Design and Build a System to Minimize the Impact of Toluene Exposure on IoT-Based Workshop Workers

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***Abstract*—Toluene is one type of organic solvent that is widely used in industry. Organic solvents can have a negative impact on health when exposed to the human body through inhalation (breathing), digestion (swallowing) and adsorption (skin contact). This compound is widely used as a basic material for solvents, dyes, paints, resins, perfumes, nail polish, gasoline, glue, solvent thinner, immersion ink, and printing. The impact on each human will vary depending on the concentration, duration and toxicity of the solvent. The effects of exposure are generally long-term and short-term. Short-term effects include respiratory complaints and eye irritation in exposed humans. An ESP32 microcontroller, HCHO sensor, and DHT11 sensor were used in this study to construct a system to lessen the effects of toluene exposure on workshop personnel. Temperature and humidity sensors picked up by DHT11 have an average value for each node. Each node's average value for the temperature and humidity sensors detected by DHT11 is available. The average error value is categorized as accurate and good for nodes A and B, which are separated by 2 meters and 4 meters, respectively. Due to the DHT11's error rates, the temperature range is 20C and the humidity range is 5% RH.**

Keywords*— *ESP32, Toluene, IoT, HCHO sensor, DHT11 sensor.

I. INTRODUCTION

Toluene (C6H5CH3) is a chemical element found in the form of a clear liquid as a basic ingredient for *solvents*, dyes, paints, resins, perfumes, nail polish, gasoline and solvent thinner. Toluene is a non-polar aromatic hydrocarbon compound which has a boiling point of 110.06° and is also volatile which means it can easily evaporate and burn [1]. Toluene is one type of organic solvent that is widely used in industry. Organic solvents can have a negative impact on health when exposed to the human body through inhalation (breathing), digestion (swallowing) and adsorption (skin contact). Exposure to toluene will affect the function of the central nervous system, liver, kidneys, skin and many others [2]. Due to the volatile nature of toluene, the most likely route of exposure is inhalation. The impact on each human will vary depending on the concentration, duration and toxicity of the solvent. The effects of exposure are generally long-term and short-term. Short-term effects include respiratory complaints and eye irritation in exposed humans.

However, toluene will be safe if used in accordance with a predetermined *threshold* value. Minister of Manpower Regulation Number 5 of 2018 concerning Occupational Safety and Health states that the safe use of toluene is 20 ppm and not more than 8 hours/day or 40 hours/week [3]. The amount of exposure to toluene vapor depends on the physical conditions of the workplace which include temperature, humidity and air pressure as well as the results of the calculation of Risk Quotients (RQ) there are 40.6% of printing workers who have a risk of health impacts from exposure to toluene [4]. The value of the physical condition of the workplace must also be in accordance with the predetermined Threshold Value (NAV). Workers who are badly affected by exposure to toluene are workshop workers because they will often have direct contact with paint and thinner. Paint particles in painting activities consist of hazardous chemicals such as cadmium, chromium, lead, mercury, acrylic resin, isocyanate and toluene solvents [5]. Exposure to toluene that is too frequent will be harmful to the health of workshop workers.

Based on this, it is necessary to have a physical environment in the workplace in order to remain in accordance with the Threshold Limit Value (NAV). The system is expected to be able to automatically adjust the temperature and humidity so as not to exceed the threshold value. So that the workshop workers can work without experiencing health problems and monitor the physical environmental factors through the android application and store data in the database in real time with ESP32 as the microcontroller. Based on the results of these studies, a system was created that can minimize the impact of exposure to toluene compounds on workshop workers.

In reference to previous research, the authors created an automatic temperature and humidity control system using the DHT-22 sensor. When the temperature exceeds 30°C it will be controlled using a DC fan, when the humidity is less than 80%RH (relative humidity), then the mist maker as a producer of dew will control it. Monitoring can be done anywhere and anytime, provided that it is connected to the internet by utilizing the Blynk IoT platform. This tool certainly makes it easier to control and monitor.[6]

Another research is the detection of formalin levels in food to facilitate the detection of formalin levels contained in food in percent units. This system is based on the Atmega8535 microcontroller and uses an HCHO type sensor. HCHO sensor to detect formalin levels, relay components as switch controllers, microcontroller ATmega8535 as the main control of the system and LCD as a display of system output results and uses a 12V adapter as the power supply. [7]

Microcontrollers are widely utilized in everything from children's toys to household electronics, automobile support equipment, telecommunications equipment, robot controllers, and military weapons because to their high capabilities, small size, low power consumption, and low cost [8]. As in the QR code-based smarthome research with a microcontroller using ESP32 as a microcontroller driving electronic devices, monitoring the current on each load and Android as a Relay controller and QR Code reader. ESP32 programming using the Arduino IDE. [9]

The sensor used to measure room temperature is the DHT-11 sensor which is a temperature and humidity sensor with a fairly high level of output stability and has long-term reliability [10]. The DHT-11 measures the surrounding temperature by outputting a digital signal on the data pin so that it does not require another analog input signal to operate [11].

Internet of Things (IoT) is an emerging networking paradigm that enhances smart device communications through Internet-enabled systems [12]. The IoT makes it possible to connect objects or things to the internet, and enables the physical world to be integrated into the digital world in order to optimize time, save costs and facilitate human labor [13].

The components that primarily form the backbone of IoT are sensors/devices, connectivity, data processing and user interface [14]. Most IoT applications entail a large number of heterogeneous geographically distributed sensors [15]. Collection of data by sensors from environment marks the beginning of the IoT process[14].

II. METHOD

A. System Block Diagram

Systematically, the workings of the tools that the system runs are made in the form of a block diagram shown in Figure 1 below.

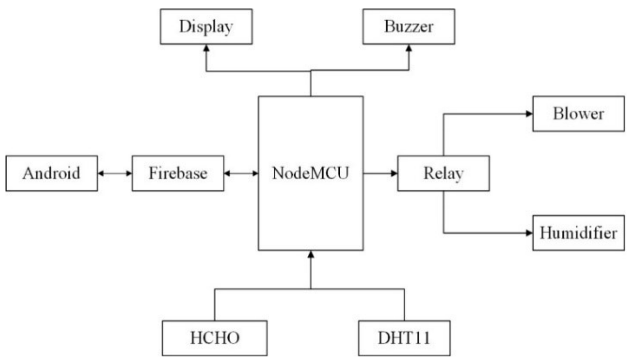

Figure 1. System block diagram

In Figure 1 the block diagram of the system will explain the work process of the system carried out during the study, the description of Figure 1 is The DHT11 sensor is a sensor used to measure room temperature and humidity. After the DHT11 sensor shows the planned temperature and humidity, the data will be sent to the ESP32. ESP32 is the control center that controls the system that has been designed. Then the humidifier will turn on which functions to increase the humidity of the air and the blower functions to remove the hot temperature and gas in the room. At that time, the HCHO sensor turns on which functions to detect the content of compounds in toluene. A buzzer will turn on which functions to make a sound when the values for temperature, humidity, and toluene gas exceed the threshold. After being detected by the DHT11 sensor and the HCHO sensor, the data will be displayed on Android and display. Android and display function to display the data contained in all sensors.

B. Flowchart System

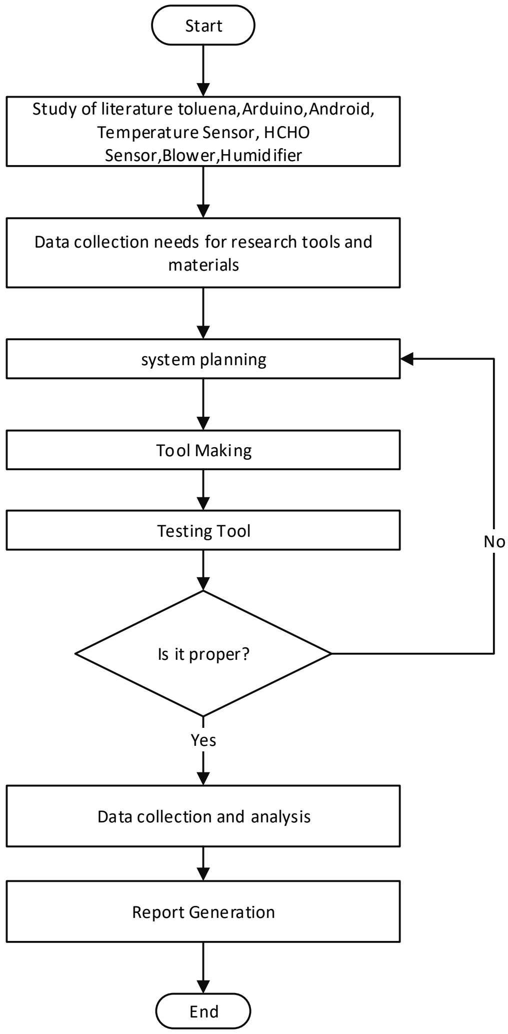

Figure 2. Flowchart system

The following is a description of Figure 2:

1. The first stage is to collect and search literature from previous research journals and determine the objects and problems to be studied.
2. The second stage is to determine the material and which will be used for the design of the tool to be made. Covers

the needs of making hardware, software and tool design planning, and application design for monitoring.

3. The third stage is to design the system. System design consists of device design.
4. The fourth stage is the implementation of the planned tool design in accordance with the initial design.
5. The fifth stage is conducting trials on the tools made by observing the indications of the required parameters. If the test results of the tool are in accordance with the design and proceed to the next stage.
6. The sixth stage is to collect data based on parameters. Then analyze the data based on these parameters.
7. The seventh stage is to make reports and conclusions from the analysis that has been made.

C. Hardware Planning

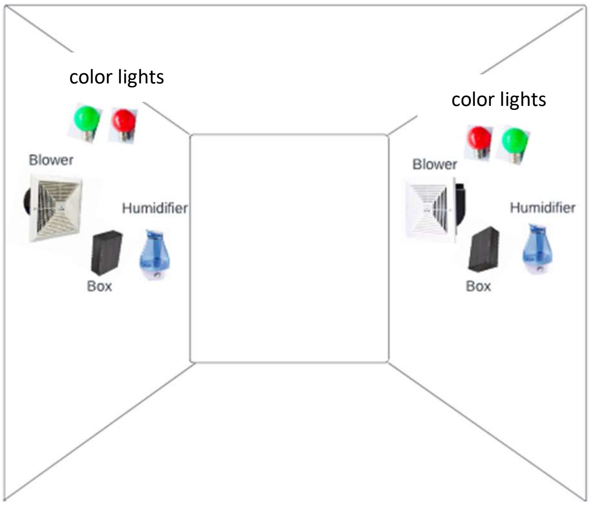

Figure 3. Overall mechanical design

Figure 3 shows the design of a monitoring tool that will be placed in a room where there are two types of tools. With each tool in the form of a blower, box, humidifier, and color lights. The blower works to circulate unwanted air or hot air to get new air. Humidifier serves to increase the humidity of the air by spraying water vapor into the air. The box will be placed between the blower and humidifier.

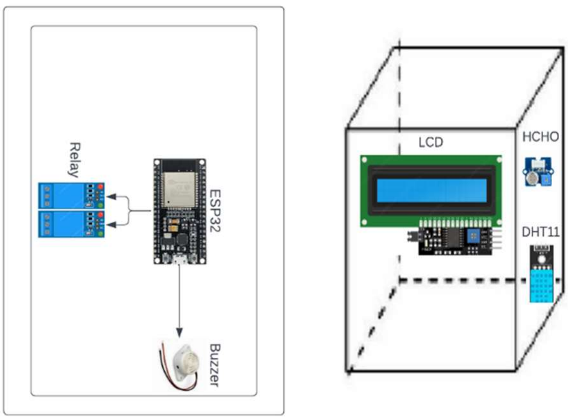

Figure 4. Mechanical design inside and outside box

Figure 4 shows the design of the monitoring tool in the box in the form of ESP32, Buzzer, and Relay placed in the box so that the circuit is safer and neater. The ESP32 functions as a platform that will connect with other components, the buzzer functions as an alarm to indicate that the value has exceeded the threshold value, and the relay functions as a timeout delay commonly used for installations that use automatic settings. And outside the box there is an LCD and two sensors, namely the HCHO sensor and the DHT11 sensor. LCD serves to display data from the microcontroller, HCHO functions to detect gas produced by objects, and DHT11 functions to detect temperature and humidity values in the room.

D. Overall Scematic Design

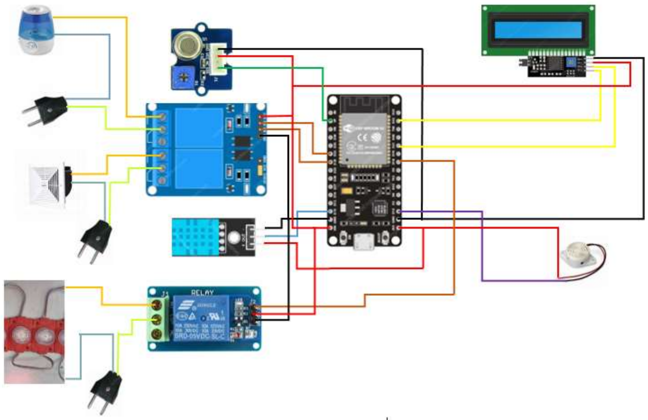

Figure 5. System-wide pin connection circuit

Figure 5 shows the components contained by ESP32, DHT11 sensor, HCHO sensor, Buzzer, LCD 16x2, Relay, Exhaust Fan, and Humidifier. The data that has been read by the DHT11 sensor and the HCHO sensor will be sent to the ESP32. The data will be displayed on the LCD and the application on android.

III. RESULTS AND DISCUSSION

A. Result of Product

1. Mechanical Implementation Result

Figure 2. Mechanical implementation result

Figure 6 shows mechanical prototyping uses blowers, humidifiers, sensors and other components. The sensors and components are placed in a black plastic box such as the HCHO sensor, DHT11 sensor, Relay, LCD, Buzzer, and ESP32 microcontroller.

2. Hardware Implementation Result

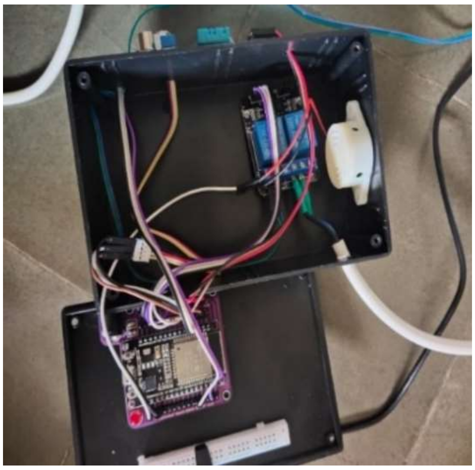

Figure 3. Hardware implementation result

The Figure shows the contents of the access box which is an implementation of Figure 7. The selected components are then implemented in the form of a series of devices connected to the ESP32 microcontroller.

3. Software Implementation Result

Figure 4. Software implementation result

Figure 8 will show the monitoring results of room temperature, room humidity, gas levels measured by sensors, and control systems.

Figure 9 will show information about the condition of the monitored room. The results of data that have been stored such as data on room temperature, room humidity and gas levels measured by the sensor.

Figure 9. Software implementation result

4. DHT11 Sensor Accuracy Test Results

In testing the DHT11 temperature sensor, it aims to determine the level of accuracy of the data read by the DHT11 sensor, namely temperature and humidity. Testing is done by comparing the values contained in the measuring instrument in the room. In addition, the temperature and humidity readings in the room can be calculated error values and the average error using the following equation:

$$\textit{Error Value}\ \% = \frac{\textit{Hygrometer Measuring Value} - \textit{DHT11 Measuring Value}}{\textit{Hygrometer measurement val}} \times 100\% \quad (1)$$

$$\textit{Average Error}\ \% = \frac{\textit{total error}_{\textit{valuer}}\ \%}{\textit{Total testing}}\ x\ 100\% \quad (2)$$

Figure 10. Temperature sensor testing

TABLE 1
TEMPERATURE SENSOR TEST RESULTS

Termometer sensor DHT11 (^{O}C)		**Higrometer (^{O}C)**		**Error %**	
Node A	**Node B**	**Node A**	**Node B**	**Node A**	**Node B**
31.4	31.4	31.3	30.7	0.31	2.28
31.4	31.8	31.1	32.3	0.96	1.54
31.4	31.8	31.9	31.0	1.56	2.58
31.4	32.3	31.7	32.5	0.94	0.61
31.4	32.3	31.0	32.3	1.29	0
31.4	32.3	31.1	31.5	0.96	2.53
31.8	32.8	31.8	31.7	0	3.47
31.8	32.2	31.9	31.6	0.31	1.89
30.9	32.4	31.3	31.2	1.27	3.84
31.4	31.9	31.5	32.0	0.31	0.31
Average Error				0.791	1.905

Based on the table data above, the DHT11 test is classified as accurate and good. In addition, from the table data above, observations of the temperature on the DHT11 sensor that there is a change between the temperature value and the measuring instrument are made, a graph is made as follows:

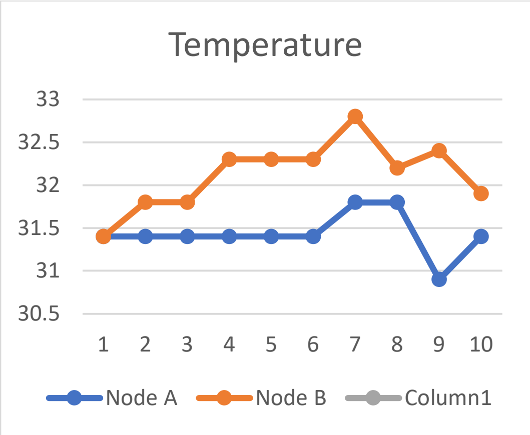

Figure 11. DHT11 temperature sensor testing characteristic curve

Figure 12. Humidity sensor testing

TABLE 2
HUMIDITY SENSOR TEST RESULTS

Humidity Sensor DHT11 (%)		Higrometer (%)		Error %	
Node A	Node B	Node A	Node B	Node A	Node B
. 55	52	54	52	1.85	0
55	51	54	53	1.85	3.77
57	51	55	50	3.63	2
56	53	54	52	3.70	1.92
55	52	55	51	0	1.96
55	52	55	53	0	1.88
54	50	54	52	0	3.84
54	52	54	53	0	1.88
57	51	57	52	0	1.92
56	55	56	54	0	1.85
Average Error				1.103	2.102

Based on the table data above, the DHT11 test is classified as accurate and good. In addition, from the table data above, humidity observations were made on the DHT11 sensor that there was a change between the humidity value and the hygrometer measuring instrument, then a graph was made as follows:

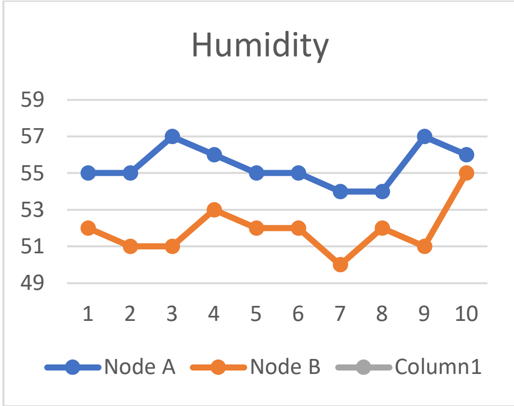

Figure 13. DHT11 humidity sensor testing characteristic curve

5. *HCHO Sensor Accuracy Test Results*

In testing the HCHO gas sensor, it aims to determine the level of accuracy of the data read by the HCHO sensor, namely toluene gas. Testing is done by comparing the values contained in the measuring instrument in the room. In addition, the temperature and humidity readings in the room can be calculated error values and the average error using the following equation:

$$Error\ Value\ \% = \frac{Air\ Quality\ Detector\ Measuring\ Value - HCHO\ Measuring\ Value}{Air\ Quality\ Detector\ measurement\ value} \times 100\% \quad (3)$$

$$Average\ Error\ \% = \frac{total\ error\ valuer\ \%}{Total\ testing} \times 100\% \quad (3)$$

Figure 14. HCHO sensor testing

TABLE 3
HCHO SENSOR TEST RESULTS

Gas Sensor HCHO (ppm)		Air Quality Detector (ppm)		Error %	
Node A	Node B	Node A	Node B	Node A	Node B
0.85	0.68	0.85	0.673	0	1.04
1.76	1.44	1.718	1.456	2.44	1.09
1.13	1.49	1.147	1.456	1.48	2.29
8.37	9.30	8.411	9.357	0.48	0.61
21.40	16.85	21.443	16.898	0.20	0.28
20.19	22.16	20.236	22.208	0.22	0.21
13.62	11.06	13.687	11.096	0.48	0.32
6.27	5.17	6.312	5.214	0.55	0.70
9.72	11.53	9.763	11.563	0.44	0.28
16.64	14.29	16.681	14.337	0.24	0.32
Average Error				0.653	0.714

Based on the table data above, the HCHO test is classified as accurate and good. In addition, from the table data above, observations were made on the HCHO sensor that there was a change between the value of Toluene and the measuring instrument, so a graph was made as shown in the figure below as follows:

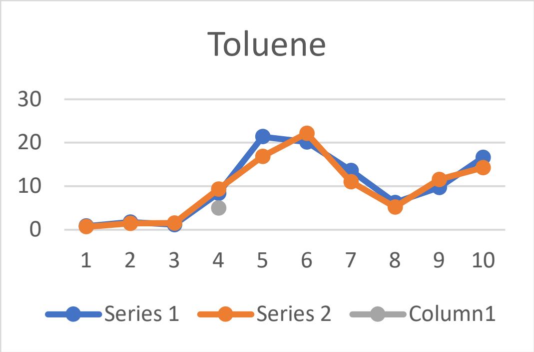

Figure 15. HCHO sensor testing characteristic curve

IV. CONCLUSION

From the background, problem formulation, planning, and implementation as well as discussion, it can be concluded that: The system to minimize the impact of toluene is designed using an ESP32 microcontroller which functions as a control system. The data obtained from reading the sensor results will be stored so that they can monitor the workshop worker's room using the internet. Sensors detected by DHT11 in the form of temperature and humidity have an average value for each node. For nodes A and Node B, both with a distance of 2 meters and 4 meters, the average error value is classified as accurate and good. Due to the error rate of the temperature range on DHT11 is 20C and the humidity error range on DHT11 is 5% RH. The entire designed system was successfully implemented.

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