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Use of a Portable Particle Counter to Analyze Particle Stability Time in a Biological Safety Cabinet

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ABSTRACT Biological Safety Cabinet (BSC) is a laboratory work area with air ventilation that has been engineered to protect workers working with material samples, the environment and material samples from the possible danger of contamination or causing the spread of pathogenic bacteria or viruses. The purpose of this study is to analyze the stability of the time required for the BSC to reach the condition of no particles in the BSC space. This is done by making a module using the PMS7003 sensor to detect the number of particles. This study uses the Arduino Mega system for data processing and then displays it in the form of graphs and numbers. In the condition of the number of particles of 162,965, the time required for the BSC is 29 seconds, while in the condition of the number of particles of 186,408, the time required is 38 seconds. So it is known that if the number of particles in the BSC space is more and more particles in the BSC space, the longer it takes for the BSC to reach the no-particle condition. BSC that uses a single fan blower cannot achieve a stable number of particles simultaneously.

INDEX TERMS BSC, Time Analysis, Sensor PMS7003

I. INTRODUCTION

The SARS-CoV-2 outbreak has prompted us to reconsider air quality and methods for removing, diluting, and sterilizing harmful organisms from the environment [1][2][3]. Air quality should be constantly examined to verify that no unknown particle producers are present [4][5][6]. Many modern high-tech industrial practices, such as microelectronics, medical equipment, and recent pharmaceutical production in the preparation of advanced medical therapy products made up of cells and tissues, necessitate hygiene, particularly for those who demand particle contamination-free products [4][7][8]. Particle contamination can be caused by a variety of circumstances, including insufficient pressure between compartments, temperatures above 25°C, humidity levels above 55 percent, and superfluous equipment or tools that easily generate particles [9][10]. During the Covid-19 pandemic, WHO provided instructions for managing the SARS-Cov-2 examination spacing, at the very least using biological safety cabinets, as a public health emergency (BCS) [11][12]. According to the circular letter HK.02.01/Menkes/234/2020 regarding Guidelines for the Examination of the Covid-19 RT PCR test, laboratories that are permitted to conduct Covid-19 testing must meet a minimum level of biosafety. effective laboratory methods and human resources. The biological safety cabinet (BSC) or biosafety cabinet is a tool used in the microbiology field to safeguard people, minimize contamination from harmful viruses/bacteria, and protect the work area environment through air ventilation engineering [13][14][15]. As a result, it is predicted that the BSC's region or space will be free of particle contamination. In compliance with the BSC Working Method for Testing. As a result, it's important to figure out how long it takes to get to the BSC's optimal circumstances [16][17][18]. BPFK Surabaya, as a medical equipment testing and calibration institution, offers testing services for biological safety cabinets (BSC). The number of particles is one of the parameters examined on the BSC. Optical particle counters are devices that work on the principle of light scattering from particles [4][19][20]. A collimated beam of light, such as a laser or LED lamp, illuminates the particles in the air, scattering them in all directions. Using a lens or mirror, the fraction of scattered light is focused on an optical photodetector, resulting in a peak proportion of the signal to particle size [1][21][22]. The number of particles in the BSC is counted using a tool called the Particle Counter [23][24][25].

Michele Pazienza et al. published a study in 2014 on the use of a particle counting system to optimize sampling, identification, and decontamination procedures for biological aerosol dispersions in a confined environment using an efficient detection/identification method due to incubation time, which slows outbreak symptoms and spread. The detection of biological agents (such as poisons, viruses, and bacteria) dispersed in the atmosphere is a critical concern for human and environmental safety. Another important consideration is the effectiveness of the sample method used to identify the released chemical; in fact, good sampling methods are required to detect contamination and verify decontamination operations. Environmental monitoring is one technique to increase the rapid detection of biological agents; for example, when the number of biological particles surpasses a specific threshold, a particle counter that can discriminate between biological and non-biological particles is employed as a first warning. The advantages of this study are that it is simple to use (as well as sample preparation) and interpret results, and it can easily become part of a "network" of sensors, samplers, and identification tools. The disadvantages of this system are that it is unable to distinguish between pathogenic and non-pathogenic organisms, so traditional "laboratory" tests are still required to clearly identify the particle that triggers the warning signal [26]. In 2019, Konstantania et al published the first comprehensive inter-comparison for particle sizes up to 5 m and total concentrations up to 2cm using a detection system consisting of a custom-made optical particle counter positioned precisely at the homogenizer's outlet to minimize particle loss due to tube bending. The sample aerosol enters the detecting chamber through a 0.2 mm aperture nozzle and is surrounded by an airflow envelope to keep the particle beam from wandering. A tracked calibrated mass flow meter is used to measure the sampling flow. A continuous wave laser (Verdi V-5, Coherent) emits a 0.7mm wide laser beam with a wavelength of 532nm, which is focussed by a cylindrical lens at the point of interaction with the aerosol stream. The light is scattered by the particles in the laser beam, which is detected by a photomultiplier tube at a 90° angle. This study has the advantage that the analytical results for all particle sizes correspond to a reference value within 7%, which is commensurate with the indicated uncertainties and flaws of random particle distribution but excludes any effects deriving from aerosol production instability [7]. Stephanie Kirschbaum did a study on laminar airflow to lower particle burdens in 2020, utilizing a measurement approach that was repeated three times during the operation. First, with no one in the OR, the particle load was referenced before the start of the day of operation. The second measurement was taken after the surgical setting had been set up but before the patient entered the OR. The third measurement was performed after electro-cautery had exposed the knee joint but before the cut was made. The particle load was measured three times in the operating room at three different locations. Position 1 is right next to the operational column, in the center of the laminar flow system. Position 2 is on the anesthetic device at a certain place. It's on the outskirts of the LAF zone. The control point outside the LAF area near the surgical image amplifier was designated as Position 3. This study has the benefit of demonstrating that inhaled particles, which cannot be filtered out by surgical masks, exhibit a significant increase in concentration as surgery begins. Because the use of LAF resulted in a considerable reduction of inhaled particles, it appears to be a protective factor for the surgical team's health, regardless of whether it is used to prevent infection. However, it has the drawback of a lack of data taken at precise time intervals [27]. The number of particles in the BSC was checked using a particle counter by dividing the flat region of the BSC into 3 (three) pieces in the BSC Testing and Calibration Work Method carried out by BPFK Surabaya. A particle counter was used to test the number of particles in the BSC at three (three) sites according to the partition of the flat plane region on the BSC. BPFK Surabaya's particle counter has just one counter particle sensor, so the particle counter measurement on the BCS must be repeated three times, and the particle counter tool must be moved and positioned manually three times. Because the particles are continually in motion, this can result in the same particle being counted many times. As a result, it is required to investigate the detection of particle number employing three (three) counter particle sensors. Purbakawaca et al. conducted particle counter research at ITB in 2016. The concentration of PM10 in the air can be used to define the air quality category. The goal of this research is to create a PM10 monitoring instrument that is portable, easy to use, and can produce data quickly. The PPD42NS sensor is employed in this investigation, and it can only detect particles with a diameter of 1m.

According to the above description, it is capable of conditioning the air by filtering the air so that there are no particles in the Biosafety cabinet.

This article is consists of Chapter 1 Introduction, Chapter 2 Material and Methods, Chapter 3 Result, Chapter 4 Discussion, Chapter 5 Conclusion, and Chapter 6 Reference.

II. MATERIALS AND METHODS

A. EXPERIMENTAL SETUP

This author's thesis module includes a function to compute the amount of time the BSC tool will be ready to use by designating the particles in the tool as 0. This thesis module is equipped with three particle sensors, each of which has the function of determining the number of particles in each of the three areas. For the BSC test and to examine the stability of the time when the number of particles is attained from the three BSC tool rooms, the BSC tool is in accordance with the MK. This utility also has an SD Card module, which can be used to save data that has been retrieved using it. Using the Arduino's programming language, this tool can show data in the form of numbers and graphs.

1) MATERIALS AND TOOLS

This study makes use of a the PMS7003 sensor is a digital and universal particle concentration sensor that may be used to measure the number of suspended particles in the air, or particle concentration, and then digitally eject them. This sensor works by scattering light using a laser to emit suspended particles in the air, then collecting light to a certain extent.

2) EXPERIMENT

The sensor output is directly linked to the Arduino, according to the PMS7003 data sheet, so that the sensor readings may be read and displayed. A comparison test with Smartfast F00121 material was performed to confirm the PMS7003 sensor's values. The results of reading the number of particles on the module were compared to a BPFK Surabaya standard instrument. The correction value for reading the number of particles in the module is determined using this comparison. It is known that there are discrepancies in the readings of the number of counter particles of the tool and the particle counter of the BPFK Surabaya tool based on the comparison findings of the readings of the number of counter particles of the tool and the particle counter of the BPFK Surabaya tool. As a result, the data in the software must be corrected. The average difference between the values of each sensor is used to calculate the correction amount.

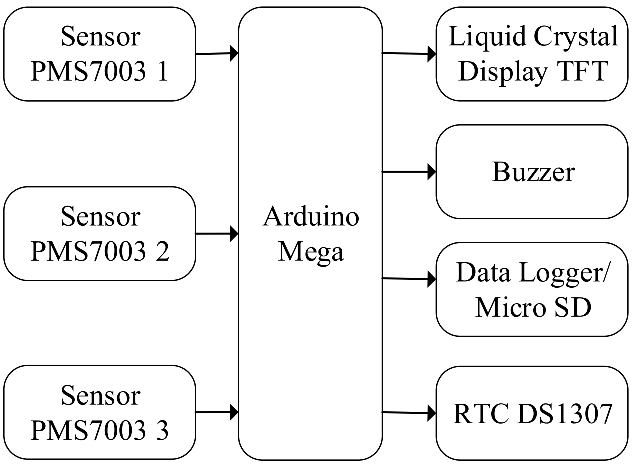

FIGURE 1. Particle counter diagram block system

B. THE DIAGRAM BLOCK

FIGURE 1 shows a rechargeable battery used to power this tool. The particle counter equipment used in this work has three PMS7003 sensors, each of which can count particles with sizes of 0.3, 0.5, and 5 microns. The output of this sensor lead will be processed using an Arduino software, and the data will be shown on the LCD as numbers and graphs of the number of particles versus time. Because this tool analyzes time, it necessitates the usage of RTC, which calculates real-time time in order to determine how long it takes the BSC to reach the ideal operating parameters. The buzzer will sound when the BSC has reached the optimal condition, which is when there are no particles in the BSC space and no particles are detected by the three sensors. This equipment comes with a data logger that stores measurement findings to make data processing easier.

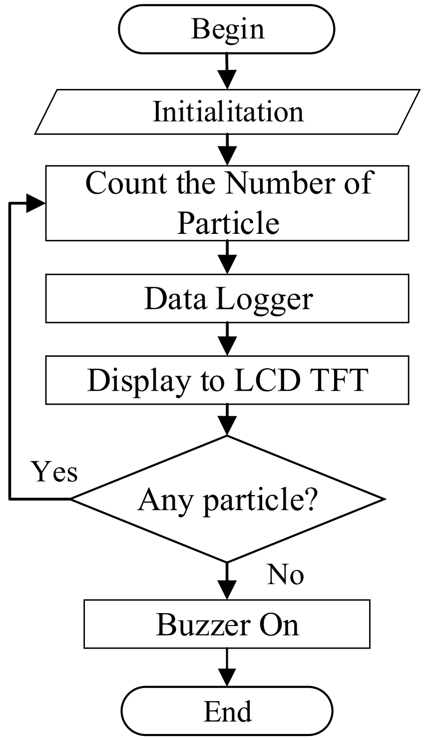

FIGURE 2. Flowchart of Particle counter

C. THE FLOWCHART

After the tool has started to work, the initialization process will begin (FIGURE 2). The particle count will be detected by the linked sensor. The number of detected particles will be entered into the data logger, and the time on the RTC will begin counting and be recorded on the SD-Card module. The result of reading the number of particles and calculating the time will be displayed on the display as a graph. The buzzer will sound if no particles are identified.

III. RESULT

The PMS7003 sensor output is directly linked to the Arduino, allowing the sensor readings to be read and displayed. A comparison test with Smartfast F00121 was performed to confirm the PMS7003 sensor's readings.

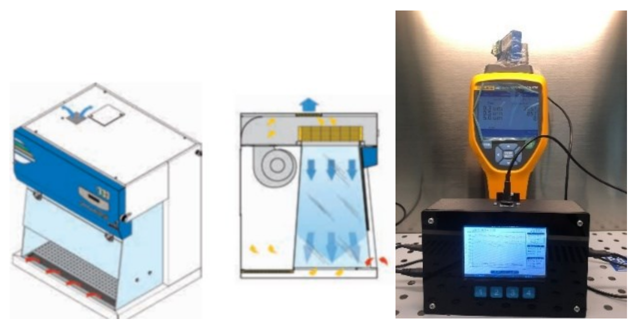

FIGURE 3. Module Design

A. DESIGN MODULE BUILD

The no-particle condition was obtained in all three BSC tool chambers at the same time (FIGURE 3). In comparison to the center and leftmost space locations, the rightmost space always reaches the final no-particle state. This is due to the fact that the smartfast code F000121 only has one fan blower and the exhouse is on the left side of the tool.

There are changes in the quantity of particles in the BSC space after conditioning in the form of misting with a nebulizer. The longer the fogging process takes, the longer it takes for the BSC to reach the no-particle condition, according to the test data.

B. COMPARISON RESULT

The following is a comparison of the data from the module/reading tool's of the number of particles compared to the reference data from the reading of the number of particles from BPFK Surabaya's particle count using the ZScore computation (TABLE 1, TABLE 2 and TABLE 3).

TABLE 1
Calculation the comparison number of sensor particle 1

Data	Tool data		Data ref (X)		Mean		Z-score	
	1.3 µM	0.5 µM	1.3 µM	0.5 µM	1.3 µM	0.5 µM	1.3 µM	0.5 µM
1	9615	1103	9329	975	286	128	1.2	3.18
2	9772	1107	9648	1012	124	95	0.52	2.36
3	9390	1071	9395	995	-5	76	-0.02	1.89
4	9405	1057	9586	1001	-181	56	-0.76	1.39
5	9562	1035	9296	1029	266	6	1.12	0.15
6	8715	986	8981	914	-266	72	-1.12	1.79

It is known that there are no extreme data or outliers based on these computations.

TABLE 2
Calculation the comparison number of sensor Particle 2

Data	Tool data		Data ref (X)		Mean		Z-score	
	1.5 µM	0.5 µM	1.5 µM	0.5 µM	1.5 µM	0.5 µM	1.5 µM	0.5 µM
1	0	6892	2	7475	-2	-583	-2.45	-1.05
2	0	6532	4	7295	-4	-763	-4.9	-1.37
3	2	6367	4	7529	-2	-1162	-2.45	-2.09
4	2	7660	4	7880	-2	-220	-2.45	-0.4
5	4	8122	4	8851	0	-729	0	-1.31
6	4	7620	4	7859	0	-239	0	-0.43

There is data whose Z-Score value above the upper threshold, with a value of 4.90, as seen in the comparison data above.

TABLE 3
Calculation the comparison number of sensor particle 3

Data	Tool data		Data ref (X)		Mean		Z-score	
	0.3 µM	0.5 µM	0.3 µM	0.5 µM	0.3 µM	0.5 µM	0.3 µM	0.5 µM
1	5100	506	5886	609	-786	-103	-0.5	-0.58
2	4830	526	5047	533	-217	-7	-0.14	-0.04
3	4875	518	5448	587	-573	-69	-0.36	-0.39
4	7035	756	7989	851	-954	-95	-0.6	-0.54
5	4050	420	4093	415	-43	5	-0.03	0.03
6	6930	740	7951	857	-1021	-117	-0.64	-0.66

It is clear from the comparison that no data exceeds the threshold or contains outliers.

IV. DISCUSSION

It can be deduced from the comparison data on the number of particles from the tool data compared to reference data, namely the results of the particle counter readings belonging to BPFK Surabaya that were analyzed using the ZScore calculation method, that there are readings whose values are extreme or outliers exceed the threshold set in the ZScore calculation according to ISO 13528:2015. Through comparing tests between laboratories, statistical approaches are used in proficiency testing. Extreme results can result from a variety of factors, including discrepancies in the counter particle sensor's properties and a comparative test process that fails to meet the counter particle comparison test standard.

This particle counting gadget has been compared to BPFK Surabaya's standard equipment. And it's well established that different readers produce different results. The particle counter reading has been corrected based on the comparison results, which is better than prior studies [4][11][12].There are two flaws in this study: the discrepancy in readings with comparison tools and the lack of a wide enough display.

If the number of particles in the BSC space rises, the longer it takes for the BSC to reach the no-particle condition, this research can be implemented in the community. Because a BSC with a single fan blower cannot produce a consistent number of particles at the same time, the operator must consider the amount of particles used when applying it to the patient.

V. CONCLUSION

The purpose of this study is to analyze the stability of the time required for the BSC to reach the condition of no particles in the BSC space. This is done by making a module using the PMS7003 sensor to detect the number of particles. This study uses the Arduino Mega system for data processing and then displays it in the form of graphs and numbers. In the condition of the number of particles of 162,965, the time required for the BSC is 29 seconds, while in the condition of the number of particles of 186,408, the time required is 38 seconds. In the future, this module can be constructed by adding sensors in accordance with the biological Safety Cabinet's testing and calibration equipment, such as a temperature sensor, humidity sensor, air flow sensor, luxmeter sensor, and noise sensor.

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APPENDIX

1) INITIALITATION RTC PROGRAM.

```
//RTC
#include <Wire.h>
#include "RTClib.h"
RTC_DS1307 rtc;
int posisi_x;
String waktu3, waktu4, waktu5, waktu6;
char counter[20];
```

2) THE BEGINNING RESET RTC PROGRAM

```
Serial.begin(9600);
  jam = 0;
  menit = 0;
  detik = 0;
```

3) READING TIME RTC PROGRAM

```
// setup rtc
  if (! rtc.begin()) {
    Serial.println("Couldn't find RTC");
    Serial.flush();
    abort();
  }
  if (! rtc.isrunning()) {
    Serial.println("RTC is NOT running, let's set the time!");
    rtc.adjust(DateTime(F(__DATE__), F(__TIME__)));
  }
```

4) GRAPHIC X RTC PROGRAM.

```
//nilai X
    resettime();
  }
  if (i > 59 && i <= 119) waktu3 = now.toString(waktu2);
  else if (i > 119 && i <= 179) waktu4 = now.toString(waktu2);
  else if (i > 179 && i <= 239) waktu5 = now.toString(waktu2);
  else if (i > 0 && i <= 59) waktu6 = now.toString(waktu2);
```

5) LIFE TIME RTC PROGRAM.

```
Serial.print(waktu2);
  Serial.print(" | ");
  Serial.print(waktu3);
  Serial.print(" | ");
  Serial.print(waktu4);
  Serial.print(" | ");
  Serial.print(waktu5);
  Serial.print(" | ");
  Serial.println(waktu6);
  waktumulai();
}
```

6) TIME WALK RTC PROGRAM.

```
void waktujalan() {
  detik++;
  if (detik == 60) {
    detik = 0;
    menit++;
  }
  if (menit == 59) {
    menit = 0;
    jam++;
  }
}
```

7) ARRAY PROGRAM.

```
//ARRAY
int arr[240][9];
int i = 0;
int no = 1;
int val_count, val;
int val_pause = 0;
```

8) ARRAY FUNCTION PROGRAM.

```
void callArray() {
  clearScr();
  if (val == 1) val_count = 0;
  else if (val == 2)val_count = 60;
  else if (val == 3)val_count = 120;
  else if (val == 4)val_count = 179;
for (int count = val_count; count <= (val_count + 59); count++)
```

9) STORAGE ARRAY PROGRAM.

```
id saveArray() {
  arr[i][0] = last_sens1_03;
  arr[i][1] = last_sens1_05;
  arr[i][2] = last_sens1_50;
  arr[i][3] = last_sens2_03;
  arr[i][4] = last_sens2_05;
  arr[i][5] = last_sens2_50;
  arr[i][6] = last_sens3_03;
  arr[i][7] = last_sens3_05;
  arr[i][8] = last_sens3_50;
  Serial.print("Array ");
  Serial.print(i);
  Serial.print(" = sens 1 || ");
  Serial.print(val_sen1_03);
  Serial.print(" | ");
  Serial.print(val_sen1_05);
  Serial.print(" | ");
  Serial.print(val_sen1_50);
  Serial.print(" || sens 2 = ");
  Serial.print(val_sen2_03);
  Serial.print(" | ");
```

```
  Serial.print(val_sen2_05);
  Serial.print(" | ");
  Serial.print(val_sen2_50);
  Serial.print(" || sens 3 = ");
  Serial.print(val_sen3_03);
  Serial.print(" | ");
  Serial.print(val_sen3_05);
  Serial.print(" | ");
  Serial.print(val_sen3_50);
  Serial.println(" ||");
  i++;
  no++;
  if (i >= 240) i = 0;
```

10) SD CARD READING PROGRAM.

```
//setup sd card
  Serial.print("Initializing SD card...");
  if (!SD.begin(chipSelect)) {
    Serial.println("Card failed, or not present");
    return;
  }
  Serial.println("card initialized.");
  sdcard_reset();
```

ATTACHMENT

- Schematic and Board : https://drive.google.com/drive/folders/1wgjkSeqHR-2f1xyAiC2eWt-QR0kFJ_Gi?usp=sharing
- Listing Program : https://drive.google.com/drive/folders/1wgjkSeqHR-2f1xyAiC2eWt-QR0kFJ_Gi?usp=sharing