RESEARCH ARTICLE

Air Quality Evaluation with a Low-cost Dust Sensor for a Hencoop

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Abstract

A hygienic working environment is essential for human health. It includes environmental conditions like light, airflow, gasses, sound, and rubble. It became more important for agricultural indoor and outdoor applications. For example; the dust intensity in a hencoop sometimes negatively affects human and animal health as an environmental component. On account of this ground, dust concentration measurement is crucial for agricultural indoor and outdoor applications. Because of this reason, the intensity of dust has been evaluated and analyzed in this research. For this purpose, a microcontroller-based dust intensity measurement unit was developed. The dust intensity measurement unit contains an Arduino based development board and Sharp dust sensor. Additionally, an SD card module and a real-time clock (RTC) was utilized for a data-logging operation. The addition of air stream, air filtering technique, and dust removing machines can be qualified regarding the dust intensity or dust balance.

Keywords: Animal health, Arduino, Dust analysis, Dust sensor, Hencoop, Human health.

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Introduction

Atmospheric particles can be sorted in three widths. The first particle diameter is smaller than 100 µm, and it is called 'total suspended particles'. The second changes from 2.5–10 µm, also it is named 'particulate matter'. Another diameter group is under 2.5 µm; it is known as 'fine particulate matter'. The first diameter group affected human breathing. The third diameter group has directly impacted the blood with respiratory, and this condition can negatively affect the human cardiovascular, nervous, and different organs (Tianhua and Ying, 2014). The pros and cons of particulate matter on health have been widely discussed in the past years. The consequences are that fine dust has several health risks, related to or result with cardiovascular diseases. Because of this reason, lots of regulations were made by governments around the globe to prevent or decrease of human-made particulate matter. This kind of standards usually lay limits for particle matter intensity, which may not be surpassed. Nowadays, there are different maximum allowable values for different particle diameters and different periods (Budde *et al.,* 2012).

Singh and Sharma (2000) worked on litter materials at commercial broilers, and also Khan *et al.,* (2009) studied on the effect of some litter materials at broiler performance of commercial broilers in temperate agro-climatic conditions. They both express that litter material plays a critical role in the rearing of poultry.

Khadem *et al*. (2014) described the invention and deployment of smart sensor nodes for dust monitoring applications by employing two types of dust sensors which can be deployed in indoor or outdoor conditions. A generic system architecture is proposed, with the integration of smart sensor nodes for dust detection by applying two types of detectors - Sharp GP2Y1010AU0F and Shine PPD4NS. The plan is based on Memsic IRIS motes and specific considerations regarding the consolidation of two cases of optical dust sensing devices with the sensor nodes. Ultimately, outcomes have been evaluated from both data collection and the two forms of optical sensor relation with an acknowledgment system to assess the suitability of the proposed nodes to be utilized in a wireless sensor network (WSN).

Weekly *et al.* (2013) formed an energy-efficient house, which supports different, services, like lighting and external respiration. Similarly, to increase quality, different kinds of environmental sensors were placed by them in the buildings for the best services of the building. Additionally, they concentrate on the particle matter by using particle matter sensor readings. They were correlated dust intensity and people activity with the help of statistic science.

Budde *et al.* (2013) in their study demonstrated a mobile, low-cost particulate matter sensing method for the use in particle sensing events. They used a cheap commercial-off-the-shelf (COTS) dust sensors to measure dust intensity at environmental air or mobile personal measurement devices at a cost less than the current handheld solutions which have reliable accuracy. They carried on a group of experiments to make high-accuracy measurement device with a cheap COTS sensor which serves with a bluetooth-enabled sensor module that can be connected with a mobile telephone.

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Not a great deal of inquiry has been done by this embedded mobile measurement of particulate matter system, neither in general nor specific for particle sensing applications (Budde *et al.,* 2012).

Devarakonda *et al.* (2013) work on two mobile platforms for fine-grained real-time pollution measurement; they developed a mobile sensing unit which was applied on public transportation infrastructure. Additionally, a personal sensing device (NODE) which can be applied to make a social pollution sensing. They conclude that both approaches are feasible.

Naticchiaa *et al.* (2014) have studied the feasibility of dust monitoring and devices to be incorporated within a wireless non-invasive dust monitoring network of building websites.

Ruslan (2015) worked on producing a mobile, low-cost air pollutant monitoring system, which contains a sharp GP2Y1010AU0F optical dust detect unit as a sensor for dust with the support of Arduino UNO and LCD keypad shield in his master's thesis.

The initial step for dust intensity measurement was performed utilizing a portable measurement unit which contains an Atmel based Atmega 328 microcontroller, a sharp dust sensor, SD card module, RTC. This research analyze and monitors the source of dust intensity according to working time by applying a dust detector.

Material and methods

All tests had been done Atmel Atmega 328 microcontroller, which is placed on Arduino UNO R3 development card. Arduino UNO R3 is an open-source development card as hardware and software. The board has Atmega 328 microcontroller on it. It has 14 digital input-output pins, six analog DC input. Also, 6 PWM outputs with 32 kB flash memory card onboard (Figure 1). Besides, the board microcontroller evaluates the sensor information. The different pin structure helps to produce several types of analog and digital sensor data. The detector can be easily connected to the development board and sense the environmental information. In this work, the Arduino UNO R3 microcontroller was adapted to evaluate dust concentration and monitor with the program developed at C language for Arduino programming compiled into Arduino IDE and placed into Atmega 328 microcontroller unit.

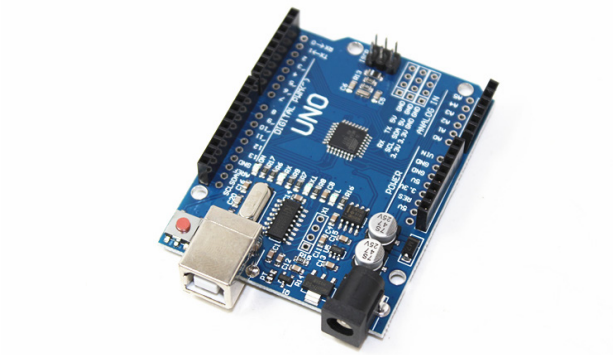


Fig 1: Arduino UNO R3 Development Board

In this research, a GP2Y1010AU0F model dust sensor was used, which has > 0.8 µm particle detection capability with 0.5 V/0.1 mg/m^{3}sensitivity. The detector can detect flower pollen, cigarette smoke, and house dust. It mainly contains a light-emitting diode with lens 1, a photoelectric diode with lens 2, the flow channel, the measuring chamber, and electric fan, as depicted in Figure 2. The light-emitting diode (LED) gives a strong light into the lens; when every dust mote in the airflow passes through the measurement point, lens one will change the light emitted from the LED into parallel light launched into the flow of measurement spots. So it light pulse signal. The reflected light pulse signal is beamed through the lens 2. Then PD transforms the light signal. At the end dust sensor gives an out between 0–5 V voltage signal. The voltage signal goes into Atmega 328 microcontroller. Then the data transform into the dust concentration data.

The sharp optical dust sensor GP2Y1010AU0F was selected for evaluations as a detector. The measurement process of this sensor is based on an infra-red light reflection: an infrared LED and a photodetector used in the detector-the particles sense from IRLED reflection which is assessed by the PD. The sensor needs 5–7 V DC. Also, between 0–3 V DC signal according to the total dust measurement. A single measurement takes 0.28 ms into the high pulse. The microcontroller takes 100 samples of each 10 ms and records their average (Olivares and Edwards, 2015). Also, the electro-optical characteristics of GP2Y1010 dust sensors can be viewed in Table 1. Additionally, the output voltage vs. dust concentration characteristics of the sensor can be examined in Figure 3.

The data logging process were carried out with an SD card module. The Arduino SD Card module is a solution for data logging to a standard SD card. The pinout of the SD card is appropriate for Arduino pin connection. Besides, it can be applied to other development cards. It yields us a chance for data storage (Figure 4).

Additionally, DS 3231 real-time clock (RTC) module was used for a time and date data (Figure 5).

Also, in this study, an HC-05 Bluetooth module was used to secure, fast, and free connection. Wireless data transfers helped data transfer. The HC-05 module is simple to use the Bluetooth Serial Port Protocol (SPP) module. It was developed for wireless connection. The serial port module is bluetooth V2. 0+EDR (enhanced data rate) data transport protocol. It also has 3 Mbps data transfer capability, with 2.4 GHz radio transceiver. It uses CSR Bluecore 04-external single-chip bluetooth system. Additionally, CMOS technology with adaptive frequency hopping feature (AFH). It has compact dimensions as 12.7 x 27 mm (Figure 6).

For the measurements, dust sensors attached with the HC-05 Bluetooth module, which has a 10 m communication capability of the Arduino development board (Figure 7). In the research, a 9V power supply used at Arduino-based development board which needs minimum 5V power (potential). In this way, long-term data measurements have been provided. They needed a code for Arduino Atmega 328

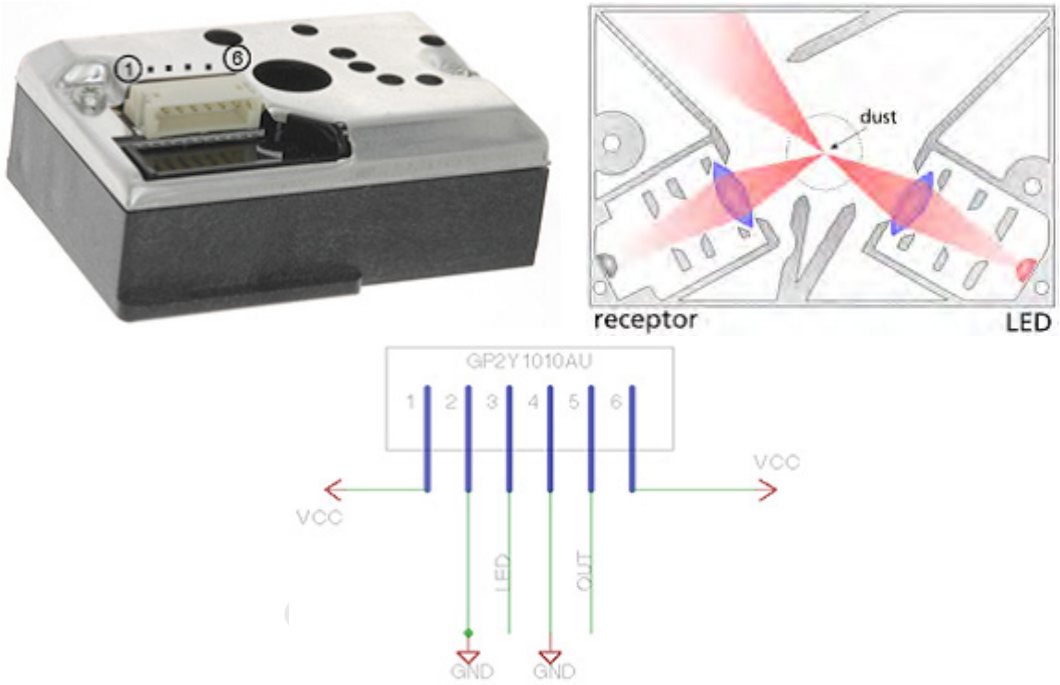


Fig 2: GP2Y1010 dust sensors, pinouts,and working system

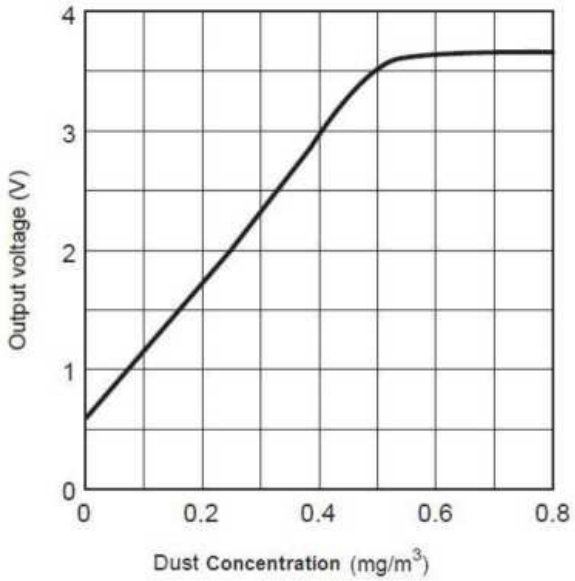


Fig 3: Output Voltage vs. Dust Concentration (Anonymous 2016)

Table 1: Electro-optical characteristics of GP2Y1010 dust sensors (T_a = 25°C, V_{cc} = 5V) (Anonymous 2016).

Parameter	*Symbol*	*Conditions*	*Min.*	*Type*	*Max.*	*Unit*
Sensitivity	K	*1 *2 *3	0.35	0.5	0.65	V/(0.1mg/m^3)
Output voltage at no dust	V_{oc}	*2 *3	0	0.9	1.5	V
Output voltage range	V_{oh}	*2 *3 R_l = 4.7kΩ	3.4	-	-	V
LED terminal current	I_{led}	*2 LED terminal voltage = 0	-	10	20	mA
Consumption current	I_{cc}	*2 R_l = ∞	-	11	20	mA

*1 Sensitivity is specified by the amount of output voltage change when dust density changes by 0.1 mg/m^3. And the dust density for detection is a value of the density of cigarette (MILD SEVEN®) smoke measured by the digital dust monitor (P-5L2: manufactured by Shibata Scientific Technology Ltd.).
*2 Input condition is shown in Figure 1 *3 Output sampling timing is shown in Figure 2

microcontroller on the development card was set up from the USB interface by using the Arduino IDE.

Data entry was set to be 1 data per second. One data was recorded by taking an average of 60 measurement data. Indoor environment (in the laboratory) experiments performed with manual measurements. Measurement results were compared according to the values in Table 2 and 3. The relationship between the research results was presented in the research.

Measurement unit was used in a small experimental chicken growth hencoop, which has 5*4*3 meter dimensions (Figure 8). The weather conditions in the hencoop change between 18–28°C according to a chicken growth period. Also, an axial fan system use in the hencoop for optimization the heat combination in the air. The specifications of the fan system are 230 voltage with 50 Hz power need, 215-watt power consumption, 1300 RPM cycle, 6900 m^3/h airflow capacity (Figure 9).

Measurement unit was placed 1.5-meter height in the hencoop. Because the total height of hencoop was three meters (Figure 10). One hundred fifty chicks were staying in hencoop during the growth period of an experiment. Dust



Fig 4: SD card module

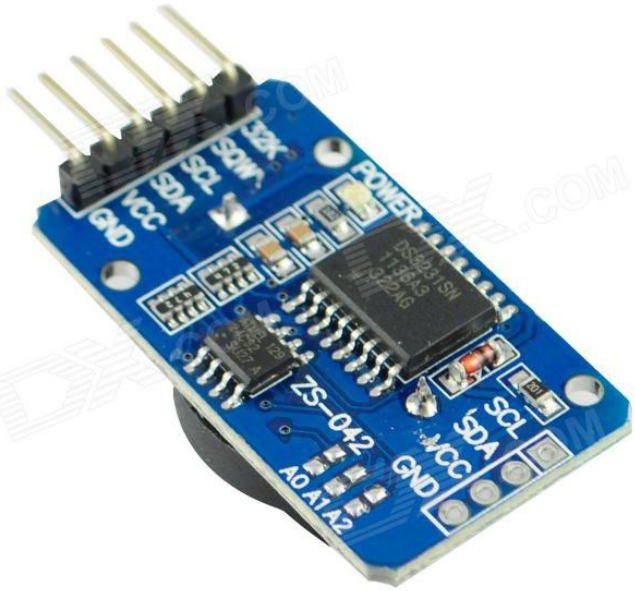


Fig 5: DS 3231 real-time clock (RTC) modüle

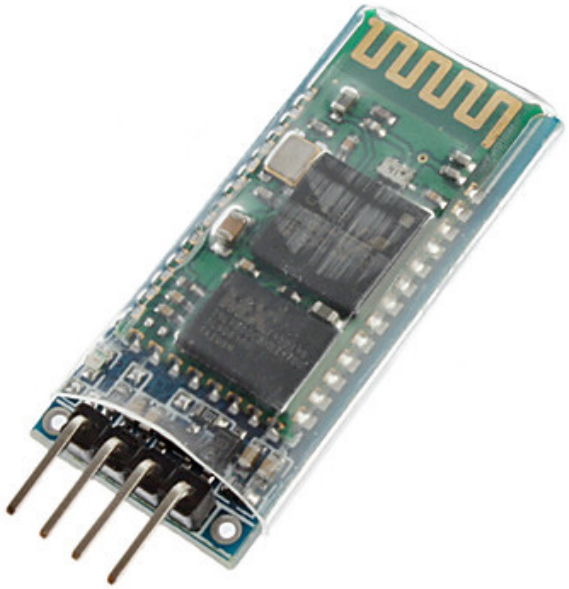


Fig 6: HC-05 Bluetooth module

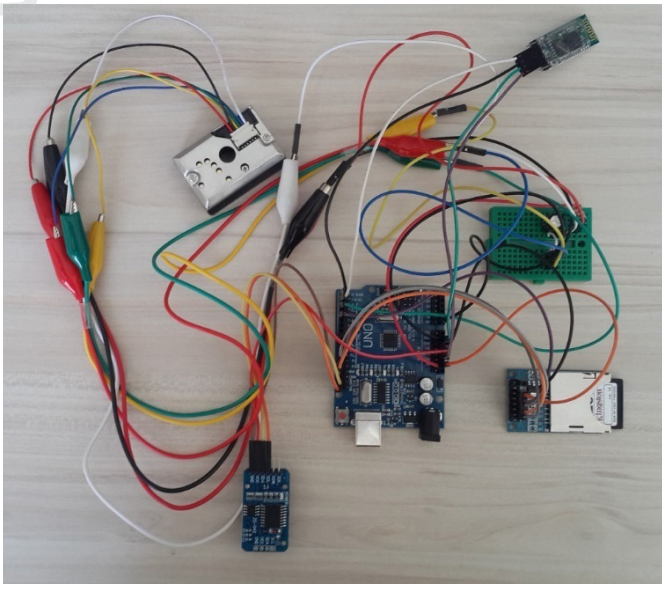


Fig 7: Dust measurement unit

level measured during the growth rate of chicks every week. Chicks became a chicken in 32 days so; analysis had been done four weeks. Additionally, measures had been taken in normal air conditions and weight measurement process.

Results and discussion

There are various interesting applications can be performed with cheap sensors that can evaluate the particulate intensity. These include exposure logs or warning arrangements. At the same time, a few low-cost sensors that are usable in the market fit the universal demands of mobile measurement devices.

In this study, environmental and work time dust measurements had been done for determining environmental health conditions in a small experimental hencoop. The measurement period was 4 weeks. Environmental and worked time dust measurements had been done for each week (Figures 11–14). Then mean of each data group determined for dust value of the environment.

These values can be seen in Table 4. The Environmental



Fig 8: Small experimental hencoop



Fig 9: The axial fan system of the experimental hencoop

Table 2: The air quality criterion (Anonymous, 2016).

PM2.5 density value (µg/m^3)	*Air quality index*	*Air quality levels*	*Air quality evaluation*
0-35	0-50	Level 1	Excellent
35-75	51-100	Level 2	Average
75-115	101-150	Level 3	Lightpollution
115-150	151-200	Level 4	Moderatepollution
150-250	201-300	Level 5	Heavypollution
250-500	>300	Level 6	Seriouspollution

Table 3: WHO (2005), The EU (1999), And EPA (USA) (2006) Maximum permissible values for particulate matter

	Class	*The maximum permitted*		*Tolerated exceeds*
WHO	PM2.5	10µg/m^3	(Annual mean)	—
		25 µg/m^3	(24-hour mean)	—
	PM 10	20 µg/m^3	(Annual mean)	—
		50 µg/m^3	(24-hour mean)	-
EU	PM 10	40 µg/m^3	(Annual mean)	
		50 µg/m^3	(24-hour mean)	Max. 35 days per year
USA	PM2.5	15 µg/m^3	(Annual mean)	
		35 µg/m^3	(24-hour mean)	
	PM 10	150 µg/m^3	(24-hour mean)	Max. 1 day in 3 years

dust is 74.69 µg/m^3 and work time dust is 94.90 µg/m^3 for the first week; environmental dust is 119.48µg/m^3 and work time dust is 131,55 µg/m^3 for the second week; environmental dust is 127.01 µg/m^3 and work time dust is 148.49 µg/m^3 for the third week; environmental dust is 234.81µg/m^3 and work time dust is 242.55µg/m^3 for the fourth week.

These dust values are very high for small hencoop and may create adverse health effects for humans and animals. Also, Gustafsson (1999), in his research, explained that dust in pig confinement buildings might create adverse health effects on people like on the animals. Additionally, Tianhua and Ying (2014) tell that inhalable particles and fine particulates in dust will pollute the indoor environment and endanger human health.

When looking at the results in Figure 15, it is seen that dust intensity increasing when working time and also dust intensity of each week because of chicken growth. Regression between environmental and work time dust measurements is $R^2 = 0.99$. The same environmental conditions observed in different literature.

For example, Prabakar *et al.* (2015) produced a low-cost particulate matter tracking unit using Shinyei's PPD42NS sensor. They have observed the day to day variation of particulate matter in Shinyei's PPD42NS data. It matched well with the massive particle's data obtained using Dylos DC1100 Pro. They found a high correlation with R = 0.81.

Alvarado *et al.* (2015) developed a low-cost airborne sensing system for tracking dust particles after blasting at open-pit mine sites. They fixed SHARP GP2Y10, into a small-wing and multi-rotor copter. The collection the data streamed during flight with correlation coefficients (R) greater than 0,90. Moulick and Roy (2015) express that air particles have an order between 0.001 to 1000 micrometers.

Weekly *et al.* (2013) presented experimentation of local human activity, measured visually and correlated to the absorption of coarse particles with them. The types of



Fig 10: Placement of measurement unit

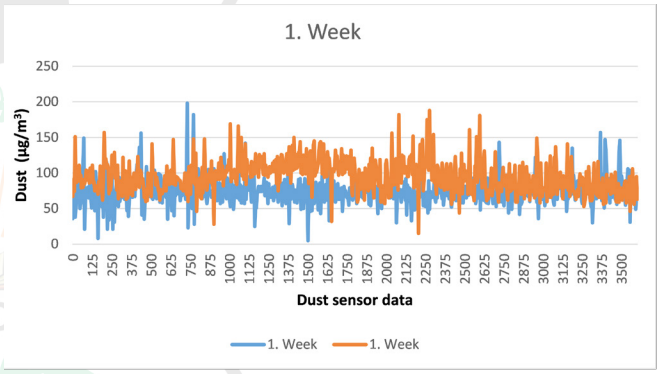


Fig 11: Environmental and work time dust (µg/m^3) for 1.week

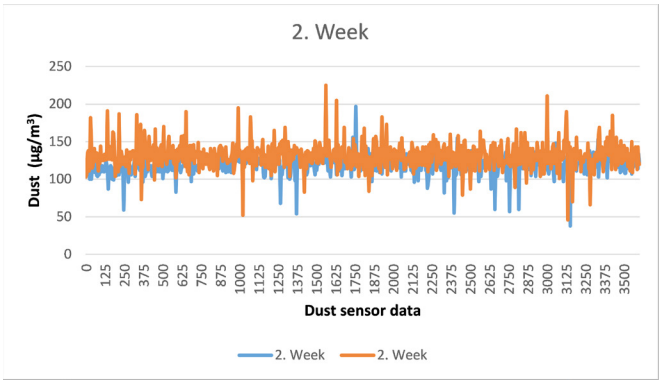


Fig 12: Environmental and work time dust (µg/m^3) for 2.week

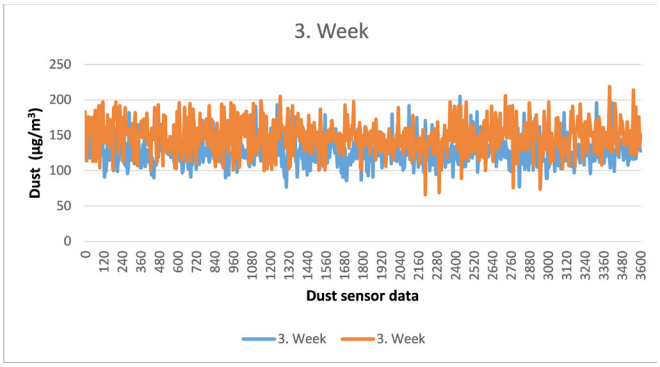


Fig 13: Environmental and work time dust (µg/m^3) for 3.week

Table 4: Average of dust sensor measurements according to weeks

1. Week		*2. Week*		*3. Week*		*4. Week*	
Environmental Dust (µg/m^3)	*Work Time Dust (µg/m^3)*	*Environmental Dust (µg/m^3)*	*Work Time Dust (µg/m^3)*	*Environmental Dust (µg/m^3)*	*Work Time Dust (µg/m^3)*	*Environmental Dust (µg/m^3)*	*Work Time Dust (µg/m^3)*
74,69	94,90	119,48	131,55	127,01	148,49	234,81	242,55

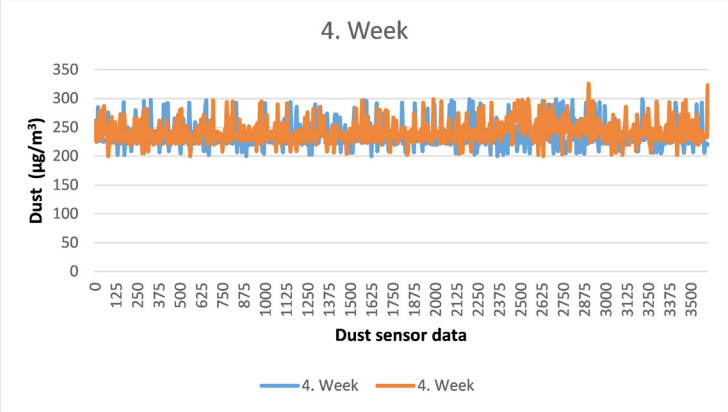


Fig 14: Environmental and work time dust (µg/m^3) for 4.week

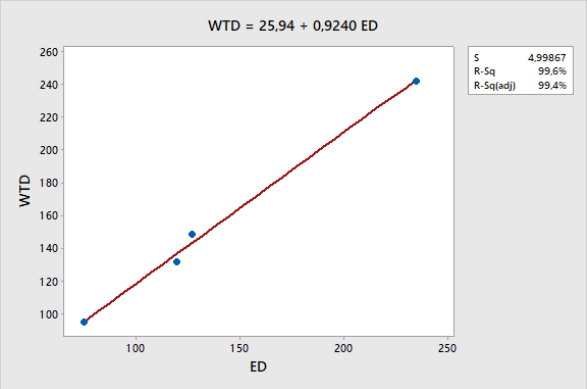


Fig 15: Regression and correlation coefficients of average dust sensor values (µg/m^3)

molecules easily sensed by low-cost PM sensors such as the DSM501A. If smoother data is needed, more low-cost sensors could be totted up, while still being economical.

In this theme, the use of low-cost particulate sensors for mobile measurements worked in this research. Also, in the literature, there are several dust intensity measurement applications with different dust sensors for several scenarios.

Conclusion

In conclusion, in this research, we chose SHARP dust sensor (higher spatial and temporal resolution, low price, low-force, relatively compact size) for the experiments which is suitable for the measurement of particulate matter. In light of the literature and research results, it can be said that low-cost dust sensors are useful sensors for dust measurements with Arduino support. Also, in the future of the work, low-cost dust sensors can be more suitable and useful for the new measurement approaches with the increasing the sensing accuracy.

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