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PARTICULATE MATTER – ARDUINO GUIDE

1. Description of the parameter

"**Particulate matter** (PM), also known as particle pollution, is a complex mixture of extremely small particles and liquid droplets that get into the air." (source: https://www.epa.gov/pm-pollution)

They are mainly emitted into the atmosphere by industrial activities or transportation and can cause environmental damage (eg. acid rains, visibility impairment, depleting the nutrients in soil).

The Particulate Matters pollution can also have negative impacts on humans' health, hence the importance of studying and monitoring their concentration in the air. Among the **health effects** of Particulate Matters pollution we encounter lung problems (asthma, irritation of the airways, coughing, difficulty breathing) and heart diseases when the ultrafine particles get into the bloodstream.

The Particulate Matters have different diameters:
- **PM10**, between 10µm and 2.5µm (coarse particles);
- **PM2.5**, between 2.5µm and 0.1µm (fine particles);
- **PM0.1**, under 0.1µm (ultrafine particles).

Regarding their origin and composition, the Particulate Matters are characterized as follows:
- PM10 includes dust, pollen and mold spores.
- PM2.5 includes combustion particles, organic compounds and metals.
- PM0.1 includes viruses, suspended atmospheric dust and gaseous contaminants.

Coarse particles settle relatively quickly while both fine and ultrafine particles remain in suspension for longer.

2. Standard values for the parameter

"The Clean Air Act, which was last amended in 1990, requires EPA to set **National Ambient Air Quality Standards** for pollutants considered harmful to public health and the environment." (source: https://www.epa.gov/criteria-air-pollutants/naaqs-table)

Thus the Air Quality Standards set by **US Environmental Protection Agency** present the following values for Particulate Matters:
- $35 \mu g/m^3$ for PM2.5 particles for an averaging time of 24 hours;
- $12 \mu g/m^3$ (Primary standard*) and $15 \mu g/m^3$ (Secondary standard**) for PM2.5 particles, over an averaging period of 1 year;
- $150 \mu g/m^3$ for PM10 particles based on a 24 hours average.

* ***Primary standards*** provide public health protection, including protecting the health of "sensitive" populations such as asthmatics, children, and the elderly. (source: epa.gov)
** ***Secondary standards*** provide public welfare protection, including protection against decreased visibility and damage to animals, crops, vegetation, and buildings. (source: epa.gov)

According to the **Air Quality Standards of the European Union**, the concentration of pollutants allowed into the air is as follows (source: EU Environment website):
- 25μg/m^3 for fine particles (PM2.5), over an averaging period of 1 year;
- 50μg/m^3 for PM10 particles on an averaging period of 24 hours;
- 40μg/m^3 for PM10 particles on an averaging period of 1 year.

For PM0.1 particles, there was **no standard value** found.

3. Description of the way the sensor works

The Particulate Matter sensor (**Plantower PMS7003**, in our case) works with various lasers. The laser scatters around. While scattering, it reaches a certain angle and collects solid and liquid particles from the air (e.g. dust, smoke and pollen). The data that it collects are the size and volume amount of the particles in the air, using various algorithms.

4. Use of the sensor at the University of Aruba

In order to verify the sensor and to proceed to data collection, measurements were taken at the University of Aruba, on 30th of October, in different places along the Campus:
- interior garden, next to library (**location no.1**);
- designated smoking area near the Aula and the gazebo (**location no. 2**);
- restrooms (**location no.3**);
- garden area behind classroom D2 (**location no.4**);
- library – bookshelves area (**location no.5**);
- University canteen (**location no.6**);
- front garden (**location no.7**);
- classroom A (**location no.8**).

In each of the locations, an average of 5 to 6 values was measured.

5. Values from measurements at the University of Aruba

Measurement results

The values measured in the different locations at the University of Aruba are shown in the table below. The time period and the average values for the three parameters are also included in the table.

	PM0.1 (μg/m3)	PM2.5 (μg/m3)	PM10 (μg/m3)
Location no.1	6	13	13
12:25-12:26 pm	7	12	15
	7	11	13
	7	9	11
	7	9	9
AVERAGE	**6,8**	**10,8**	**12,2**
Location no.2	6	9	9
12:29-12:31 pm	5	8	9

	4	8	9
	4	7	7
	4	6	8
	5	6	10
	5	6	11
	5	5	10
AVERAGE	**4,8**	**6,875**	**9,125**
Location no.3	5	6	7
12:31-12:33 pm	5	8	10
	6	9	9
	5	8	9
AVERAGE	**5,3**	**7,75**	**8,75**
Location no.4	4	8	9
12:35-12:36 pm	6	9	9
	6	8	8
	7	10	10
	7	9	9
AVERAGE	**6,0**	**8,8**	**9**
Location no.5	6	12	12
12:37-12:38 pm	6	11	11
	5	10	10
	6	9	9
AVERAGE	**5,8**	**10,5**	**10,5**
Location no.6	11	14	14
12:39-12:40 pm	12	15	15
	13	17	17
	13	19	21
AVERAGE	**12,3**	**16,25**	**16,75**
Location no.7	4	5	6
12:40-12:42 pm	4	5	7
	5	6	8
	5	7	10
	5	10	14
	5	8	13
	4	7	12
	5	9	12
	5	8	9
AVERAGE	**4,7**	**7,22**	**10,11**
Location no.8	2	4	4
12:43-12:44 pm	1	3	3
	0	1	1
	1	2	2
	1	3	3
	0	4	4
AVERAGE	**0,8**	**2,83**	**2,83**

Results discussion

The **average values** for the measurements taken at the University of Aruba were **5.79µg/m^3** for PM0.1, **8.88µg/m^3** for PM2.5 and **9.91µg/m^3** for PM10. When comparing them with the standard values set by the European Union (25µg/m^3 for PM2.5 a year and 50µg/m^3 for PM10 on a 24 hours average), the measurements taken at the university are lower. This demonstrates that **the air** of the study area **is of a very good quality**. Even when the results are compared with the US Environmental Protection Agency standards, the outcome stays the same.

Regarding the distribution of the Particulate Matters measurements on locations, in every single case the values recorded for the particles with a smaller size are lower than those that are close to a 10 µm diameter. The **first location** was represented by the interior garden, next to library. The PM values here were a little bit higher than those encountered at the other locations and than the university averages. This could be explained by the density of plants and the lack of natural ventilation. The average for each of the parameters was below the standards set by EU and EPA. The **second location** was the designated smoking area near the University Aula and the area where the gazebo is situated. The measurements were taken when no person was smoking and as a result, the values were low. They were even lower than the averages (in the case of all of the three parameters) because of more natural ventilation and the presence of an Air-Conditioning fan outside of the Aula. **Location no.3** was represented by the restrooms. The Particulate Matters values here were low, below the average values for the entire university. The **fourth location** was represented by the garden area behind classroom D2. Again, the values measured were low. Here the values for PM2.5 and PM10 were the closest to the average measured for the University. The **fifth location** was the bookshelves area from the library. The values measured here were higher compared to the locations from outside. **Location no.6** was the place where the highest values were encountered. Being an indoor place, it lacks strong ventilation. The **seventh location** was the front garden. Here, the measurements were taken close to an Air-Conditioning fan and then 5m away from it, in the garden. The values for the AC were lower (4.5µg/m^3 for PM0.1, 5.75µg/m^3 for PM2.5 and 7.75µg/m^3 for PM10) than those from the garden (4.8µg/m^3 for PM0.1, 8.4µg/m^3 for PM2.5 and 12µg/m^3 for PM10). The **final location** (classroom A) was characterized by the lowest measurements due to the high ventilation. For PM0.1 we even encountered 0µg/m^3 as a value.

From all the locations, the greatest values were found indoor, at the University canteen, while among the outdoor locations, the interior garden presented the highest measurements (**Fig.1**).

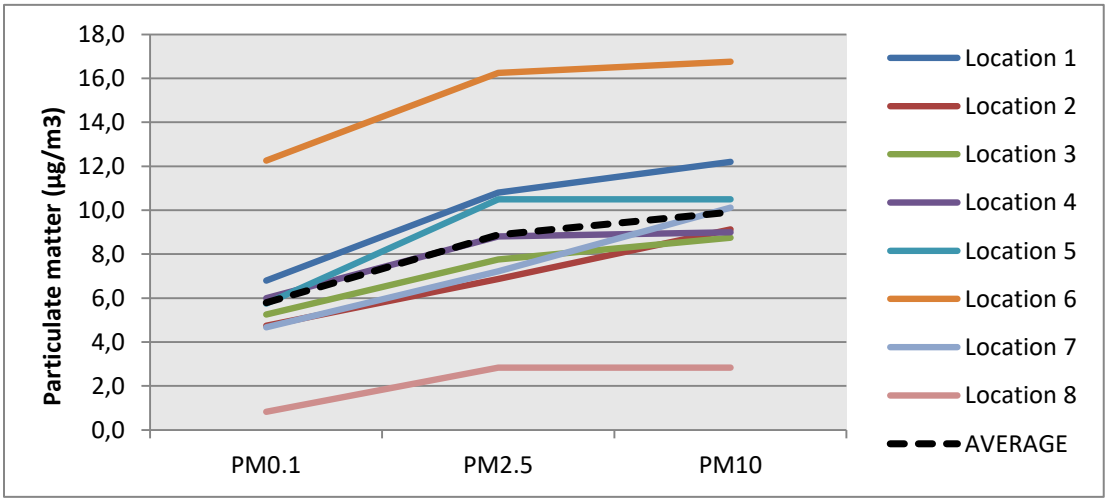


Fig.1 - Average values for the locations at the University of Aruba

APPENDIX 1 – Sensor wiring

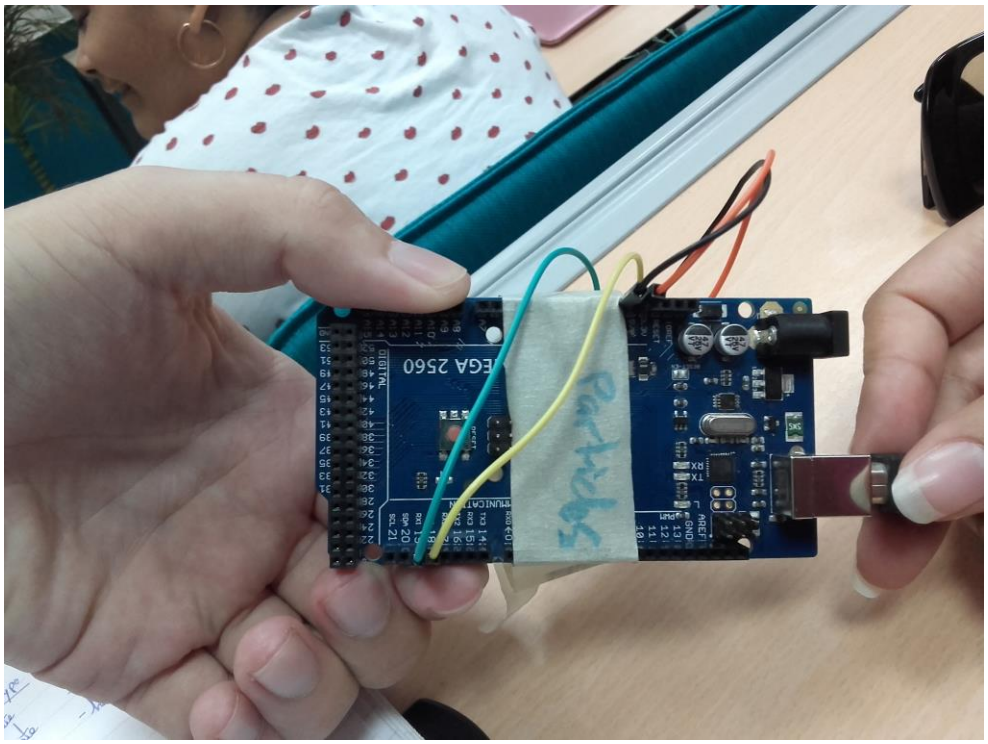


Photo no.1 – Front image of Arduino Mega 2560

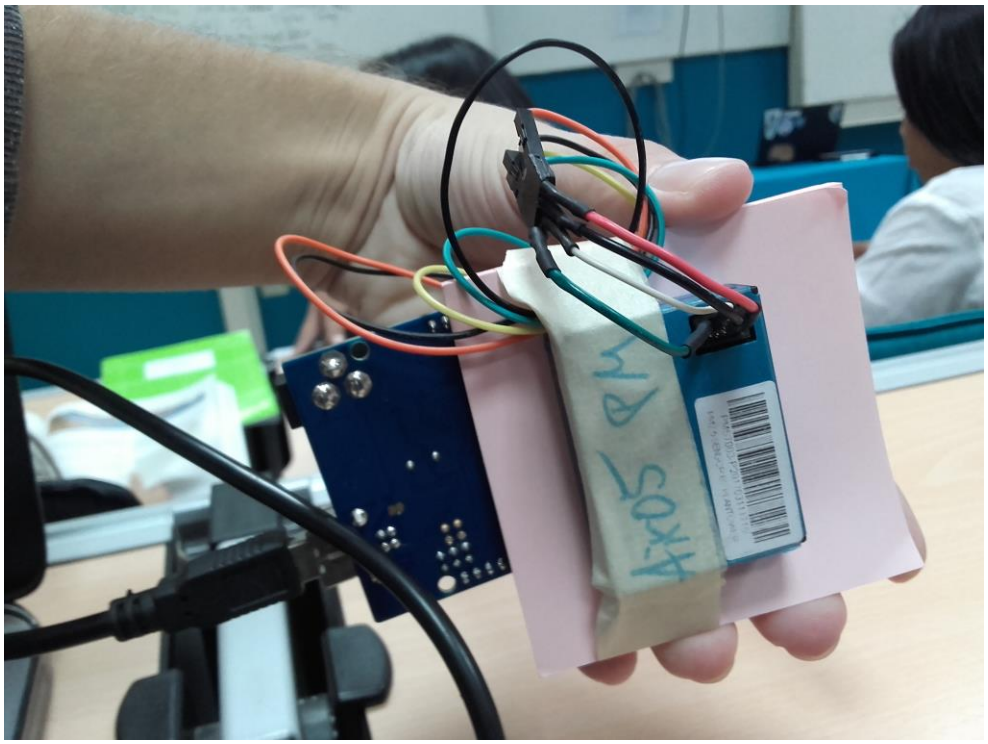


Photo no.2 – Back image of Arduino and the Plantower PMS7003 sensor

APPENDIX 2 – The code used to program the sensor

```
#include <Arduino.h>
#define LENG 31   //0x42 + 31 bytes equal to 32 bytes
unsigned char buf[LENG];

int PM01Value=0;          //define PM1.0 value of the air detector module
int PM2_5Value=0;         //define PM2.5 value of the air detector module
int PM10Value=0;          //define PM10 value of the air detector module


void setup()
{
  Serial.begin(9600);   //use serial0
  Serial.setTimeout(1500);     //set the Timeout to 1500ms, longer than the data transmission periodic time of the sensor
}

void loop()
{
  if(Serial.find(0x42)){    //start to read when detect 0x42
    Serial.readBytes(buf,LENG);

    if(buf[0] == 0x4d){
      if(checkValue(buf,LENG)){
        PM01Value=transmitPM01(buf); //count PM1.0 value of the air detector module
        PM2_5Value=transmitPM2_5(buf);//count PM2.5 value of the air detector module
        PM10Value=transmitPM10(buf); //count PM10 value of the air detector module
      }
    }
  }

  static unsigned long OledTimer=millis();
    if (millis() - OledTimer >=5000)
    {
      OledTimer=millis();

      Serial.print("PM1.0: ");
      Serial.print(PM01Value);
      Serial.println("  ug/m3");

      Serial.print("PM2.5: ");
      Serial.print(PM2_5Value);
      Serial.println("  ug/m3");

      Serial.print("PM1 0: ");
```

Changed to 5000ms from an initial value of 1000ms. That translates into 5s – time between measurements.

```
      Serial.print(PM10Value);
      Serial.println("  ug/m3");
      Serial.println();
    }

}
char checkValue(unsigned char *thebuf, char leng)
{
  char receiveflag=0;
  int receiveSum=0;

  for(int i=0; i<(leng-2); i++){
  receiveSum=receiveSum+thebuf[i];
  }
  receiveSum=receiveSum + 0x42;

  if(receiveSum == ((thebuf[leng-2]<<8)+thebuf[leng-1]))  //check the serial data
  {
    receiveSum = 0;
    receiveflag = 1;
  }
  return receiveflag;
}

int transmitPM01(unsigned char *thebuf)
{
  int PM01Val;
  PM01Val=((thebuf[3]<<8) + thebuf[4]); //count PM1.0 value of the air detector module
  return PM01Val;
}

//transmit PM Value to PC
int transmitPM2_5(unsigned char *thebuf)
{
  int PM2_5Val;
  PM2_5Val=((thebuf[5]<<8) + thebuf[6]);//count PM2.5 value of the air detector module
  return PM2_5Val;
  }

//transmit PM Value to PC
int transmitPM10(unsigned char *thebuf)
{
  int PM10Val;
  PM10Val=((thebuf[7]<<8) + thebuf[8]); //count PM10 value of the air detector module
  return PM10Val;
}
```

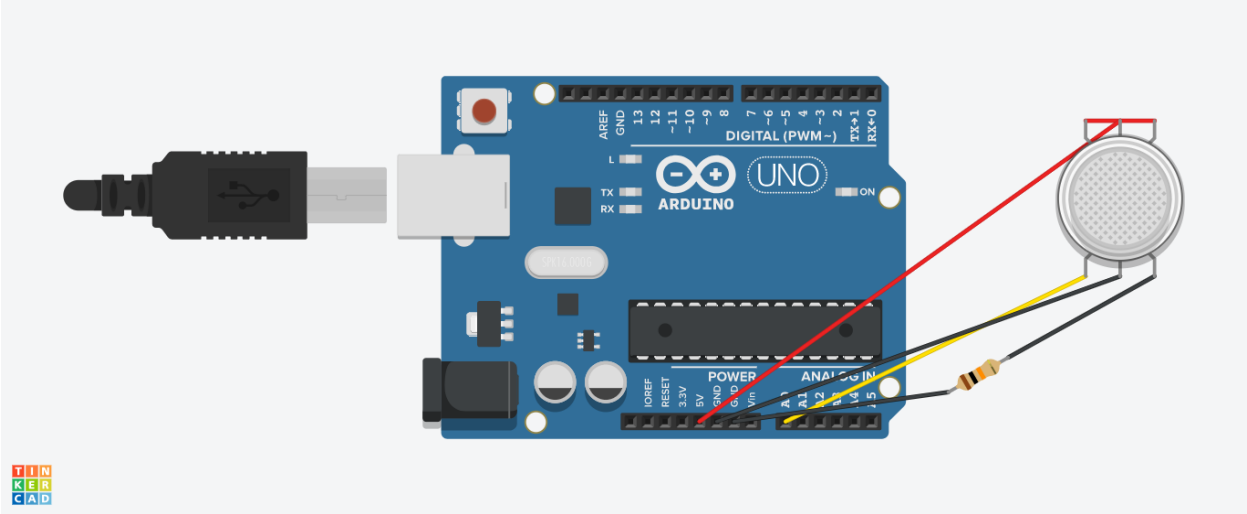
SIMULATION OF THE SENSOR

Sensor used: Gas sensor

Parameter: Propane

The simulation was made for the MQ6 Propane measuring sensor (gas sensor) using the www.tinkercad.com website. This sensor was chosen because the simulator didn't present neither an Arduino Mega 2560 nor a Particulate Metter sensor (in the Components box).

After changing the code and starting the Simulation, Serial Monitor constantly sends the following result: 535.



Link to the Gas Sensor simulation:
https://www.tinkercad.com/things/jznyjmt2YpP

Link to the Gas Sensor simulation (breadboard included):
https://www.tinkercad.com/things/jVkK0xZfplX