Impetus

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Innovative Measurement Tool towards Urban Environmental Awareness

Drones

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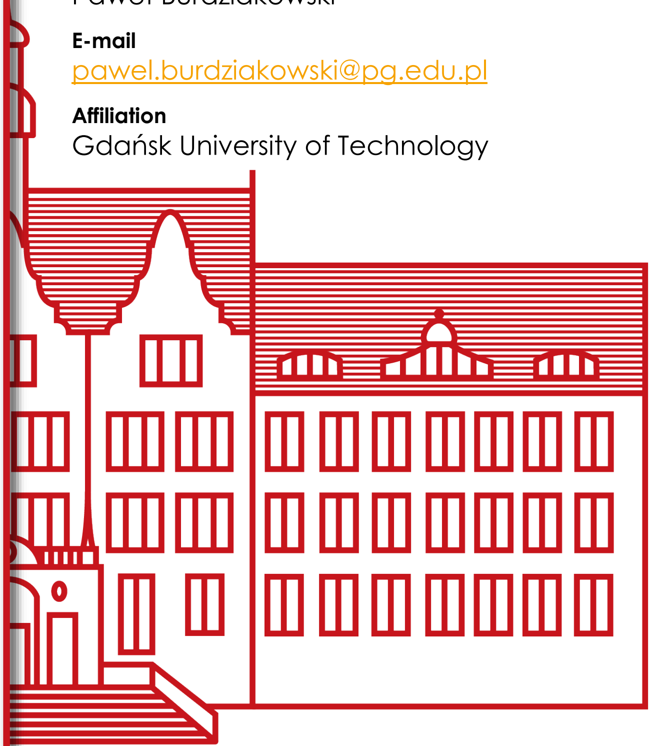

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1.1 The aim and introduction

Air pollution is not a recent phenomenon - it has always existed, but before that it was only due to natural causes in the environment. Later on, pollution was also caused by humans, but it was not significant and noticeable in the long run. Over the past centuries, different industries started to develop at different speeds. People thought about how to make a certain thing or improve it without considering the long-term effects. The Industrial Revolution that began in the 18th century saw the growth and transformation of existing industries and the creation of new offshoots. It was hard not to notice the already existing problem of air pollution. It is only since a relatively short period of time, when the cleanliness of the air deteriorated severely and the predictions for the coming years were critical, that there has been a significant increase in interest in the subject of smog and a closer look at it. For the past few decades, there has been thorough testing of pollutants in the air and strict restrictions have been put in place. Recent years have also been a period of rapid technological development, with innovative solutions being sought more intensively to improve the situation.

Particulate matter is a mixture of liquid and solid particles suspended in the air. These particles are of natural origin, such as sea salt aerosols or Sahara sand clouds, or of anthropogenic origin, such as pollution along traffic routes. Commonly used indicators are described as PM (particulate matter), indicating the content of dust with a diameter equal to or smaller than the number given in the name in micrometres. Due to the size of the fraction, it is mostly divided into PM10 and PM2.5, sometimes PM1 is also distinguished here. PM10 (particulate matter 10) are particles with a diameter of up to 10 µm. It is suspended in the air for up to several hours and consists, depending on the conditions of formation, of small particles of smoke, ash, soot, inorganic compounds such as asbestos. It is mainly formed in the combustion processes of liquid and solid fuels. Wind helps to carry and lift the particles from industrial and utility chimneys, bare soil, unpaved roads or mines. Traffic also contributes, creating dust and air turbulence.

The aim of this procedure is to describe and specify the steps for mobile air pollution (PM10, PM2.5), temperature and humidity measurements.

The measurements can be carried out either by mobile sensor attached to ground vehicle (bicycle, car, scooter) or aerial vehicle (drone). The mobile sensor is self-sustainable and do not require any external data output. Based on collected environmental data the three dimensional visualizations and spatial maps are created. The maps allow for innovative detection of heat sources, suspended dusts (smog), which contributes to the improvement of the atmosphere.

1.2 Indication of the area to be measured

The aim of this section is to point the right procedure for data collection within the specified area. The mobile measurements are to be adapted to the type of the area, human and technical resources. As the pollution harms humans at the breathing level (up to 2 meters) the measurement tool can be attached to the bicycle or backpack. By walking or riding the area of interest the parameters can be measured. The aerial measurements are very useful for large area and source seeking, as the source is usually at the chimney level (15-25 m).

The procedure covers following use cases for data collection:

- the air pollution source seeking within urban area (housing estate) (ground, aerial),
- the single air pollution source investigation (ground, aerial),
- the heat source detection (ground, mobile).

1.3 The air pollution source seeking

The air pollution source seeking case is intended for searching the source of air pollution, mainly in the area of single-family buildings (detached houses). In such areas it often happens that individual households have outdated burning stoves, in which solid materials such as wood, coal or often waste are burnt. In this case, particulate matter is released into the air, the source of which can be identified on the basis of the map. In this case, an aerial measurement using a drone can be used for the measurement, alternatively a mobile measurement can be successfully performed from the ground by placing the sensor on a bicycle or backpack.

Aerial measurement

The aerial measurement is based on single grid flight plan (Figure 1.1).

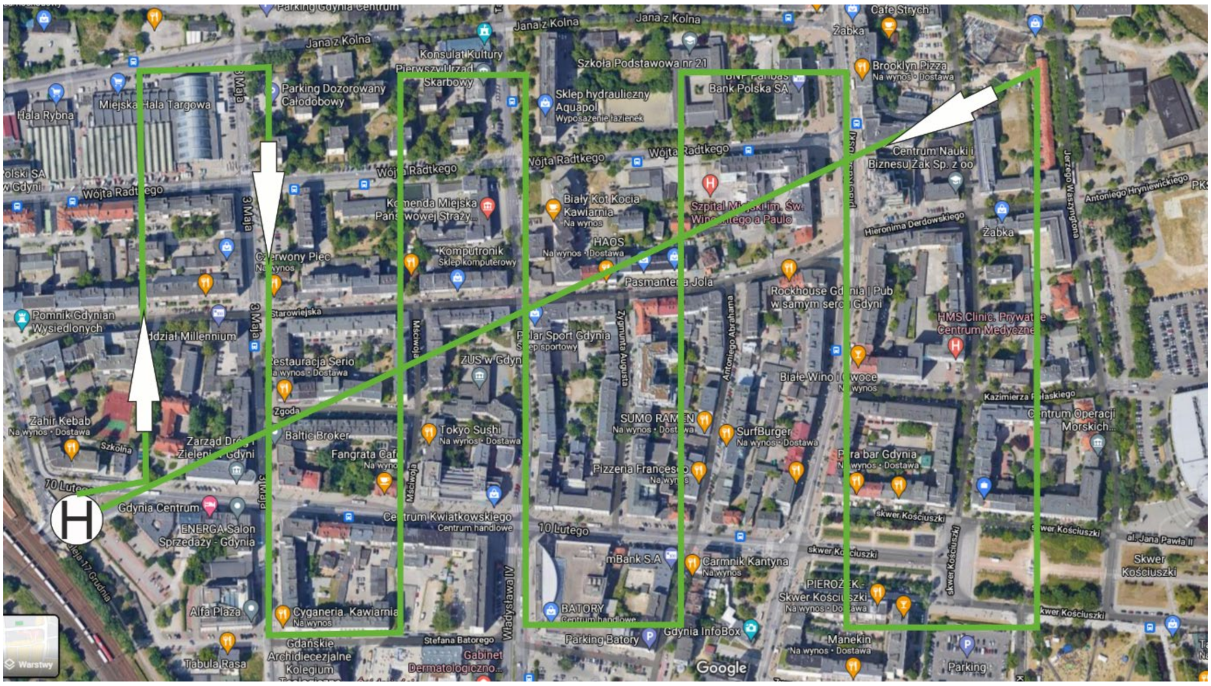

Figure 1.1. Single grid flight plan.

A single grid plan is used to regularly monitor the situation in an area. The flight plan must be programmed into the UAV system in accordance with the UAV operating manual. The flight altitude should be chosen according to the local airspace conditions, but possibly a dozen or so meters above the highest buildings.

The execution of the flight starts at the place of take-off and landing (H). The UAV performs the flight along a pre-programmed route while recording pollution sensor readings. After landing, data is downloaded and archived.

Ground measurement

Mobile ground measurements, alternatively, can be used to measure pollution in a designated area and to regularly monitor the situation in the area. For mobile measurements you can use any means of transport such as bicycle, scooter, scooter, or place the sensor on a backpack and make measurements while walking.

The realization of the measurement starts at the starting point (S) and ends at the ending point (E) (Figure 1.2). After starting the sensor, move the sensor around the measurement area. Track density and length should be adjusted to local conditions and availability of a convenient transportation route.

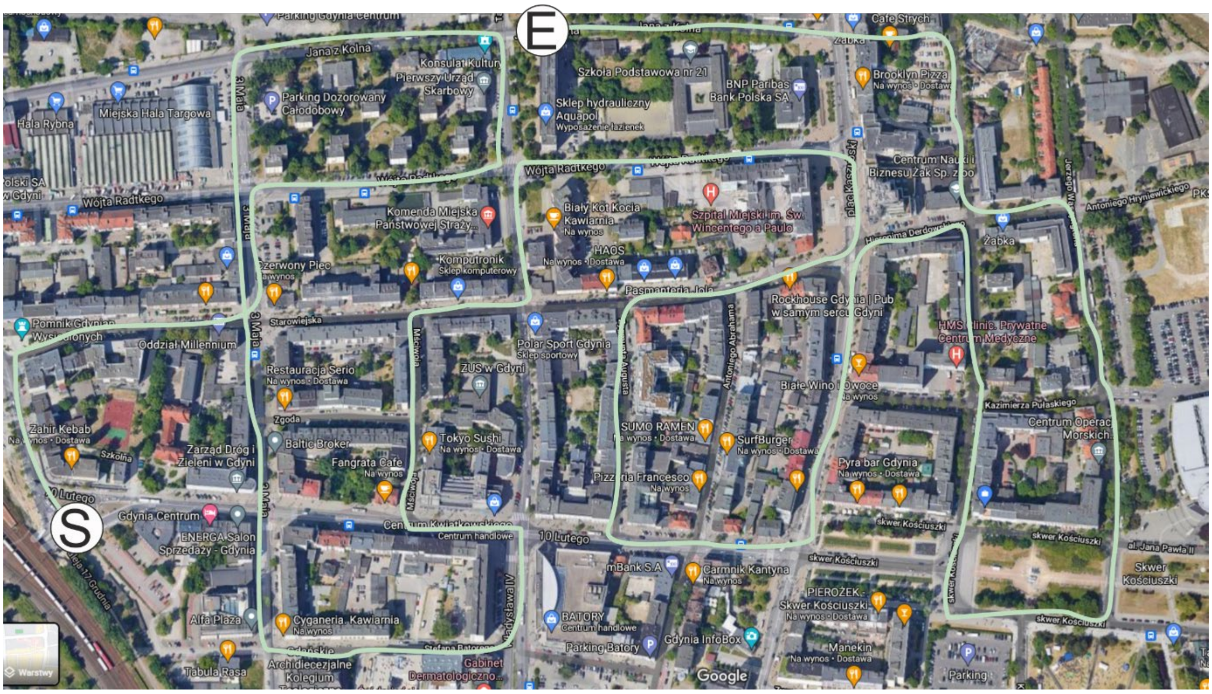

Figure 1.2. Ground measurement patch - example.

1.4 The single air pollution source investigation

In some situations, there is a need to verify a detected or known source of contamination, such as a single house, factory, or chimney. Such a measurement is based on cyclic circling of a known source position. During this time, samples are collected and readings taken by the sensor, from which the composition and concentration of the contaminant can be determined.

The flight starts at the starting point (H) (Figure 1.3). The operator arrives at the measurement location in a straight line flight and circles the position several times. During this time the readings are recorded.

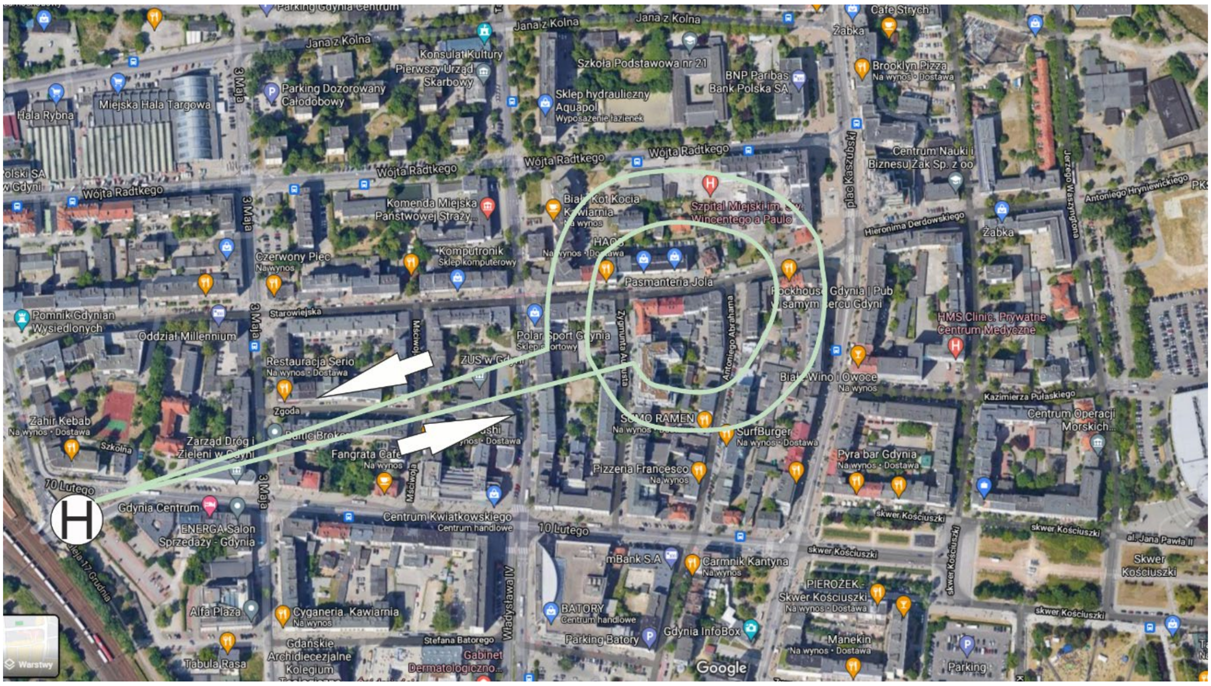

Figure 1.3. Single pollutant data collection.

1.5 The heat source detection

Measurement of heat sources is analogous to measurement of air pollution. It should be noted that in an urban area, ground-based measurement will be the preferred measurement technique. The sensor records air temperature simultaneously with other parameters, which can be used to visualize potential heat islands and heat sources in the area.

1.6 Sensor description and manual

Figure 1.4. Air pollution sensor.

Air pollution sensor is a device that records the measurement of pollution, air temperature, atmospheric pressure and humidity. Each measurement is tagged with a GPS position so that the measurement location can be tracked. Additionally, the sensor records measurement time and GPS status (number of satellites). The sensor is equipped with an inlet tube, through which the tested air flows. Do not cover this tube or block the access of air to this inlet tube. In addition, please note that the sensor must not be covered or in any other way covered, which will prevent the GPS signal from being received.

The best place to mount the sensor is on a bike rack, backpack, carrying in hand or mounting on a drone.

Procedure:

1. Connect the power supply.
2. Make sure the SD card is in the slot.
3. Check SD card status (see: LED status 1, 2).
4. Wait for the internal GPS to receive satellite signal (see: LED status 3).
5. Enable recording – long press on the button (see: LED status 4).
6. Perform measurement.
7. Turn off recording – long press on the button (see: LED status 5).

Other functions:

1. Recording for 15 seconds – two short button presses.
2. Recording every 3-4 seconds: continuous button presses.

Table 1.1. Air pollution sensor LED status.

No.	Red LED	Green LED	Status
1	On	On	No SD Card
2	1 blink/Off	Off	SD card OK
3	Off	On	GPS Fix OK
4	On		Recording data
5		Blinking	GPS signal invalid

1.7 Collection of validation data

Validation of the mobile sensor data is done by comparing the data with reference data. The reference sensor can be another measuring station. In mobile measurements, the sensor correction can be determined by stationary measurement in the vicinity of the reference sensor of another station. The reading is calibrated by establishing a constant correction (difference) between the mobile sensor and the reference sensor. The reference measurement is read online, from data presented by the owner of the reference sensor.

A map of reference sensors is available at airly.org or other local national service presenting values online.

1.8 Archiving of data and export to spatial information systems

The sensor with which the information is collected saves the data on the SD card in a .txt file. The data is semicolon separated, so it is easy to import into spatial information systems or other software. A sample data file is shown in the Table 1.2.

Table 1.2. File structure - example.

```
SAT;Lat;Lgn;alt_amsl;spd_kph;Date;Time;Press;Hum%;Temp.C;PM2.5;PM10
12;54.339680;18.360588;113.50;0.05;2019/5/30;20:4:31;1009.13;49.79;19.98;11.50;30.00
12;54.339680;18.360588;113.70;0.09;2019/5/30;20:4:32;1009.16;49.69;19.99;11.50;30.60
12;54.339680;18.360588;113.90;0.17;2019/5/30;20:4:33;1009.12;49.59;19.99;11.50;31.00
12;54.339680;18.360588;114.20;0.04;2019/5/30;20:4:34;1009.14;49.50;20.00;11.50;30.80
12;54.339680;18.360588;114.50;0.10;2019/5/30;20:4:35;1009.13;49.41;20.01;11.50;33.30
12;54.339680;18.360588;114.90;0.10;2019/5/30;20:4:36;1009.14;49.31;20.02;11.60;35.10
12;54.339680;18.360588;115.20;0.08;2019/5/30;20:4:37;1009.12;49.22;20.02;11.70;35.70
12;54.339676;18.360588;115.50;0.03;2019/5/30;20:4:38;1009.14;49.14;20.04;11.80;36.20
12;54.339676;18.360588;115.70;0.39;2019/5/30;20:4:39;1009.12;49.10;20.03;11.70;35.20
12;54.339668;18.360592;115.70;2.53;2019/5/30;20:4:40;1009.14;49.03;20.05;11.70;35.60
```

The data in the file is sorted into appropriate columns. The Table 1.3 shows the meaning of each column.

Table 1.3. Data description.

SAT	number of visible GNSS satellites
Lat	latitude according to WGS 84
Lgn	longitude according to WGS 84
alt_amsl	ellipsoidal altitude
spd_kph	speed in km/h
Date	measurement date
Time	measurement time
Press	atmospheric pressure
Hum%	humidity
Temp.C	air temperature
PM2.5	particulate matter 2.5
PM10	particulate matter 10

Archiving data involves placing the file in a new, created directory on your computer or on a dedicated server. Change the name of the file to a new one, starting with the name of the region and the date of measurement.

In order to import data into a spatial information system add new layer based on text delimited data. In QGIS software it is a place in menu Layer→Add Layer→Text Delimited Layer.

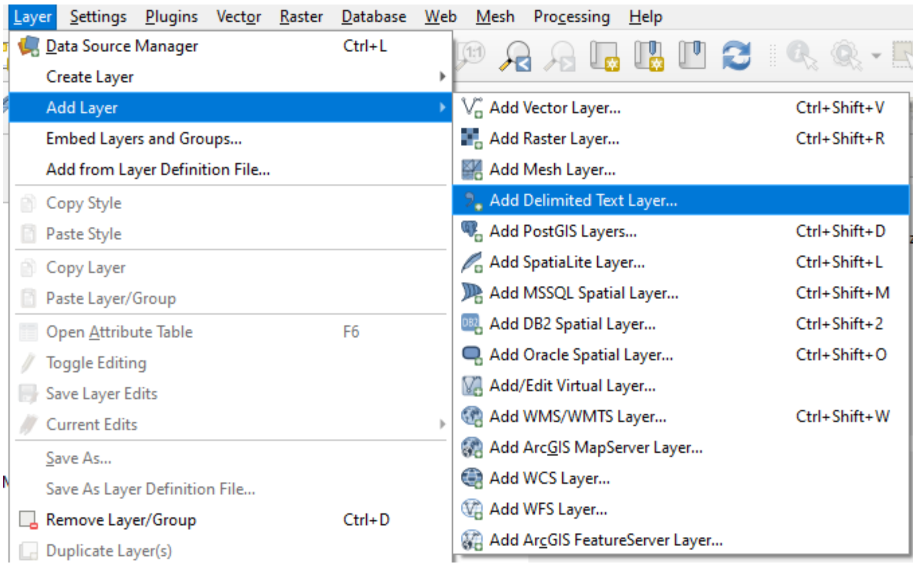

Figure 1.5. Adding new layer based on delimited text file.

This function will open a window (Figure 1.6) where we can set all the relevant data for import. If you are not familiar with QGIS, later in this manual you will find a link to a video showing in detail all the steps, i.e. how to import data and display it.

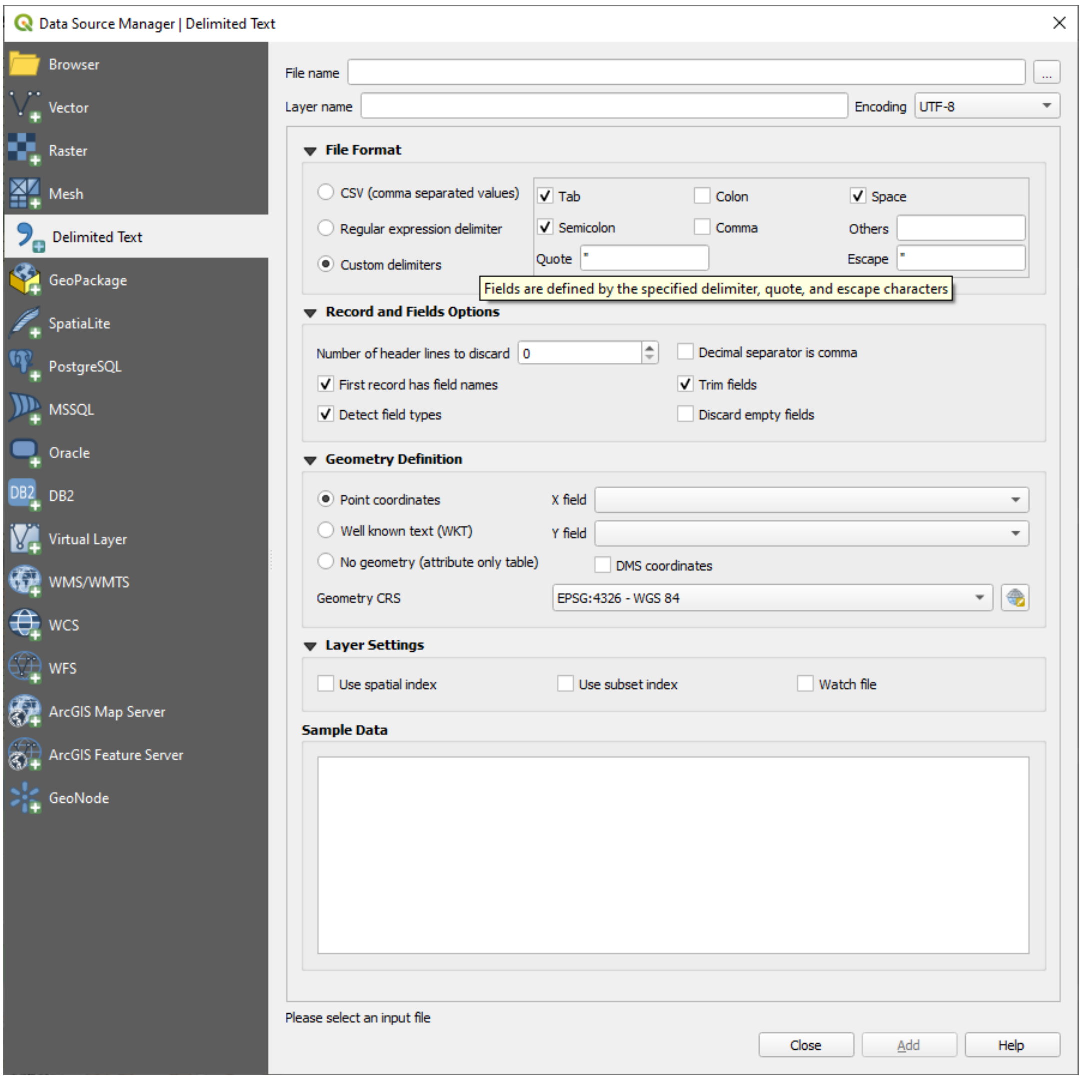

Figure 1.6. Data importing window - QGIS Data Source Manager Delimited Text.

1.9 Development of maps and visualization

The use of geo-information software makes it possible to perform visualization of measurement data, and helps in their interpretation. Pollution data taken by the sensor are recorded along with their geographical position, which makes it possible to display them in GIS software. The data are collected in points, so when working in GIS, it is necessary to interpolate them for a selected region.

The Inverse Distance Weighting (IDW) interpolation algorithm can be used to interpolate the data. A simple explanation of the algorithm can be found at (https://gisgeography.com/inverse-distance-weighting-idw-interpolation/). In GIS, the algorithm interpolates the data and presents it as a raster. Therefore, during the analysis, a transformation is made from the numerical data you recorded to raster data, in the form of a *.tiff file. Raster data displayed on a map background (Figure 1.7) is a powerful source of information about the spatial distribution of pollution. Values and colors can be adjusted accordingly to meet established norms (Figure 1.8).

Figure 1.7. Raster IDW interpolation, grey scale.

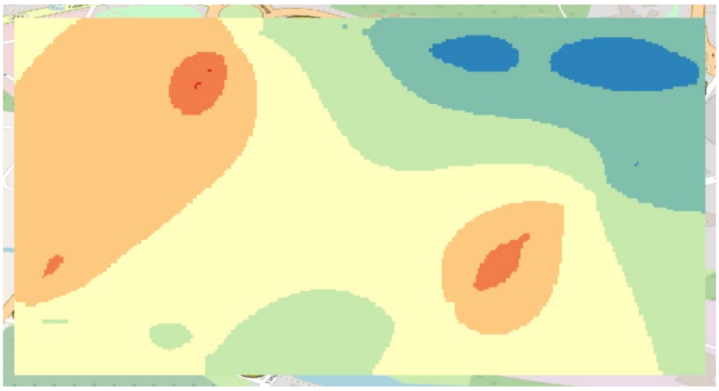

Figure 1.8. Colors and range adjusted.

The visuals and color scheme can be determined depending on the level of pollution. Based on the pollution coverage proposed in Europe for PM2.5 and PM10, the color scheme and coverage as in the Table 1.4 can be adopted.

Table 1.4. Pollutants name, range and recommended colors.

Qualitative name	Index or sub-index	Pollutant (hourly) concentration in µg/m³	
		PM_{10}	**$PM_{2.5}$ (optional)**
Very low	0–25	0–25	0–15
Low	25–50	25–50	15–30
Medium	50–75	50–90	30–55
High	75–100	90–180	55–110
Very high	>100	>180	>110

At the current stage, the data visualisation is developed based on QGIS software. QGIS software is a free and open source geographic information system. Can be downloaded and installed form the web page: https://qgis.org/en/site/.

The video tutorial for development of maps and visualization using QGIS Software and data collected by the sensor is available at: https://youtu.be/sg_uH6lFxpk.

1.10 Final results description

For the presentation of the methodology you can use the Drones measurements presentation.pptx. During measurements, the results will be collected using sensors and send the results to the Climate Scan database. Students should prepare a full report of data collection and data analysis. Report should include analysis of weather conditions and area description and collected data. The last step should include conclusions and summing up regarding the visualization of the results. For the knowledge income verification use the Drones measurement pre-post test to print.doc.

1.11 External materials

See: https://impetus.aau.at/outputs/

Folder: Drones measurements

- Drones measurements instruction.pdf
- Drones measurements pre-post test to print.doc
- Drones measurements pre-post test key.doc
- Drones measurements presentation.pptx

1.12 Literature

Air quality guidelines for Europe World Health Organization. Regional Office for Europe. (2000): https://apps.who.int/iris/handle/10665/107335.

CAQI Air quality index – Comparing Urban Air Quality across Borders – 2012" Common Information to European Air (2012-07-09): https://www.airqualitynow.eu/download/CITEAIR-Comparing_Urban_Air_Quality_across_Borders.pdf.