been converted into units of sieverts per hour. UAVs or Unmanned Aerial Vehicles are used as ERM or Emergency Radiation Monitoring, so in this research, it is hoped that the early warning system design can be used not only in situations after a disaster but can support daily monitoring as a safety test for the environment around operating reactors, and to monitor the territory of Indonesia certain parts. Like the research carried out by Wahyudi et al. [58], they recorded radiation doses in residential homes in the West Kalimantan region, with the results showing that the doses were below the world average dose. So, the results of the early warning system design in this research are expected to support the monitoring of radiation levels in terrain that is difficult to travel due to the diversity of geographical conditions for radiation officers to traverse so that monitoring can be carried out through the air supported by visual, online and real-time data reading with more accessible and faster analysis.

As a test of the effectiveness of the mode being developed, the exposure rate was carried out with a focus on the half-life parameters, the activity of the radioactive source used, and the distance, as well as the ideal calibration factor having a value of 1, but the value is still acceptable if the calibration factor is between 0.8 to 1.2. The use of this calibration factor can indicate the actual dose [59].

TABLE III
DETAILS OF RADIOACTIVE SOURCES IN LABORATORY SCALE TESTING

Isotope	Initial Activities	Activities in 2023	
Co-60	1 µCi / 01 April 2019	0.6 µCi	0.022 MBq
Cs-137	9.57 µCi / 18 Juli 1992	4.785 µCi	0.177 MBq
Am-241		400 µCi	13,800 MBq

Table III explains the radioactivity of Co-60, Cs-137, and Am-241 in initial activity and remaining activity during operation. The following is a comparison of the results between the instrument measurement values and the calibration factors

TABLE IV
CS-137 (15CM) MEASUREMENT RESULTS VALUES TIMES THE CALIBRATION FACTOR

Measurement Result Value (*µS/h*)	Calibration Factor	Acceptable Value (*µS/h*)	Calculation (*µS/h*)	Difference
0.72	0.800	0.576	0.695	0.119
0.72	0.900	0.648	0.695	0.047
0.72	**0.965**	**0.695**	**0.695**	**0**
0.72	1.000	0.72	0.695	-0.025
0.72	1.100	0.792	0.695	-0.097
0.72	1.200	0.864	0.695	-0.169

In Table IV, it is explained that the dose rate value read when measuring using handheld FLIR spectroscopy is still at an acceptable value. The dose rate value is multiplied by a calibration factor of 0.965 to get results in accordance with calculations using the formula carried out previously.

TABLE V
READING RESULT VALUES FOR EARLY WARNING SYSTEM DESIGN CS-137 (15CM) MULTIPLIED BY CALIBRATION FACTOR

Measurement Result Value (*µS/h*)	Calibration Factor	Acceptable Value (*µS/h*)	Calculation (*µS/h*)	Difference
0.68	0.800	0.544	0.695	0.151
0.68	0.900	0.612	0.695	0.083
0.68	1.000	0.68	0.695	0.015
0.68	**1.022**	**0.695**	**0.695**	**0**
0.68	1.100	0.748	0.695	-0.053
0.68	1.200	0.816	0.695	-0.121

In Table V, it is explained that the dose rate value read during laboratory scale testing using an early warning design system reading is still at an acceptable value, namely by multiplying the dose rate value by a calibration factor of 1.022 to get results by the calculation using the formula that has been carried out. previously. So, it can be concluded that the measurement data and monitoring data in the database are acceptable because they are in the range of 0.8 -1.2 times the calibration factor, namely 0.965 and 1.022.

Data from laboratory-scale testing carried out at several distances and several radioactive sources shows a graph of radiation values with peaks as an indicator of the presence of higher radiation. Table VI contains comparative results from the radiation monitoring system using an early warning design, measurements using handheld spectroscopy, and calculations.

TABLE VI
DOSE RATE USING SYSTEM, MEASUREMENT, AND CALCULATION

Radio-active Isotopes	Distance (*cm*)	Results (*µS/h*)		
		System	Measurement	Calculation
Co-60	5	1.320	1.000	3.136
	10	0.800	0.500	0.784
	15	0.760	0.300	0.348
	20	0.680	0.200	0.196
Cs-137	5	1.800	2.670	6.564
	10	2.240	1.200	1.640
	15	**0.680**	**0.720**	**0.695**
	20	0.520	0.520	0.410
Am-241	5	23.540	14.000	40.522
	10	12.550	7.248	10.130
	15	7.95	4.500	4.502

IV. CONCLUSION

The potential risk if people are exposed to radiation in the long term will become a severe health problem and a potential threat to national defense. It is necessary to have an early warning design for the possible danger of high radiation levels that is easy to access and can be accessed online so that it does not take a long time to process the data and continue the analysis process to the next stage. The results are easy to analyze in the form of data visualization in the form of dose rate graphs as an effort to mitigate disasters and routinely monitor the environment so that this can minimize the potential for health threats.

Thus, the results shown in the system design can be read in real-time radiation monitoring results by visualizing radiation levels in graphs. The graph of early earnings design results on radiation levels is easy to read and analyze by identifying the peaks displayed. Peaks on the graph indicate anomalous data because the comparison with natural radiation or background radiation with the dose rate produced from radioactive sources has very different and significant values. The half-life and activity of the radioactive source also influence the dose rate received. When detecting radiation, the radiation display will be used for further location analysis. The coordinates at the peak of high radiation levels can be forwarded to Google Maps for location accuracy. Additional analysis can be carried out to calculate the size of the area with high radiation with a radiation monitoring pattern surrounding the area indicated to be contaminated or have a radioactive source. Early warning system design can make it easier to collect radiation monitoring data because the radiation monitoring data is connected to a database that can store data history. The history in the database can be used for further analysis if necessary.

NOMENCLATURE

$\dot{X}$	exposure rate	R/hour
Γ	gamma factor	R.m2/Ci.h
A	activity	Ci

r^2	distance	m
D	Absorbed Dose Value	Rad
Wr	Radiation Weight Factor	
Wt	Body Tissue Weight Factor	
H	Equivalent Dose	Sv or Rem

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