Development of a Dust Measurement System

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ABSTRACT— *Dust particle are particulate matter that can become suspended in the atmosphere and deposited. Dust is present in the atmosphere has significant effect climate, health of human, and strong influence on the solar energy during dry season. The dust monitoring device developed consists of sharp dust sensor module that has capacity of measuring particle size about PM2.5 and above, microcontroller (arduino mega 2560), micro secure data (MicroSD) shield card, with intelligent liquid crystal display unit (LCD) and all are link together to form the complete unit. The dust measuring system compare with available dust device has the correlation of 0.999980 and maximum value of 0.541 mg/m³. Also the sensitivity, resolution and error are 5V/0.1 mg/m³, 0.001 mg/m³ and ±0.005% respectively, at 67% relative humidity and temperature of 32ºC. The total power consumption of the dust monitoring system is 1.06 W.*

**Keywords— **Dust, particle, sensor, optical, microSD card, LCD, arduino.

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1. INTRODUCTION

The word dust describes fine particles that travel around in the atmosphere. The atmosphere is made up many constituents called aerosol of which dust particle is included. This dust is formed when fine particles are being blown and carried by the action of the force often called wind. Dust emanates from different sources – indoor and outdoor. Some dust sources are from vegetation (pollen and fungi), sea salt, fossil fuel combustion, burning of biomass industrial activities, drilling, and blasting, excavating, loading and tipping, transporting, crushing, untarred road, cleaning and maintaining fixed and mobile plant. Road generated dust by traveling vehicles contribute to the release of particulate matter in the atmosphere. (Thongplang, 2015).

Often times, in this part of the world, dust particles settle in houses and house materials, offices and office materials. There are two main season in Africa – the wet and the dry season. In Nigeria, there is a variance between the northern part and the southern part of the country in terms of season in the year. The north experiences a long dry season and a very short rainy season. Sometimes, rain fall in north in four months or less. But the south has a longer wet season. The rainfall may be up to eight months in the year. And so the rate of dust particles in these regions varies. The effect accompanied in the dry season sometimes called harmattan is the same in the regions.

The control of road dust has been a significant challenge in urban areas, and also in places with high level of vehicular traffic on untired roads. Justifiably, a good number of African countries still fall victim of the control of dust especially in industrial areas. The harmattan season is accompanied by the intense heat from the sun. This dries up the sand and makes it easier for wind to carry the dust particles around in the atmosphere by a conductive force. Besides the dust particle in industrial areas which has effect on the health of human around the working environment, harmattan season is the major period when mostly everybody in this part of the world suffers from the exposure to dust (Chineke and Chiemeka, 2009).

2. CLASSIFICATION OF PARTICLE

Classifications of particles are in accordance with its aerodynamics diameter. Particle is usually categorized under two sizes – smaller than 10 µm (particle matter (PM) 10) and smaller than 2.5 µm (PM 2.5) because the measurement of particle shapes are difficult to measure. The size of the particle is defined by matching the gravitational settling velocity of a particle with a perfect sphere of a 1 g/cm³ density. This will make particle have different shapes and densities

because of different sphere sizes. An ideal sphere was chosen to limit the complexity of particles taking it to be homogeneous sphere having an ideal aerodynamics diameter which is the permissible (Geiling et al., 2011). World Health Organization (WHO) and United State of America (USA) Environmental Protection Agency (EPA) opined that particles affect more people worldwide than any other pollutant.

3.   HAZARD EFFECTS OF DUST PARTICLES

Dust particles with smaller densities have the propensity to stay longer and travel in the air as compared with particles with bigger densities. The particles may be inhaled through the mouth and nose easily which if left uncheck may pose serious public health hazard; increasing breathing problem; damaging lung tissue. Dust particle can reduce visibility and hamper road safety. Work activities like construction, building, demolition, quarry and maintaining services generates respirable dust particle. Inhalation of respirable dust particle is known to cause a disease called silicosis and cancer and it is thought to contribute to a condition known as chronic obstructive pulmonary disease (Thongplang 2015; Peter, 2011; Technical fact sheet, 2010).

4.   METHODOLOGY

The Sharp dust sensor uses electro-optical sensing method to detect the presence of dust. A light detector (photodiode) detects a deflected light by light emitter diode. The amount of light deflected correspond to the density of dust. Equation 1 relates the relationship between light transmission and the dust concentration *c* according to Lambert-Beer's law (Mokhloss, 2012).

$$I = I_0 . e^{-\varepsilon . c . l} \qquad (1)$$

Where:

I_0 = initial intensity

I = resulting intensity of the light beam

ε = coefficient of extinction (a specific constant accounting for dust type and application)

l = distance

c = dust concentration

4.1 Instrument Development

The sharp dust sensor module has six (6) connector pins. Figure 1 shows the internal circuit diagram of Sharp dust sensor. The Pin 5 (Vo) produces a voltage that is equal to the amount of dust particles passing through the hole. The pin 5 was connected to an arduino microcontroller with a micro Secure Data (SD) card shield and liquid crystal display (LCD) screen for processing, storage and LCD display magnitude of dust density respectively. The arduino was programmed to link the LCD and store the dust density to be collected using C programming language. The output pin of the Sharp dust sensor (Vo) was connected to one of the analog pin of the arduino microcontroller.

A 9V rechargeable battery and power supply was designed for the system with a power switch to control when it is ON and OFF. The designed power supply was connected to the Vin of the arduino mega 2560 to power the arduino. The Vin of the arduino mega 2560 was designed to handle voltages between 7V and 12V. The Sharp dust sensor and LCD was powered via the 5V power section of the arduino. The dust sensor is housed in black case to shield the sensor from humidity, radiation and temperature. A 7 inch plastics rod which was used to raise the sensor above the case containing all other circuit component as shown in Figure 2. The plastic case houses the arduino mega 2560 microcontroller, LCD microSD shield, rechargeable battery and power switch. The dust optical sensor is positioned outside at that height for proper exposure to air around the environment.
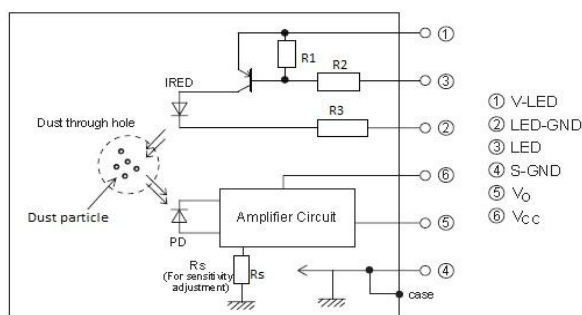

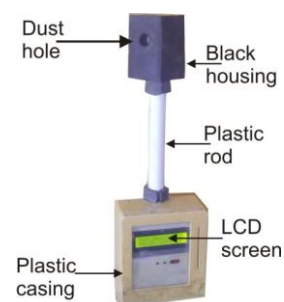**Figure 1: Internal circuitry of Sharp dust sensor**

Figure 2: Dust measurement device

4.2 Test and Calibration of the Instrument

The Dust Instrument was tested for response by blowing the dust towards the sensing point of the sensor and the value displayed on the LCD screen increases as the blowing speed increase and vice versa. The dust measuring instrument was calibrated using the sensitivity of a known sensor (0.5V/0.1mg/m^3). The output voltage ranges from 0.9V without dust (0mg/m^3) to 3.2V at maximum of 0.541mg/m^3. Using arduino ADC 0 – 5V, Vin – 0.9 = 0;

$$dust\ density = \frac{(Vin - 0.9)V}{sensitivity} \qquad (2)$$

$$dust\ density = \frac{(Vin - 0.9)V}{0.5V/0.1mg/m^3} = \left(\frac{(Vin - 0.9)}{5}\right)\frac{mg}{m^3} = 0.2Vin - 0.18 \ (3)$$

The dust measuring instrument built was compared with commercially available dust instrument (Dust Particle Measuring Device PCE-MPC10). The result of the measurement obtained is shown on table 1 and figure 3 shows the graph of comparison between the two dust instruments. The graph follows the same trend and the correlation obtained was 0.999980 which shows good agreement and performance of the dust measuring device is up to standard. At temperature 32^{0}C and relative humidity 65%, error estimated was ±0.005%. The resolution is 0.001mg/m^3. The range of measurement is between 0 to 0.541 mg/m^3. (Application note of Sharp Dust Sensor).

The dust density equation was computed on the arduino sketch using C programming language. The mg/m^3 value was multiplied by 1000 for conversion to μg/m^3. The dust density was programmed to be displayed on the LCD and at the same time stored on the microSD card every one minute interval.

Table 1: Dust density comparison measurement between developed instrument and Dust Particle Measuring Device PCE-MPC10

Time (mins)	Developed instrument (μg/m^3)	PCE-MPC10 (μg/m^3)
1	51.9143	51.90
2	42.8134	42.77
3	88.4507	88.43
4	64.3555	64.36
5	60.2051	60.21
6	59.3750	59.38
7	49.4141	49.41
8	58.5449	58.54
9	57.7248	57.71
10	55.2246	55.22
11	48.5484	48.58
12	61.0352	61.04
13	57.7248	57.71
14	49.4042	49.41
15	56.8778	56.88
16	66.0156	66.02
17	46.0938	46.09
18	41.9534	41.94
19	59.3750	59.38
20	62.8953	62.70
21	47.8639	47.75
22	49.4042	49.41
23	52.8344	52.73
24	50.3441	50.24
25	65.1879	65.19
26	61.1352	61.04
27	56.1047	56.05

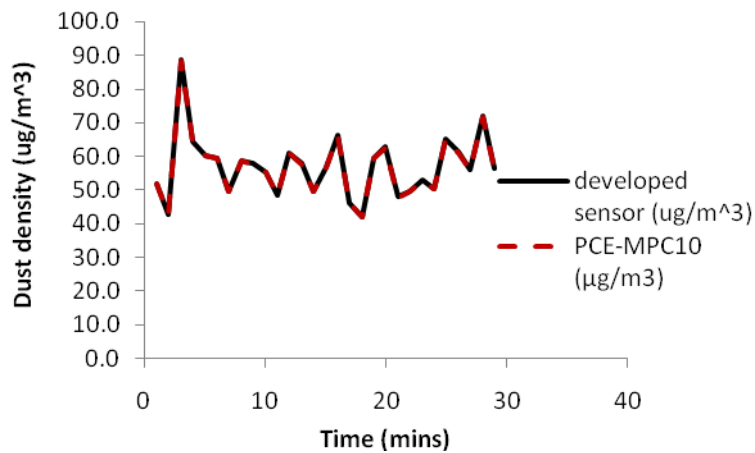| 28	71.8262	71.83
29	56.2547	56.05
		0.999980

Figure 3: Correlation graph of the developed sensor

5.   RESULT AND DISCUSSION

The dust instrument examination performance was carried out. It was found that the dust instrument measured from 0 to 0.541mg/m^3 with resolution of 0.001mg/m^3. It has minima error of ±0.005% and when compared with other dust instrument, the correlation is 0.999980 which is closed to unity and response time is 0.1μs that is fast logging system. Also, the dust instrument was used to carryout measurement at various location and the results shows positively safe area and are that needed improvement to reduce dust effect on the habitant in the near future. See figures 4 and 5.
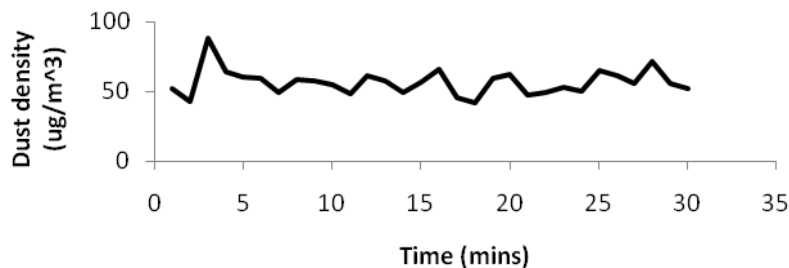

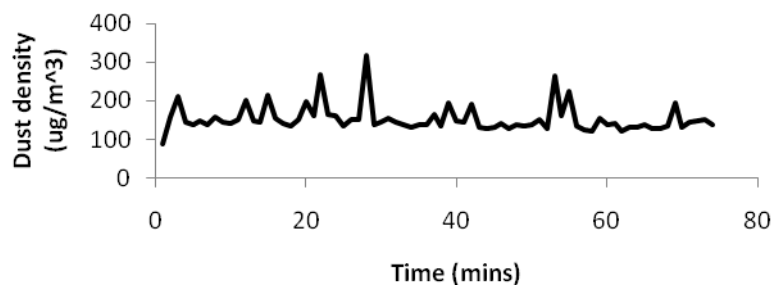**Figure 4: The graph of dust density of a room at Oye-Ekiti 13th October 2017, 7.30pm to 8:0pm**

Figure 5: The graph of dust density taking in a vehicle Ibadan to Ife, 5th November 2017. 1pm to 2.30pm

6. CONCLUSION

The dust instrument shows good response, and the performance was excellent compared with commercially available dust instrument. The range is from 0 to 0.541mg/m^3 with resolution of 0.001mg/m^3 and percentage error is $\pm0.005\%$. The dust instrument is cheap, easy to service and repair if malfunction.

The performance evaluation of the dust instrument showed that it can be used to carry out continuous measurement for dust monitory to study the effect of dust on the communication signals. Also, to see the effect of dust deposit on solar panel surface with time and its effect on the health of human being around quarry and dust producing environment.

7. ACKNOWLEDGEMENT

8. REFERENCES

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