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# Development of a low-cost portable device for the monitoring of air pollution

## 1. Abstract

The Air Quality is an ever-growing environmental issue and over time it is seen as getting worse. In this paper we will look at a case study example where we integrated a low-cost and portable air quality monitoring system in order to perform some local measurements of pollution in the Liverpool area, UK. The system is presented in its set of components and then the preliminary set of measurements and results are shown. Even if a more in depth validation should be considered, these initial results provide a good benchmark for the development of low cost and portable system for the air quality monitoring.

## 2. Keywords

Air Quality Index (AQI), Air Quality Monitoring (AQM).

## 3. Abbreviations

AQI, AQM

## 4. Introduction

Air quality monitoring has become a greatly important environmental issue and, in some countries, it seems to be only getting worse. For example, Indonesia is a country in South East Asia, which has the biggest economy in South East Asia and has one of the biggest economies in Asia. It is changing from an agricultural economy of raw materials such as crops to becoming an economy that is an industrial producer of natural gas and coal. There are a number of environmental problems that face Indonesia due to its dense large population and poverty levels with air pollution becoming a serious problem. To detect and identify these problems, the air quality can be characterized by looking at its

PM2.5. PM2.5 is the set where the particles that are contained are less than 2.5 micrometres in diameter. These particles are made by the burning of fuels and chemical reactions which happen in the air. Jakarta in 2019 had a yearly average of 49.4 $\mu g/m^3$ for its PM2.5. This reading has to be read as a 'unhealthy for sensitives groups' category. This category requires a reading of 35.5 to 55.4 $\mu g/m^3$ which has an effect on a group of the population that are vulnerable to getting exposed to this amount of unhealthy air quality. In particular those with pre-existing conditions or those with poor immune systems. But it is not only the sensitive people who are at risk, it is also harmful to those who are healthy but are exposed to it for a long time [1]. The poor levels of air quality made it in 126$^{th}$ place in the world which is very high compared to Bangkok which is another city in Asia that was in 737th place, with an average reading of 22.8 $\mu g/m^3$ in 2019. "The average Indonesian can expect to lose 1.2 years of life expectancy at current pollution levels, according to the Air Quality Life Index (AQLI), because air quality fails to meet the World Health Organization (WHO) guideline" [2].

The consequences of the poor air quality are not just death, but they can contribute to other health complications and conditions such as increase damage to the circulatory system and heart. This is because of the tiny size that PM2.5 could enter inside the blood stream through the lung tissue. Which increases the possibility of a heart attack and heart disease. Also, those who are at risk are pregnant mothers when they are in the presence of air pollution because cases of birth defects, premature birth and miscarriage are much higher when compared to cities that have much cleaner air.

"Particles in the PM2.5 size range are able to travel deeply into the respiratory tract, reaching the lungs. Exposure to fine particles can cause short-term health effects such as eye, nose, throat and lung irritation, coughing, sneezing, runny nose and shortness of breath. Exposure to fine particles can also affect lung function and worsen medical conditions such as asthma and heart disease. Scientific studies have linked increases in daily PM2.5 exposure with increased respiratory and cardiovascular hospital admissions, emergency department visits and deaths. Studies also suggest that long term exposure to fine particulate matter may be associated with increased rates of chronic bronchitis, reduced lung function and increased mortality from lung cancer and heart disease. People with breathing and heart problems, children and the elderly may be particularly sensitive to PM2.5." [3,4].

Potentially there are a few possible causes with why the PM2.5 number is so high

and in the unhealthy for sensitive groups bracket. A few possibilities could be transportation, factories or the open burning of organic materials. “Rapid economic growth, emissions and consequently atmospheric concentrations of many pollutants have increased enormously in Indonesia, particularly in big cities” [5, 6]. This could be possibly be because of the use of fossil fuel factories and power plants.

In this context, this paper aims at proposing a low-cost and portable Air Quality Monitoring device. The reason of focusing on low-cost and portability, is because there are many holes that need to be filled when it comes to this area of science [7-10]. These problems that can been identified are:

- The air quality monitoring stations are too *expensive* for researchers to buy - This has been a problem for those who want to conduct research but do not have the finances to back them up thus leading to less research being conducted. If air quality monitoring stations became cheaper then more research will be conducted for scientist to look at.

- The air quality monitoring stations are not *mobile* - If the air quality monitoring system was smaller and more mobile it will give a great opportunity to those who want to research trends in different areas. But will also be easier to move around or to have on a mode of transport such as a car or bike.

- The air quality monitoring stations are too complicated and expensive to *repair* - Having cheaper and more basic air quality monitoring stations will not only be easier to repair but will also be less expensive compared to others.

## 5. Materials

The cost of an air quality monitoring system can cost thousands, therefore the goal here is to integrate a system that would cost a fraction of that price.

In order to achieve this result, we look at low-cost and open source hardware components which represent a reliable platform for the developing of prototype bot from the hardware and software viewpoints.

Below is a table reporting the selection of components that we have identified together with the costs and a description of the functionalities, i.e. what that item does.

**Table 1** – Summary of the costs of the main components

| | |
|---|---|
| **Raspberry Pi Zero W – Zero WH (pre-soldered)**<br>This is a small board that is WIFI and Bluetooth compatible which makes it easy to connect to the internet and other resources. | £13.56 |
| **Enviro for Raspberry Pi – Enviro + Air Quality**<br>This board contains the LCD display which shows the data that is being recorded and will contain a whole bunch of other sensors that can be used for environmental causes. | £48.00 |
| **Official Raspberry Pi Universal Power Supply (Pi 3 & Zero Only)**<br>This is the power supply used to power the board with changeable socket heads so the board can be used anywhere in the world. | £8.40 |
| **PMS5003 Particulate Matter Sensor with Cable**<br>This is a small sized particle matter sensor that is cheap and accurately used. This can sense various particle sizes but most importantly PM2.5 for this research. | £24.90 |
| **Raspberry Pi Zero Adaptor Kit**<br>A kit that comes with useful things such as various adapters. | £5.10 |
| **NOOBS microSD card (3.3) – 32GB**<br>A microSD card that is 32GB large and will be useful because it already has NOOBS installed on it already. | £9 |
| **Total cost** | **£108.96** |

Thanks to this hardware selection, a Raspberry Pi NOOBS is then the software that we needed to work. This software platform comes with a Python built in, which made the programming simpler when it comes to developing the project.

Figure 1 shows the overall system according to the components reported in Table 1.

In order to perform the acquisition, the following pseudo-code needs to be executed:

1. Import *ttk library* in order to manage the tkinter widgets
2. Import *PMS5003 library* of the particle sensor for reading the output of the device
3. Set the reading variable (namely pms5003)
4. Reading the sensor by means of the *read command* inherited from the library
5. *Labelling the reading* by reporting them within a text box

## 6. Results

The system was tested in the Liverpool area, UK and precisely in 3 different locations

(Walton Area, Clayton Square, Everton Valley). The measurements, as performed with the proposed device, were then compared with the acquisition on the same day as performed on the station of the Liverpool IQ Air recording system [11]: here an average of the two monitors that are in Liverpool, one being in Clayton Square, the other in Everton Valley, was considered.

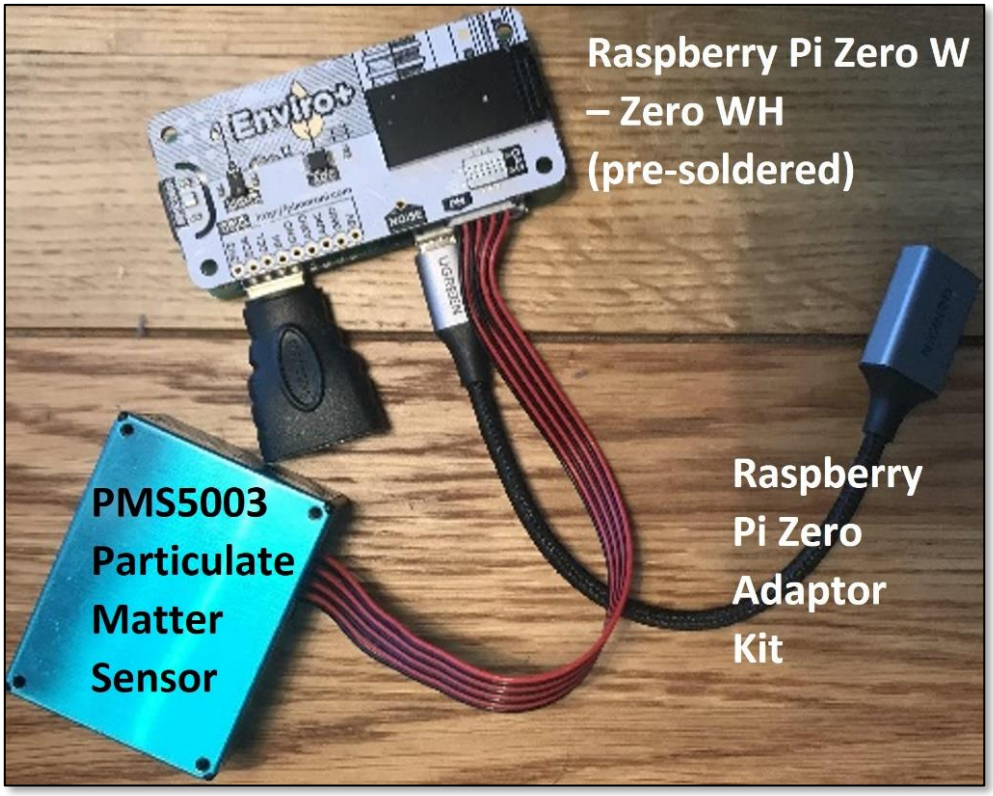


**Figure 1** - Enviro for Raspberry Pi – Enviro + Air Quality

This approach will provide an estimation whether the device that has been constructed provides accurate results vs the official measurements.

Table 2-4 show the examples of how we gathered the results in three different days (January the 7th, the 8th and the 9th) at 3 different times (9 am, 12 pm and 3 pm): the AQI rating from IQ Air are compared to the reading from the proposed device. The official IQ Air reading displays a reading of 9 while our monitor returns a reading of 11. However, it is important to reiterate that the two acquisitions were performed in different locations, namely 5 miles away from the official monitors of the Liverpool IQ Air recording system.

**Table 2** – Sensor readings on January the 7th

| Time | Liverpool IQ Air recording | Recording in Woolton area | Difference |
|---|---|---|---|
| 09:00 | 7 | 10 | 3 |
| 12:00 | 5 | 9 | 4 |
| 15:00 | 6 | 8 | 2 |

**Table 3** – Sensor readings on January the 8th

| Time | Liverpool IQ Air recording | Recording in Woolton area | Difference |
|---|---|---|---|
| 09:00 | 10 | 11 | 1 |
| 12:00 | 16 | 22 | 6 |
| 15:00 | 27 | 24 | 3 |

**Table 4** – Sensor readings on January the 9th

| Time | Liverpool IQ Air recording | Recording in Woolton area | Difference |
|---|---|---|---|
| 09:00 | 6 | 9 | 3 |
| 12:00 | 12 | 12 | 0 |
| 15:00 | 15 | 18 | 3 |

The tables are an example of how we measured and compared our recordings. A further analysis which should take into account the precision and accuracy of the system should be performed in other validation sessions. Moreover these acquisitions should involve a more extensive number of sessions, combining a variety of locations and time frames.

It is important to note that we compared the device output with the IQ air recording which is an average of the two monitors that are in the Liverpool town (Clayton Square and in Everton Valley stations), approximately 5 miles away from the site of measurement. On the first day the mean average difference was 2.25 AQI, on the second day the mean average difference was of 2.5 AQI, while on the final third day the mean average difference was down to 2 AQI. This has proven to give good and accurate results compared to the official measurements, even if more testing need to be performed to bring a conclusive result.

**Table 5** – Sensor readings on January the 14th

| Time | IQ Air recording Clayton Square | Recording in Clayton Square | Difference |
|---|---|---|---|
| 09:00 | 14 | 11 | 3 |
| 12:00 | 15 | 17 | 2 |
| 15:00 | 22 | 22 | 0 |
| 18:00 | 20 | 29 | 1 |

**Table 6** – Sensor readings on January the 15th

| Time | IQ Air recording Clayton Square | Recording in Clayton Square | Difference |
|---|---|---|---|
| 09:00 | 19 | 19 | 0 |
| 12:00 | 22 | 25 | 3 |
| 15:00 | 25 | 27 | 2 |
| 18:00 | 27 | 27 | 0 |

**Table 7** – Sensor readings on January the 16th

| Time | IQ Air recording Clayton Square | Recording in Clayton Square | Difference |
|---|---|---|---|
| 09:00 | 10 | 11 | 1 |
| 12:00 | 14 | 14 | 0 |
| 15:00 | 20 | 22 | 2 |
| 18:00 | 29 | 30 | 1 |

Tables 5-7 refer to the next testing where we measure and compare the monitor at the same location in Clayton Square, comparing the results of the device vs the station. This would hopefully give a more clear picture whether this monitor is as accurate as the official IQ Air reading: on the first day the mean average difference was 1.5 AQI, on the second day the mean average difference went down to 1.25 AQI and on the final day the mean average difference was of 1 AQI. These results are starting to paint the picture of how accurate the inexpensive monitor is compared to the official system. However, another third test was conducted to ensure and consolidate these results.

**Table 8** – Sensor readings on January the 21st

| Time | IQ Air recording Everton Valley | Recording in Everton Valley | Difference |
|---|---|---|---|
| 09:00 | 8 | 9 | 1 |
| 12:00 | 11 | 11 | 0 |
| 15:00 | 18 | 18 | 0 |
| 18:00 | 28 | 30 | 2 |

**Table 9** – Sensor readings on January the 22nd

| Time | IQ Air recording Everton Valley | Recording in Everton Valley | Difference |
|---|---|---|---|
| 09:00 | 9 | 11 | 2 |
| 12:00 | 12 | 12 | 0 |
| 15:00 | 18 | 19 | 1 |
| 18:00 | 24 | 24 | 0 |

**Table 10** – Sensor readings on January the 23rd

| Time | IQ Air recording Everton Valley | Recording in Everton Valley | Difference |
|---|---|---|---|
| 09:00 | 11 | 13 | 2 |
| 12:00 | 17 | 19 | 2 |
| 15:00 | 22 | 22 | 0 |

Tables 8-10 refer to the final test where we measure the two instrumental performance in the Everton Valley: here, on the first day the mean average difference was 0.75 AQI, on the second day the mean average difference was the same, namely 0.75 AQI and on the final day the mean average difference was 1 AQI.

These results finally supported the idea that using an inexpensive monitoring system could provide an accurate measurement of the air pollution as the official monitor that is currently being used in the Liverpool city.

## 7. Conclusion

*The importance of air quality monitors* - Throughout this paper it has become clear how important air quality monitors are, they help provide evidence for this important health and environmental issue. Without evidence no research can be conducted therefore it is vital that more air quality monitors are produced and with them being available for use to the public. They can also set the targets to reduce the air pollution for specific areas by spotting unhealthy patterns and trends that are being produced. Different areas at different times will play a significant role in this: for example it will be important to discover what times and what areas are the worst at producing poor air quality. Then this evidence can be brought forward to a local authority or council to show and provide evidence of the poor air quality that is going on. This will also enable those who are at risk of the poor air quality to stay indoors and away from the harmful pollutants, whilst the area is at its worse peak. This will also give confidence to those who are vulnerable to poor air pollution that the local authority care about them and there is research being conducted to ensure that they are not at risk.

*The negative effects of bad air pollution* - There are many negative consequences and effects of bad air pollution, mainly the negative effects they have on people's health is an issue that effects the general public and especially to those who are most vulnerable. These include children, the elderly and those with underlying health conditions particularly with the respiratory system will be most at risk. This can affect many people

throughout their different stages of life:

- During pregnancy it can cause low birth weight.
- In children it can cause asthma, slower development of lung function and other development issues.
- In adults it can cause asthma, coronary heart disease, stroke and lung cancer.
- In the elderly it can cause asthma, an accelerated decline lung function and lung cancer

This will also have a negative effect on health services because it will see an increase in people arriving in hospitals which will also cause an increase in costs, time and resources for something which could be avoided if the air quality was at a satisfactory standard. Poor levels of air quality can lead to damage to crops and trees, leading to reduced growth and reducing the chances of the seeds being able to survive. This will also have a negative effect on animals needing those plants to survive [12-13].

*The results from the experiment comparing the inexpensive monitor to the official IQ air readings* - It was important to compare the official IQair readings to the inexpensive air quality monitor that we had made. The results we obtained from the experiment made us able to conclude that the inexpensive air quality monitor may provide very similar results to its competitive official IQair readings [14]. Hopefully even more inexpensive technologies [15-17], such as basic air quality monitoring devices will be constructed into the response of the poor air quality which is only getting worse in places such as, for example, the town of Jakarta that we mentioned in the Introduction.

*Overall conclusion* - Overall, the research and findings that have been conducted in this paper have been hugely successful and encouraging. This is because of the positive results and solid evidence that this paper has provided from start to finish. Especially when it came to providing the evidence of the linkage between cars and the problem with poor levels of air quality in Jakarta and being able to produce an effective low-cost air quality monitor that works just as well as its competitor the official monitor. This will hopefully bring inspiration to those who are also passionate about providing better quality of air.

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