PollutionPi: An Indicative Air Quality Index Compatible Raspberry Pi Powered Air Quality Station

Project Proposal

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Contents

1 Design Problem

Bosnia and Herzegovina is one of the most polluted countries in the world. According to the World Health Organization, it has one of the highest fine particle concentrations in urban areas within Europe. It is due to this that the health of the population suffers, with mortality rates due to air pollution among the highest in Europe. [1][2]

Bosnia and Herzegovina lacks sufficient historic and current data regarding air pollution and the existing data is not properly distributed in a way that individuals and organisations can access it. The data that exists is obtained through various municipalities throughout Bosnia and Herzegovina, as well as the Federal Hydrometeorological Institute. The municipalities that have meteorological stations that often provide pollution data such as PM2.5, PM10, SO2, NO2, O3, and CO. However, the utilised meteorological stations tend to be very expensive and prone to malfunction. Due to their expense, they are typically only purchased to cover larger cities within Bosnian and Herzegovina [3].

In order to provide greater coverage of air pollution data in Bosnia and Herzegovina, CPI Fondacija is currently developing an all inclusive, open source, open data, and real time platform to gather data from all currently available and future sources for all pollutants. Data will be collected by accessing open data resources, web scraping, and from IoT ready devices. Open source software and resources will be used for data processing, data presentation and visualization.

To increase the coverage and accuracy of air pollution data, CPI Fondacija are working with CityOs Air and assembling "Boxy" devices that are capable of measuring PM1, PM2.5, PM10, temperature, and humidity [4]. These "Boxy" devices are extremely affordable, however they offer limited measurements and have board tolerances in regards to the measured results.

Another prototype is also being constructed with a local engineering firm in Sarajevo that hopes develop an accurate sensor capable of providing reliable air pollution data. This prototype will incur a significantly higher cost to build, but provide more reliable data for the proposed platform.

While these prototypes both contribute to the aim of increasing the availability of air pollution data within Bosnia and Herzegovina, there is scope for the design and construction of a second prototype that has more accurate and diverse measurements than the CityOs "Boxy" unit, and is cheaper to construct than the prototype being constructed by the local firm in Sarajevo.

2 Research

2.1 Air Pollution in Bosnia and Herzegovina

The severity and causes for air pollution differ from region to region, however three separate areas have historically suffered from high levels of air pollution in the last century. These areas are Tuzla, Zenica, and Sarajevo.

2.1.1 Tuzla

Tuzla is the third largest city within Bosnia and Herzegovina with a population of around 120000 people. Its main economic driving force in the broader Tuzla region is heavy industry, with six coals mines, a coal power plant, and chemical processing factories. These industries, as well geographical basin that Tuzla rests in, all contribute to poor quality of air that exists within the region [5]. In addition, low grade heating fuels used by residents and apartments also contribute to air pollution in the winter months.

2.1.2 Zenica

Zenica is the forth largest city within Bosnia and Herzegovina with a population of around 115000 people. It is home to a massive steelworks plant owned by ArcelorMittal. It is this steel plant that is largely cited as the reason for the poor air quality in the Zenica area. While low grade heating fuels used in winter months have also been blamed for the air quality issues facing the area, significantly more fuels usually associated with producing significant pollutants such as coal are used by the steelworks plant on an annual basis [6].

2.1.3 Sarajevo

Sarajevo is the largest city within Bosnia and Herzegovina with a population of over 500000 people in the greater region. The causes of poor air quality in Sarajevo are complex, with many aspects contributing. Historically, Sarajevo had the most severe air pollution problem in Yugoslavia.

Sarajevo lays in a mountain-valley configuration. This configuration affects natural air flows within the city and causes a lack of ventilating characteristics throughout the terrain in which the city exists. It is also due to this characteristic of the terrain that significant temperature inversions exist. Temperature inversion is the phenomenon in which is air temperature increases significantly as altitude increases. This causes a majority of pollutants that exist in the city to be trapped bellow the temperature inversions when they exist. This phenomenon usually occurs in the winter months, and thus air quality within the city usually suffers during this period.

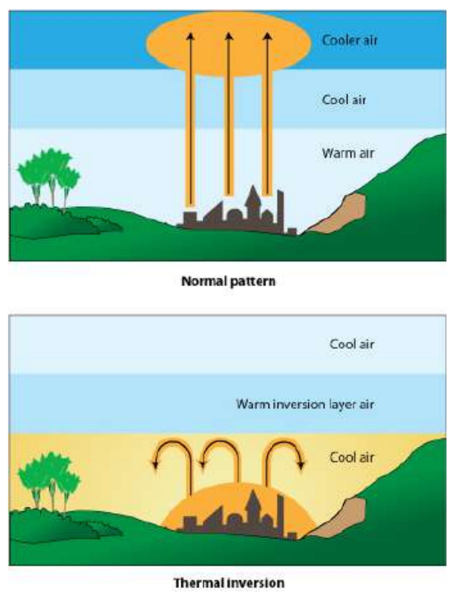


Figure 1: Image depicting the mechanism of temperature inversion [7].

Due to this geographical condition, pollution tends to linger in the atmosphere and cause a variety of health related issues for the citizens. Heating fuels that emit large amounts of pollutants such as lignite, coal, and wood tend to exacerbate this issue. It is these two characteristics, the use of dirty heating fuels and the prevalence of temperature inversion, that have historically caused high pollution levels in Sarajevo.

A number of projects have existing in the last 50 years that have attempted to reduce that poor air quality within Sarajevo with varying levels of success.

The Sarajevo Air Pollution Control Project The Sarajevo Air Pollution Project was a project financed by a loan from the World Bank beginning in 1976 with aim of reducing Sarajevo's then chronic air pollution problem [8].

Studies undertaken at the time identified the use of heating fuels such as lignite, coal, and wood as one of the primary causes for pollution in the area in addition to the geographical difficulties of Sarajevo. These same studies identified the most cost effective solution to meeting emission reduction standards was to use natural gas as a primary heating fuel within the city.

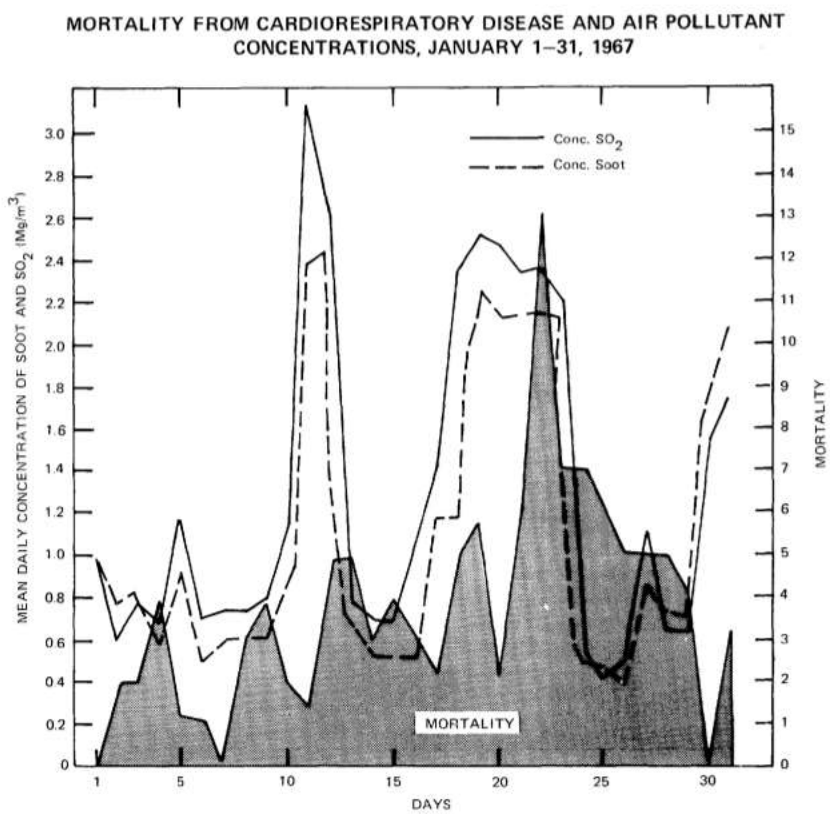


Figure 2: SO2 and soot emissions with correlated mortality rates during winter in Sarajevo, 1967. [8].

The project financed the facilities required to convert 300 central-heating plants and 10000 additional households to natural gas consumption by extending gas pipelines from Belgrade to Sarajevo and constructing pressure regulating facilities within the city.

No.	Alternatives	% of Consumers which could be supplied	Average SO_2 Concentration 1985 $\mu g/m^3$	Resulting Pollution Levels in Winter: Probable number of days on which standards would be exceeded/1 — US standard/2	Serbian standard/2
	Present Situation		400/3	50	68
1.	1985 situation without corrective action		800	51	74
2.	1985 situation according to resolution passed by City Assembly/4		600	42	68
3.	Use of light fuel oil and smokeless fuel	100	275	20	45
4.	Central power-heating plant:				
	without scrubbing	50-60	150	9	27
	with scrubbing		240	7	25
5.	Coal gasification and distribution	80-100	50	1	6
6.	Natural gas transmission and distribution	80-100	50	1	6
7.	Oil fired central heating plant	50	140	7	25

/1 These figures relate only to the 90-day winter period (Dec.-Feb.) Annual number of days would considerably exceed these as heating is usually required from October to May.
/2 US standards are 365 $\mu g/m^3$ and Serbian (USSR) standards are 150 $\mu g/m^3$.
/3 Average concentration 1973.
/4 The resolution still allows some heavy fuel oil to be used in certain areas.

Figure 3: Pollution reduction alternatives in 1973 as reported in the World Bank Sarajevo Air Pollution Control Project appraisal [8].

The project concluded in 1983 and was considered a success. Natural gas usage increased and SO2 pollution levels dropped significantly after the completion of the project.

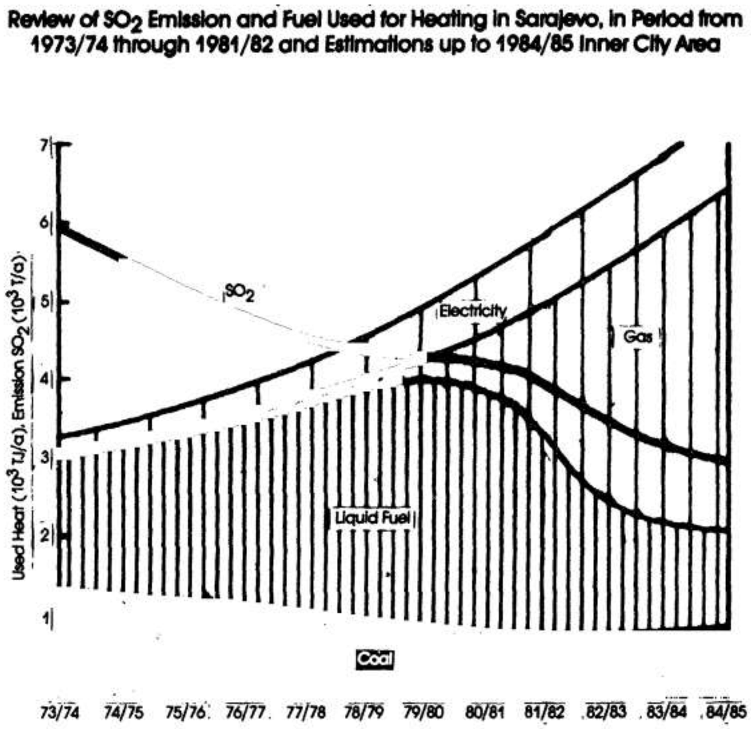


Figure 4: SO2 pollution reduction after completion of Sarajevo Air Pollution Control Project. [9].

2.1.4 The Emergency District Heating Reconstruction Project

In response to the end of the Bosnian War and the devastating state of heating infrastructure within Sarajevo, The World Bank helped to initiate the Emergency District Heating Reconstruction Project. The Emergency District Heating Reconstruction Projects objectives were to restore district heating service in Sarajevo as soon as possible and enable Bosnia and Herzegovina to gain energy security by installing "fuel switching" capability in to the district heating network. This would allow the usage of both natural gas and fuel oils within the district heating system.

Within the Technical annex of the Emergency District Heating Reconstruction Project proposal, the potential effects on air quality due to the completion of the project if the government were to decide to utilised fuel oil rather than natural gas were hypothesised.

"Substituting distillate and residual fuel oil for natural gas could result in a deterioration of the ambient air quality on a limited number of winter days when heat demand is very high and, simultaneously, persistent stagnation of the air occurs. Emissions of SO_2, particulates and possibly nitrogen oxides will increase due to oil firing. The general contribution of sulfur dioxide loading to the Sarajevo air shed may be noticeable, and the ambient air quality in the immediate vicinity of individual boiler units will vary to a greater or lesser extent depending on the individual source characteristics and location relative to nearby structures."

2.1.5 Current Causes of Air Pollution in Sarajevo

The effects of the Bosnian War have had a lasting effect on air quality in Sarajevo two decades on. A sharp fall in measured air pollution was detected in the years after the war due to the destruction of industry, infrastructure, and economy. Due to the postwar mix of heating infrastructure and the poor and stagnating economic state of Bosnia and Herzegovina, cheaper heating fuels that produce poorer air quality are being used by individuals and apartment buildings alike throughout Bosnia and Herzegovina. Less natural gas is being used as a heating fuel in Bosnia and Herzegovina as time goes on, and this is causing greater spike in air pollution within Bosnia and Herzegovina during the winter period. In the past ten years the usage of natural gas has decreased in the vicinity of 5%, and use of light fuel oil usage has almost ceased in favor of wood and wood waste based fuels

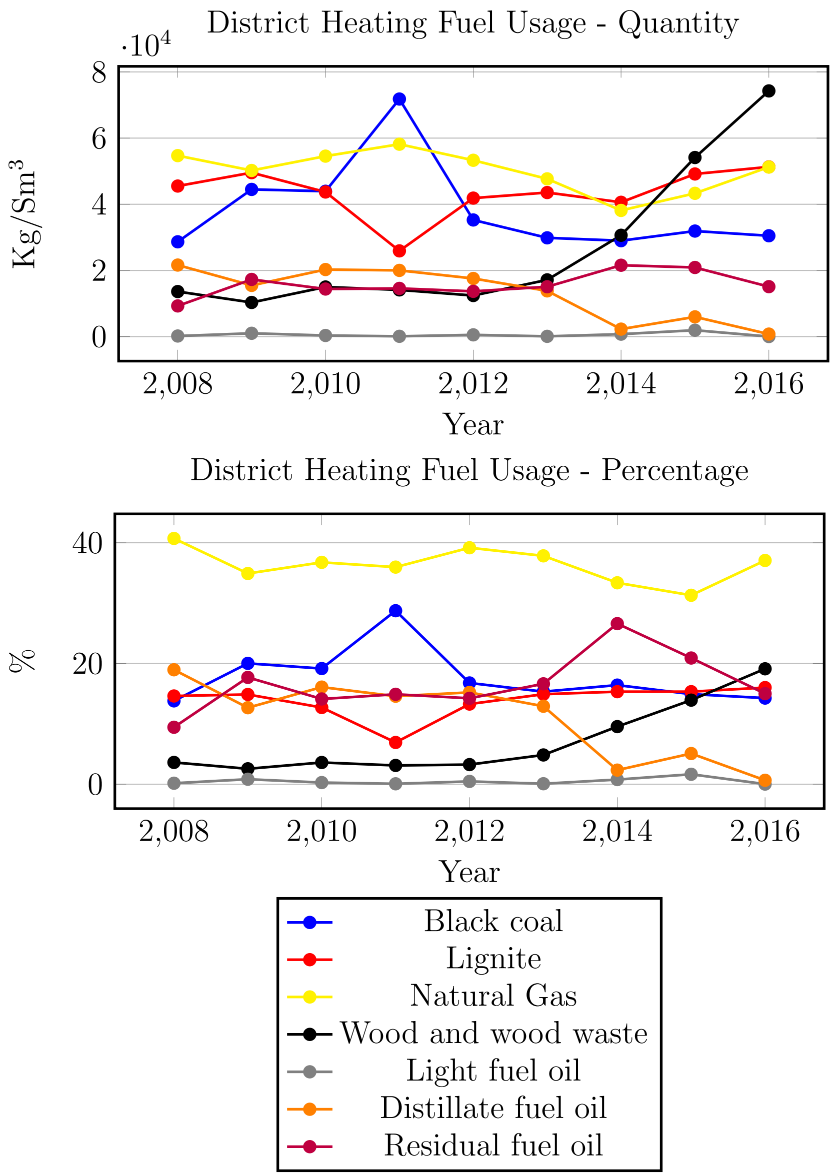


Figure 5: Statistics of heating fuel usage in Bosnia and Herzegovina from 2008-2016 [10] [11] [12] [13] [14] [15] [16] [17] [18]. Percentage of Heat was calculated by conversion formulas defined by the EPA [19].

2.1.6 Current Air Pollution Levels in Sarajevo

Statistics on air pollution levels in Sarajevo and Bosnia and Herzegovina as a whole are disjointed, unreliable, and at times misleading. Consistent and reliable data on historic air pollution levels does not exist making it hard to meaningfully compare the air quality situation in Sarajevo and to the past and find recent trends in air pollution.

In recent years, efforts have been made by the Federalni Hidrometeorloki Zvod to publish air quality data measured throughout the Federation of Bosnia and Herzegovina. However, this data is made available to the public in report form that is hard to use for any independent purposes and the reporting style can be inconsistent throughout different years [20]. Historic raw air pollution data is available through the EEA mandataed Exchange on Information decision (EoI) on Air web portal [21]. This portal hosts air pollution data in Bosnia and Herzegovina from the period of 2002-2012.

Several air pollution stations exist within the Sarajevo area. There locations are detailed in the Figure **??**.

Figure 6: Pollution station locations around Sarajevo [22]

The following figures detail the yearly averages, 98th percentiles, and maximums of PM10, SO2, CO, O3, and NO2 from each air pollution station in the Sarajevo

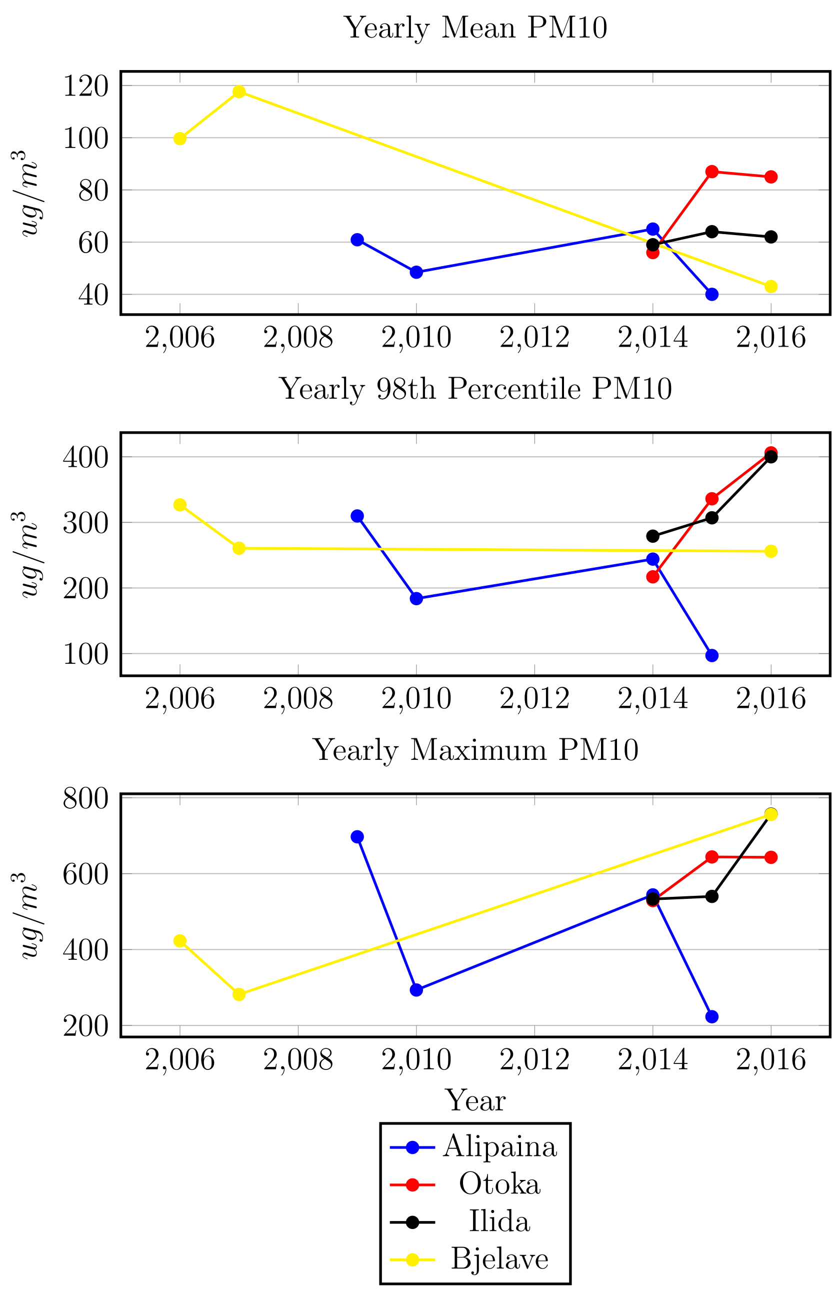


Figure 7: Available Yearly PM10 values for Sarajevo from the period of 2002-2016 [21][23][24][25].

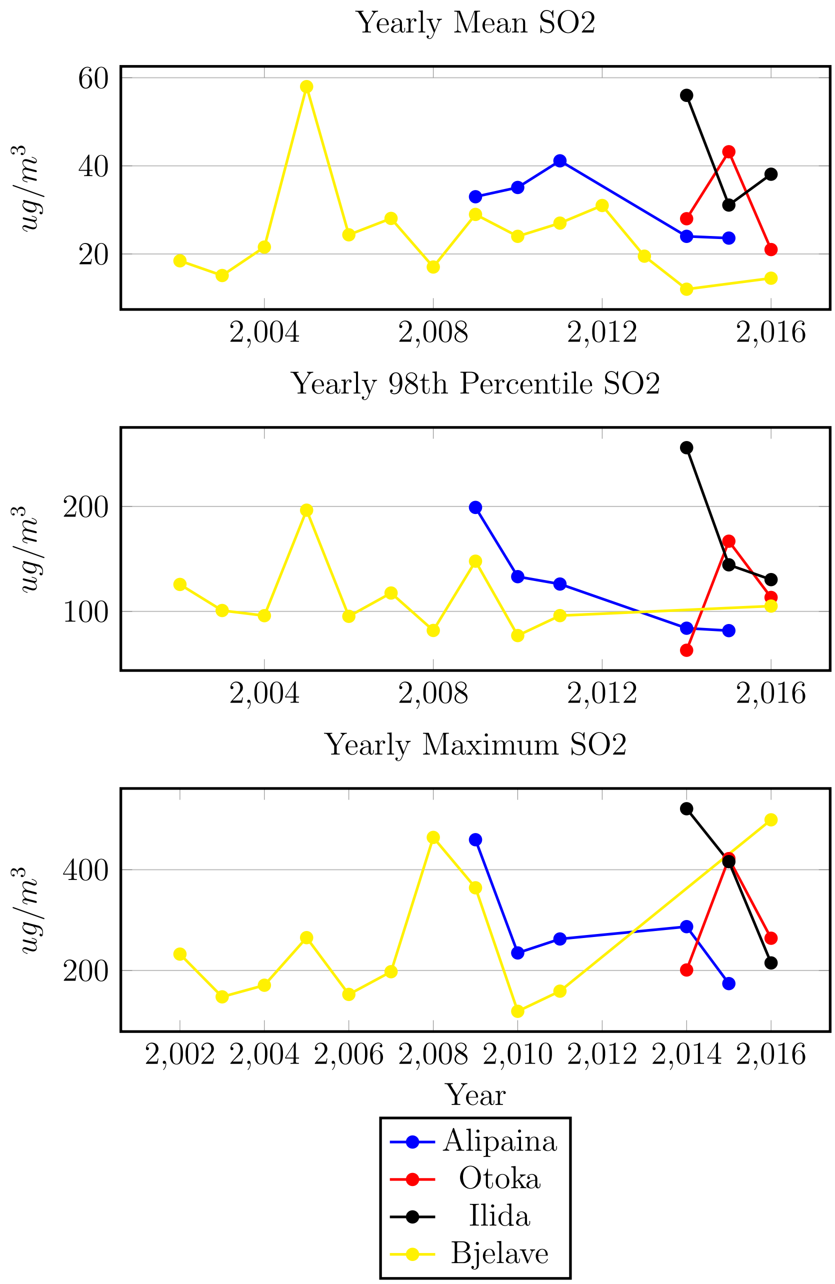


Figure 8: Available Yearly SO2 values for Sarajevo from the period of 2002-2016 [21][23][24][25].

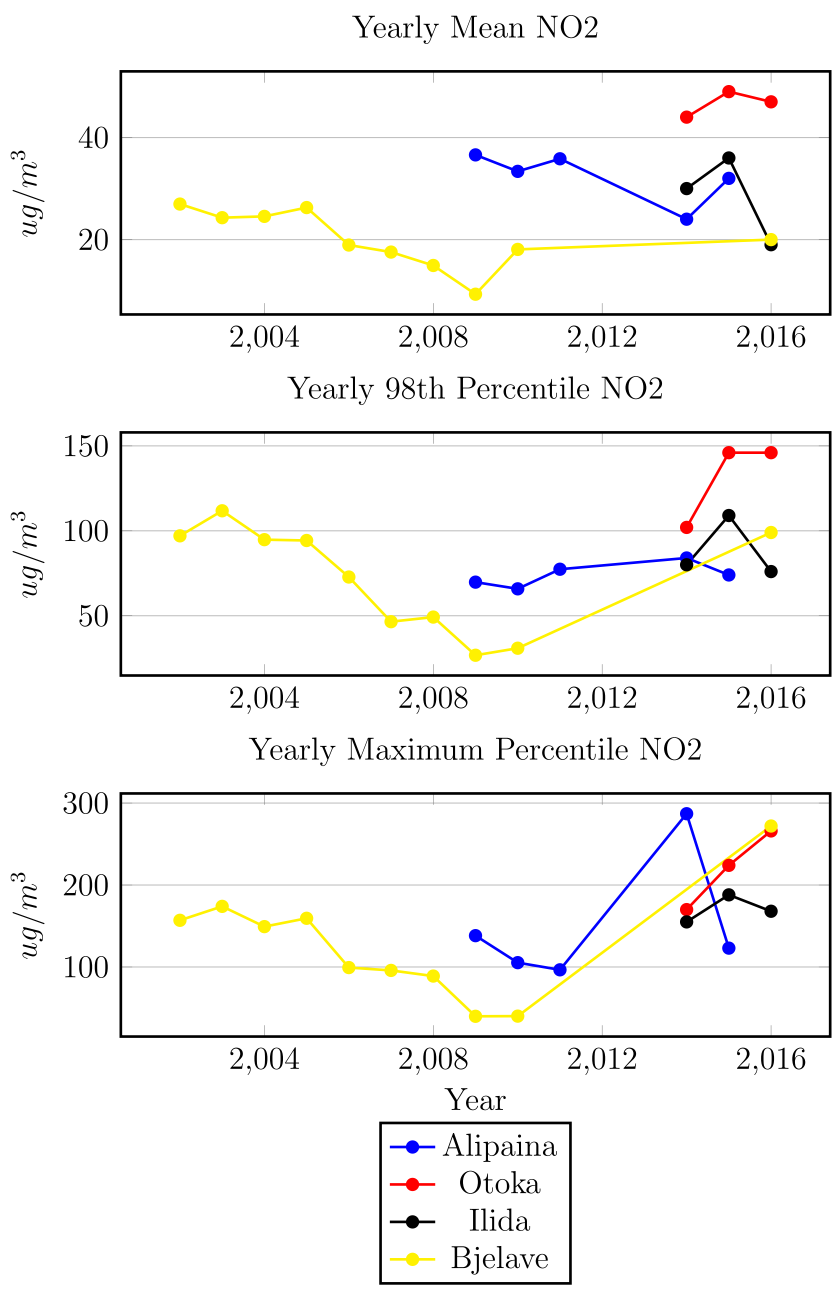


Figure 9: Available Yearly NO2 values for Sarajevo from the period of 2002-2016 [21][23][24][25].

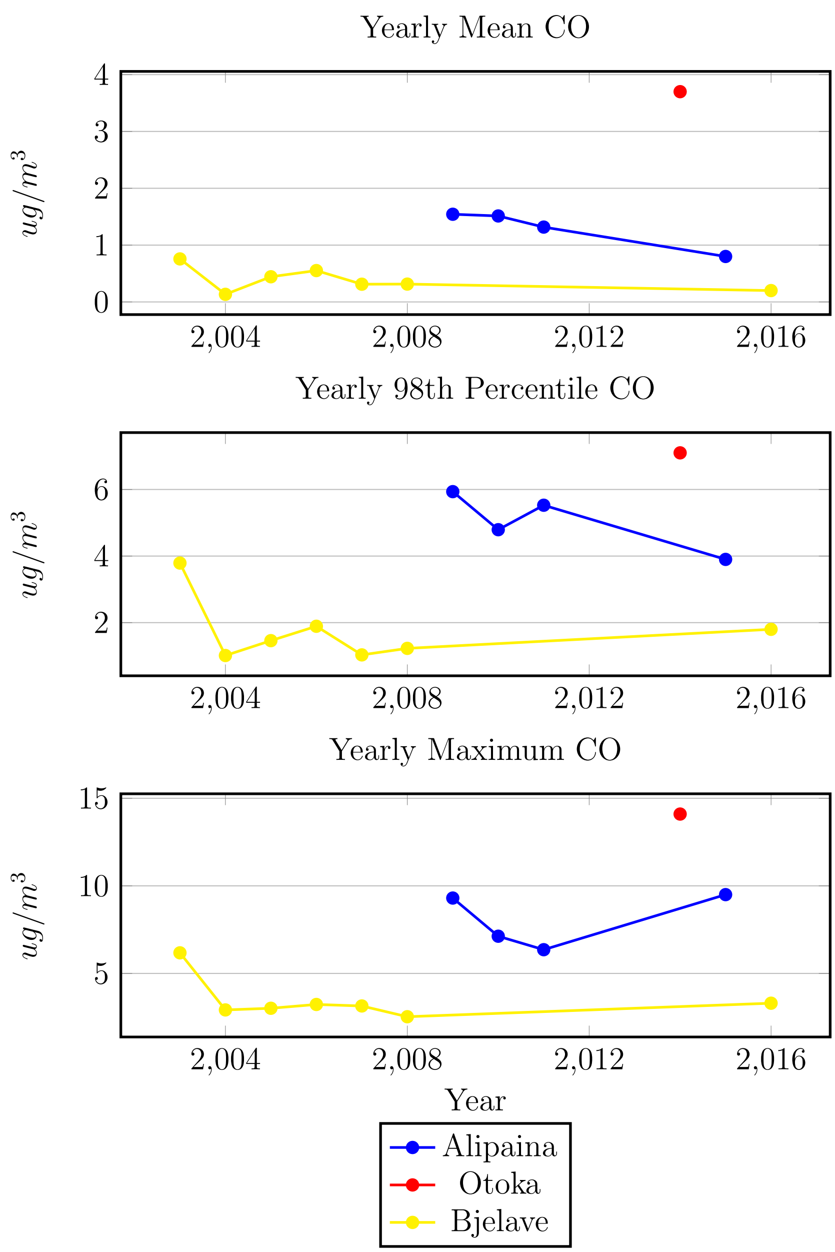


Figure 10: Available Yearly CO values for Sarajevo from the period of 2002-2016 [21][23][24][25].

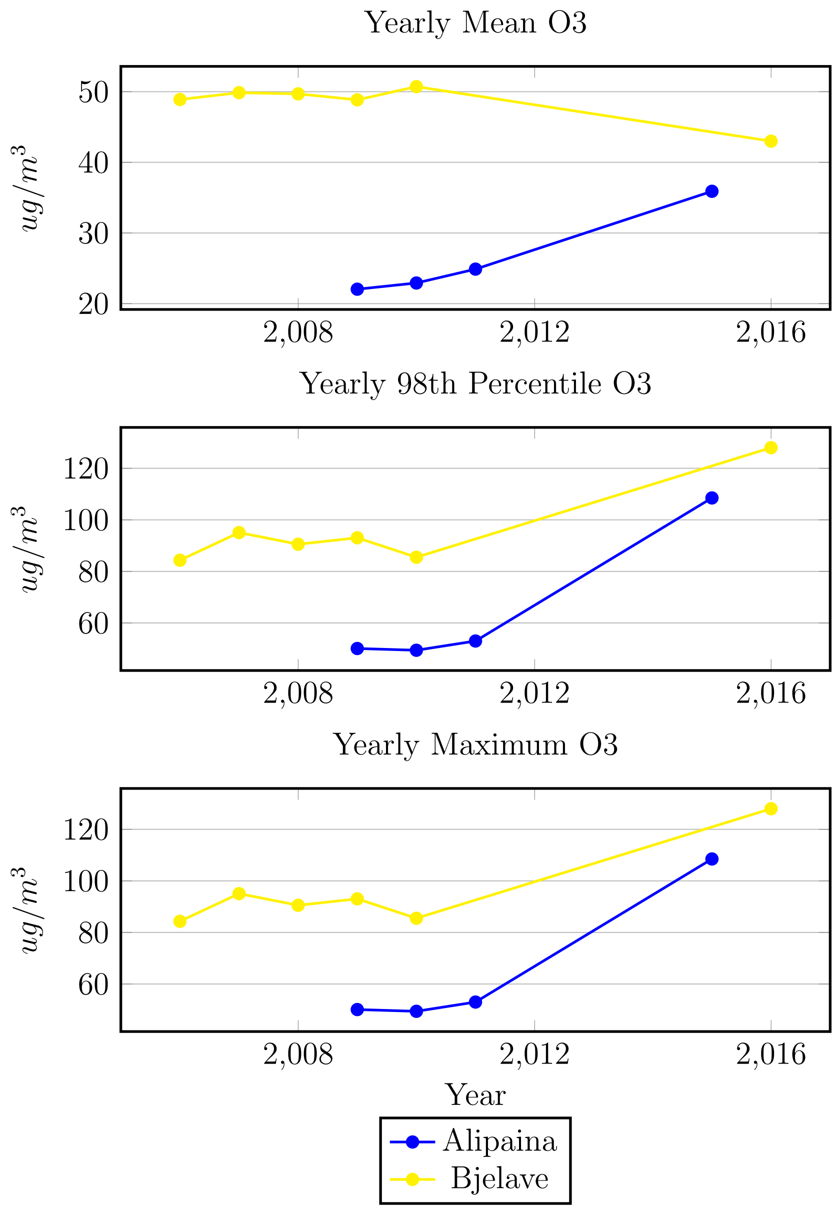


Figure 11: Available Yearly O3 values for Sarajevo from the period of 2002-2016 [21][23][24][25].

It is difficult to detect trends based on the data available from the past decade, however the following observations can be made.

- While average PM10 measurements seem to not be increasing, peak PM10 measurements are significantly increasing over the period of 2014-2016. This may be to the increased usage of wood and wood waste in district heating systems.

- SO2 measurements have generally been decreasing over the past decade.

- NO2 peaks have been increasing over the past decade. Possibly due to increased car traffic.

- Not enough data is available of CO emissions to accurately detect any trend.

- Measurements show a significant rise in the peak values of O3. This, like NO2, may be due to increased traffic.

2.2 Existing Open Source Air Pollution Sensors

A number of open source projects already exist that measure air quality using a variety of sensors. These projects give individuals a way to build their own air quality sensors using open source hardware such as Arduino and Raspberry Pi's. The following table shows the capabilities of these projects.

Project Name	**Hardware Used**	**Measurments**
PiAQ [26]	Raspberry Pi	Temperature, Humidity, Volatile Organic Compounds, CO2, Pressure, Light Intensity, CO, NO2, and Sound Intensity
LivPi [27]	Raspberry Pi	CO2, Temperature, Humidity, Air Pressure
AirPi [28]	Raspberry Pi	Temperature, Humidity, Pressure, light levels, smoke, CO, NO2
Sensly HAT [29]	Raspberry Pi	Broad range of amalgamated pollutants
Airbeam [30]	Arduino	PM2.5
AirOwl [31]	Arduino	PM2.5, and PM10
CityOs Air Boxy [4]	NodeMCU	Temperature, humidity, PM2.5, and PM10

Table 1: Different open source projects for measuring air quality.

These projects tend to focus of broad definitions of air quality that do not follow any specific standards or definitions on air quality. Some focus on metrics known to be particularly hazardous to human health such as particulate matter, while others use sensors that detect a wide range of pollutants that cannot be separated in to individual measurements. While these devices can be useful and add to available measured data, none of these devices can comprehensibly cover the wide range of measurements required to contribute or create a compatible dataset with various air quality indices such as the AQI.

2.3 Existing Open Source Air Pollution Projects

2.3.1 The Village Green Project

The Village Green Project is a community-based activity in the USA to demonstrate the capabilities of new real-time monitoring technology for res-

Figure 12: A Village Green Project station [32].

idents to learn about local air quality [32].

The goal of the project is to provide the public and communities with information previously not available about their local air quality and engage communities in air pollution awareness within the USA. Initially, a prototype system was developed to demonstrate the systems ability to monitor several common air pollutants in real-time and make the data available online. The system includes a solar and wind powered station that is also a park bench structure. This structure contains instruments that provide minute-to-minute air measurements for ozone, particle pollution and weather conditions.

The system is capable of measing fine particle pollution such as PM2.5, ozone, nitrogen dioxide, black carbon, total volatile organic compounds, wind speed, temperature, and humidity. The data collected by these sensors are streamed live on the web with minute by minute updates which any user can access around the world.

The data collected by Village Green stations is used in research to improve the understanding of air quality and increase community awareness of local air quality conditions. Due to the lower cost sensors used in Village Green stations, the measurements are not suitable for official air quality standards. However they are still suitable for research and educational purposes. They are particularly useful to see how air pollution changes in local areas with respect to time and whether.

2.4 Air Quality Indices

Country	**Air quality index name**	**Pollutants measured**
Canada	Air Quality Health Index (AQHI Canada) [33]	NO2, O3, and PM2.5
Hong Kong	Air Quality Health Index (AQHI Hong Kong) [34]	NO2, O3, SO2, PM2.5, and PM10
China	Air Quality Index (AQI)	NO2, O3, SO2, C0, PM2.5, and PM10
India	National Air Quality Index (NAQI) [35]	NO2, O3, SO2, NH3, Pb, PM2.5, and PM10
Singapore	Pollutant Standards Index (PSI)	NO2, O3, SO2, C0, PM2.5, and PM10
South Korea	Comprehensive Air-quality Index (CAI) [36]	NO2, O3, SO2, C0, PM2.5, and PM10
United Kingdom	Daily Air Quality Index (DAQI) [37]	NO2, O3, SO2, PM2.5, and PM10
Europe	Common Air Quality Index (CAQI) [38] European Air Quality Index (EAQI)	NO2, O3, SO2, C0, PM2.5, and PM10
United States	Air Quality Index (AQI)	NO2, O3, SO2, C0, PM2.5, and PM10

Table 2: Different metrics for measuring air quality around the world. [39]

Many different metrics for measuring air quality exist around the world. However, a common theme among the different metrics are the types of pollution that measured in order to generate an index value that can be widely understood by the public. The most common pollutants measured are Nitrogen Dioxide (NO2), Ozone (O3), Sulfur Dioxide (SO2), Carbon Monoxide (CO), suspended particulates smaller than 2.5 m in aerodynamic diameter (PM2.5), and suspended particulates smaller than 10 m in aerodynamic diameter (PM10).

2.4.1 The Air Quality Index (AQI)

What is the AQI? The AQI is a sliding scale index for reporting daily air quality that has a numerical and colour based system to convey the air quality and associated health effects of that air quality in a specific area. The five air pollutants that contribute to the calculation of the AQI are NO2, O3, SO2, CO, and PM2.5, and PM10 [40].

Air Quality Index (AQI) Values	Levels of Health Concern	Colors
When the AQI is in this range:	*..air quality conditions are:*	*...as symbolized by this color:*
0 to 50	Good	Green
51 to 100	Moderate	Yellow
101 to 150	Unhealthy for Sensitive Groups	Orange
151 to 200	Unhealthy	Red
201 to 300	Very Unhealthy	Purple
301 to 500	Hazardous	Maroon

Figure 13: AQI scaling system.

Figure 13 shows how the AQI sliding scales runs from 0 to 500, with a higher AQI value indicating a greater level of air pollution. The index follows a colour based system, with each colour representing a different health risk as seen in Figure 14.

Air Quality Index Levels of Health Concern	Numerical Value	Meaning
Good	0 to 50	Air quality is considered satisfactory, and air pollution poses little or no risk.
Moderate	51 to 100	Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people who are unusually sensitive to air pollution.
Unhealthy for Sensitive Groups	101 to 150	Members of sensitive groups may experience health effects. The general public is not likely to be affected.
Unhealthy	151 to 200	Everyone may begin to experience health effects; members of sensitive groups may experience more serious health effects.
Very Unhealthy	201 to 300	Health alert: everyone may experience more serious health effects.
Hazardous	301 to 500	Health warnings of emergency conditions. The entire population is more likely to be affected.

Figure 14: AQI colour code and associated health risks.

Why Use the AQI? The AQI and its derivatives are used by many countries around the world to report air pollution. The AQI comes with strict reporting guidelines that define not only the calculations required to generate an AQI score, but also health and at-risk groups based on the current AQI of an area. Technical specifications are easily accessible online [41]. This makes the AQI ideal for communicating to the public the current health risks relating to air pollution in a specific area.

Many of the specifications that define the AQI are also compatible with other air pollution indices. By requiring the measurment of a wide range of air pollutants, data measured in the calculation of the AQI can also be used to generate other European relevant indices such as the CAQI, and the EAQI.

Required Measurements for Calculating an AQI Table 3 describes the measurements required to generate an AQI. Averaging of results over time is required when generating the AQI. This is due to the specifications of the EPAs national air quality standards, otherwise known as the National Ambient Air Quality Standards (NAAQS) [42]. The NAAQS was developed using the extensive research into the effects of long term air pollution on human beings. The AQI compiles with the NAAQS.

Pollutant	**Time Period/Averaging**
Ozone (*ppm*)	1-hour
Ozone (*ppm*)	8-hours
PM2.5 (ug/m^3)	24-hours
PM10 (ug/m^3)	24-hours
Carbon Monoxide (*ppm*)	8-hours
Sulfur Dioxide (*ppb*)	1-hour
Sulfur Dioxide (*ppb*)	24-hour
Nitrogen Dioxide (*ppb*)	1-hour

Table 3: Different metrics for measuring air quality around the world. [39]

For information on calculating and reporting an AQI with measured pollutant concentrations, please refer to Appendix A.0.1.

2.4.2 The European Air Quality Index (EAQI)

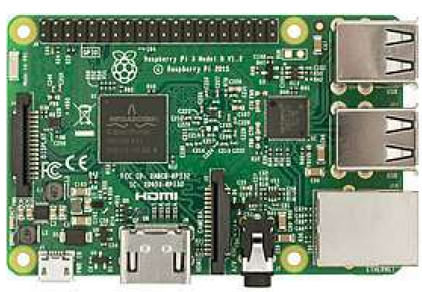
The European Air Quality Index (EAQI) was launched in late 2017 as an effort to provide up to date air quality information across all EEA member countries. It provides a way to easily compare air quality across much of continental Europe. The EAQI converts air quality measurements to a simple colour coded system enabling users to quickly understand the quality of the air in their area. An interactive map allows users to view individual air quality measurements at a station by station level across Europe [43]. The index and its colour coded system are based on the EU Ambient Air Quality Directive of 2008 [44]. While the EAQI is calculated differently to that of other indices such as the AQI, the core measured pollutants that appear to reported among participating countries are NO2, O3, SO2, CO, and PM2.5, and PM10 [45]. With these measurements, it is possible to both calculate the EAQI and AQI from the same dataset.

3 Proposed Design

The proposed design will be a modular air quality station with the ability to measure all pollutants required to calculate an AQI. The design fully assembled will measure SO2, NO2, CO, O3, PM2.5, PM10, temperature, and humidity. The modularity of the design will allow less sensors to be used if required. The design will utilise a Raspberry Pi as to provide a good capability to expand the project in the future to include other measurements and features such as wind speed, wind direction, remote connectivity, and solar powered operation. The design will be calibrated against an air pollution station utilising an approved reference method in order to improve measurement accuracy. The design will be capable of uploading result immediately to an external database so results can be viewed in real time. The design will be entirely open source.

Further additions to the design, such as cellular connectivity, and wind speed and direction sensors will be designed to use the Raspberry Pi USB connections. Scope for the sensor station being solar and battery powered will be explored.

The design will keep in mind the possibility of emulating projects such as The Village Green Project. This includes the placing of sensors in public seating and other open public areas. A prime candidate for this are the public seats installed around Sarajevo by QBen [46].



(a) Figure A

(b) Figure B

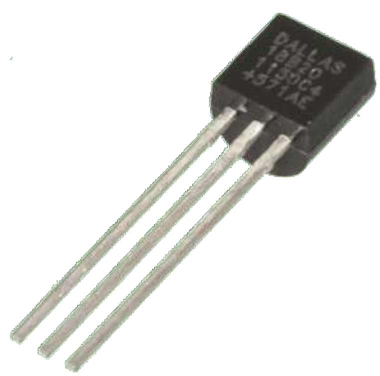
Figure 15: A: A Raspberry Pi. B: A Raspberry Pi with HAT installed.

3.1 Sensors

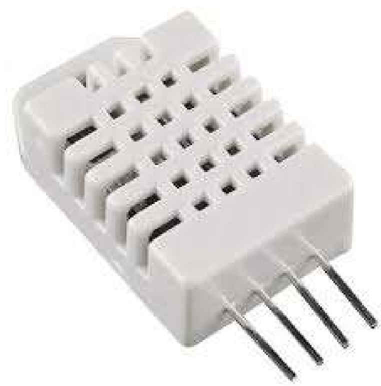
The CO, NO2, O3, and SO2 sensors for the design will be sourced from Spec Sensors [47]. The PM2.5/PM10 sensor will be a HPM series sensor sourced from Honeywell [48]. The Maxim Integrated DS18B20 temperature sensor will be used for calibration purposes, and the DHT22 sensor will be used for outside enclosure temperature and humidity. Due to the single serial interface on the Raspberry Pi, a SN74HC151N logic multiplexer will be used to enable all sensors to communicate with the Raspberry Pi.

(a) Spec Sensor digital CO sensor

(b) Honeywell HPM series digital particle sensor.



(c) DS18B20 digital temperature sensor.



(d) DHT22 digital temperature and humidity sensor.

Figure 16: Sensors used in the proposed design.

3.2 Construction

A PCB for the HAT will be designed and printed. Initially, this HAT will be designed to be mounted directly on the Raspberry Pi with sensors on board. The sensors will be mounted on the HAT using connectors allowing easy installation, de-installation, and hot-swapping of faulty sensors. This HAT will also be able to be externally connected to the Raspberry Pi instead of being directly mounted. This will ensure that more accurate pollution measurements can take place due in the future due to less CPU caused sensor temperature variances.

The case for the unit must be able to hit a HAT mounted Raspberry Pi inside and still have good ventilation properties.

3.3 Design Performance Criteria

The design will be that of an indicative air pollution sensor, and thus will not be completely accurate. The design aims to be within a tolerance of +-30% in comparison to a reference method air pollution station operating in similar conditions. The design will be of a strong construction to ensure that down time of the sensor will be kept to a minimum.

To ensure this criteria is met, calibration of the units will be performed. This calibration will take place in one of two ways. The first involves having a unit referenced to a reference method air pollution station. The second involves place the unit in an environment known to have absolutely no pollutants with a specific temperature. The method of calibration will be decided based on the availability of the specific method.

3.4 Project Schedule

The following Gantt chart describes a tentative schedule for the project. Design work can be completed while waiting for parts to arrive. Once various components arrive after being ordered, testing can be conducted. As soon as the HAT PCB is ordered, printed, and recieved, calibration can be performed in the field. A generous time buffer of one month has been allocated to account for any time delays.

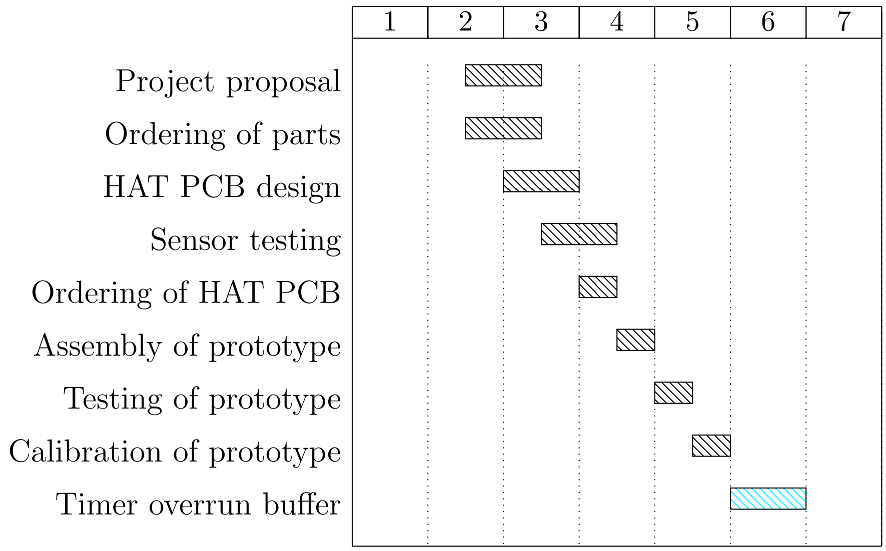


Figure 17: A Gantt chart of the proposed project schedule.

3.5 Overall Project Expectations

By the end of the project, it is hoped that an affordable indicative air pollution sensor has been developed that is capable of measuring trends in air pollution within Bosnia and Herzegovina. It is hoped that in the future this sensor will be able to be constructed on scale in order to provide a network of sensors within Bosnia and Herzegovina. It is also hoped that the data collected from this network of sensors can be used to convey to the broader public the issues that Bosnia and Herzegovina faces in regards to air quality, and that trends in air pollution can better be detected in the future.

A Appendix

A.0.1 Calculating an AQI

The AQI of an area is determined by calculating the individual AQI of each pollutant. The highest AQI of all the pollutants measured determines the overall AQI for a specific area. Keeping this in mind, the following steps will calculate the individual and overall AQI of an area:

$$I_p = \frac{I_H - I_L}{BP_H - BP_L)}(C_p - BP_L) + I_L \tag{1}$$

Where:

C_p is truncated concentration of pollutant p

BP_H is the concentration breakpoint that is greater than or equal to C_p

BP_L is the concentration breakpoint that is less than or equal to C_p

I_p is index for pollutant p

I_H is the AQI value corresponding to BP_H

I_L is the AQI value corresponding to BP_L

C_p is truncated concentration of pollutant p

1: The AQI Equation

- Define truncated pollutant measurments for all concentrations in in accordance to Table 4.

Pollutant	**Truncate to...**
Ozone (*ppm*)	3 decimal places
PM2.5 (ug/m^3)	1 decimal place
PM10 (ug/m^3)	Integer
Carbon Monoxide (*ppm*)	1 decimal place
Sulfur Dioxide (*ppb*)	Integer
Nitrogen Dioxide (*ppb*)	Integer

Table 4: Truncation values for each pollutant measurement in AQI calculation

- Using the truncated concentrations, define B_L and B_H from Equation 1 by finding the low and high breakpoints that the truncated fall between for each pollutant in Table 5.

O_3 (ppm) $8hours$	O_3 (ppm) $1hour$	$PM_2.5$ (ug/m^3) $24hours$	PM_10 (ug/m^3) $24hours$	CO (ppm) $8hours$	SO_2 (ppb) $1hours$	SO_2 (ppb) $24hours$	NO_2 (ppb) $1hour$	AQI	Catergory
B_L=0.000 B_H=0.054	-	B_L=0.0 B_H=12.0	B_L=0 B_H=54	B_L=0.0 B_H=4.4	B_L=0 B_H=35	-	B_L=0 B_H=53	I_L=0 I_H=50	Good
B_L=0.055 B_H=0.070	-	B_L=12.1 B_H=35.4	B_L=55 B_H=154	B_L=4.5 B_H=9.4	B_L=36 B_H=75	-	B_L=54 B_H=100	I_L=51 I_H=100	Moderate
B_L=0.071 B_H=0.085	B_L=0.125 B_H=0.164	B_L=35.5 B_H=55.4	B_L=155 B_H=254	B_L=9.5 B_H=12.4	B_L=76 B_H=185	-	B_L=101 B_H=360	I_L=101 I_H=150	Unhealthy for Sensitive Groups
B_L=0.086 B_H=0.105	B_L=0.165 B_H=0.204	B_L=55.5 B_H=150.4	B_L=255 B_H=354	B_L=12.5 B_H=15.4	B_L=186 B_H=304	B_L=186 B_H=304	B_L=361 B_H=649	I_L=151 I_H=200	Unhealthy
B_L=0.106 B_H=0.200	B_L=0.205 B_H=0.404	B_L=150.5 B_H=250.4	B_L=355 B_H=424	B_L=15.4 B_H=30.4	B_L=305 B_H=604	B_L=305 B_H=604	B_L=650 B_H=1249	I_L=201 I_H=300	Very un-healthy
-	B_L=0.405 B_H=0.504	B_L=250.5 B_H=350.4	B_L=425 B_H=504	B_L=30.5 B_H=40.4	B_L=605 B_H=804	B_L=605 B_H=804	B_L=1250 B_H=1649	I_L=301 I_H=400	Hazardous
-	B_L=0.505 B_H=0.604	B_L=350.5 B_H=500.4	B_L=505 B_H=604	B_L=40.5 B_H=50.4	B_L=805 B_H=1004	B_L=805 B_H=1004	B_L=1650 B_H=2049	I_L=405 I_H=500	Hazardous

Table 5: Truncation values for each pollutant measurement in AQI calculation

- Use Equation 1 to calculate the AQI for each polluntant, rounding to the nearest integer.
- Find the highest AQI from all pollutants.

A.0.2 Required Information for Reporting AQI

Due to the 24 hour averaging of particulate matter measurements such as PM2.5 and PM10, a full 24 hours is required in order to generate an AQI value. Particulate matter is often averaged over the short and long term in order to smooth out transient sources of pollution. When reporting an AQI, the following information is mandatory:

- Reporting area
- Reporting period
- Pollutant with the highest AQI
- Overall AQI value
- Category descriptor with colour
- The sensitive groups for all pollutants with an AQI over 100. Table 6]

When this pollutant has an AQI above 100...	**Report these Sensitive Groups**
Ozone	People with lung disease, children, older adults, people who are active outdoors (including outdoor workers), people with certain genetic variants, and people with diets limited in certain nutrients are the groups most at risk
PM2.5	People with heart or lung disease, older adults, children, and people of lower socioeconomic status are the groups most at risk
PM10	People with heart or lung disease, older adults, children, and people of lower socioeconomic status are the groups most at risk
CO	People with heart disease is the group most at risk
NO2	People with asthma, children, and older adults are the groups most at risk
SO2	People with asthma, children, and older adults are the groups most at risk

Table 6: Pollutant-Specific Sensitive Groups

Other information can be added to the reporting of an AQI. This additional information can be as follows:

- Forecast and all current AQI values.
- Health effects and cautionary statements for pollutants with high AQI's
- Potential causes for unusual AQI values
- The AQI for nearby areas of the reporting area

- Pollutant concentrations
- Name and AQI for other pollutants, particularly those with an AQI greater than 100

AQI Colour Code The following table describes the precise colour assigned to each colour code in the AQI.

Color	R	G	B	C	M	Y	K
Green	0	228	0	40	0	100	0
Yellow	255	255	0	0	0	100	0
Orange	255	126	0	0	52	100	0
Red	255	0	0	0	100	100	0
Purple	143	63	151	51	89	0	0
Maroon	126	0	35	30	100	100	30

A.0.3 Bosnia and Herzegovina Air Pollution Targets in 2016

	Granična vrijednost				Tolerantna vrijednost				Prag upozorenja	Prag uzbune
	1h	8h	24h	god.	1h	8h	24h	god	1h	1h
SO_2 (sumpor-dioksid) (μg/m³)	350		125	50	425 - 2016 410 - 2017 395 - 2018 380 - 2019 365 - 2020 350 - 2021		125	50	425 - 2016 410 - 2017 395 - 2018 380 - 2019 365 - 2020 350 - 2021	500
NO_2 (azotdioksid) (μg/m³)	200	-	85	40	250 - 2016 240 - 2017 230 - 2018 220 - 2019 210 - 2020 200 - 2021		105 - 2016 101 - 2017 97 - 2018 93 - 2019 89 - 2020 85 - 2021	50 - 2016 48 - 2017 46 - 2018 44 - 2019 42 - 2020 40 - 2021	250 - 2016 240 - 2017 230 - 2018 220 - 2019 210 - 2020 200 - 2021	400
CO (ugljični monoksid) (mg/m³)	-	10	5	3	-	10	5	3	-	-
O_3 (prizemni ozon) (μg/m³)	-	120	-	-	-	-	-	-	180	240
Suspendovane / lebdeće čestice (PM10) (μg/m³)	-	-	50	40	-	-	65 - 2016 62 - 2017 59 - 2018 56 - 2019 53 - 2020 50 - 2021	44 - 2016 43 - 2017 42 - 2018 41,5 - 2019 41 - 2020 40 - 2021	-	-
Suspendovane / lebdeće čestice (PM2,5) (μg/m³)	-	-	-	25	-	-	-	27,5 - 2016 27 - 2017 26,5 - 2018 26 - 2019 25,5 - 2020 25 - 2021	-	-

Figure 18: Air pollution targets for 2016 in the Federation of Bosnia and Herzegovina [22].

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