Hochschule Rhein-Waal
Rhine-Waal University of Applied Sciences
Faculty of Communication and Environment

Degree Program Information Engineering and Computer Science, M. Sc.
Prof. Dr. Timo Kahl

ENVIRONMENTAL PHENOMENA IN KAMP-LINTFORT

Term Paper

WS 2018/2019

Module “Applied Research Project B”

by

Bhuwan Acharya (Matriculation Number: 26129),

Bikash Paudel (Matriculation Number: 26192),

Md. Ashikul Islam (Matriculation Number: 24387), &

Md. Monsur Ali (Matriculation Number: 24547)

Acknowledgement

We would like to express our hearty appreciation to all those who helped us and make it possible to complete this project. A special gratitude to Prof. Dr. Timo Kahl, whose contribution in stimulating suggestions and encouragement and investment of his full effort in guiding the team in achieving the project goal.

Moreover, we would also like to acknowledge for the crucial role of the staff of Marcel Dogotari, who gave the permission to use all required equipment and the necessary materials to complete this project like Microcontroller, sensors and other required connecting cables. We have to appreciate the comment and advices from the colleagues especially in our project presentation that has improved our presentation skills and also gave more idea for the further improvement of our project.

Abstract

Kamp-Lintfort, a small town in Wesel district with around 38,510 population is separated by green meadows, fields and forests. Air quality of this place is unknown and no any research has been done to know the environmental condition here, which was the aim of this project to aware people about the environmental condition in Kamp-Lintfort. Since Kamp-Lintfort lacks air quality data centers, devices were constructed to collect data. Comparing the air quality of Kamp-Lintfort with the neighbouring cities like Duisburg, Krefeld and Wesel in order to know how well this place is for living considering environmental aspects is another goal. Also comparing air quality data with the world health data.

Devices like Arduino boards which was programmed using Arduino ide and sensors Nova SDS011, MICS 2714 and MQ-9 for $PM_{2.5}$, PM_{10}, NOx and CO were used for the construction of required device. Nova SDS011 and MQ-9 was connected with Arduino boards and NOx sensor Mics 2714 was configured with SMT32 nucleo board. Sensor was implemented in the roadside for proper data. Afterward, Data were pre-processed and analysed using R. Various kind of graphs were constructed and comparison was also shown and also the comparison was done with WHO data.

It was found that NOx and CO concentration was normal and was under the standard or threshold value maintained by EU but PM concentration was rather higher. In comparison to other nearby cities it is found that concentration of pollutants is a bit more. In case of health is was found to be moderate i.e. it falls under the criteria of moderate according to the criteria made by WHO.

Table of Contents

List of Figures ***Page no.***

List of Table | ***Page no.***

List of Abbreviation

EAQI	European Air Quality Index
EBA	Eyller Berg Abfallgesellschaft
EU	European Union
i.e. –	Id est, Latin for “this means”
LaGa	Landesgartenschau
LANUV	Landesamt für Natur Umwelt- und Verbraucherschutz Nordrhein-Westfalen
LINEG	Linksniederrheinische Entwässerungs-Genossenschaft
m	Meter
n.d. –	No date
NO_2	Nitrogen dioxide
NRW	North Rhine-Westphalia
PM	Particular Matter
CO	Carbon monoxide
RAG	Ruhrkohle AG
UVO	Umweltdaten vor Ort
WHO	World Health Organization
EEA	European Environment Agency
AQI	Air quality index
IDE	Integrated development environment

LIST OF SYMBOLS

English character set

CI	Confidence Interval
M	Arithmetic mean
p	Probability
r	Pearson product-moment correlation coefficient
SD	Standard deviation
t	t-value
N	Total number of cases

Greek character set

α	Cronbach’s alpha
β	Standardized regression weight
µ	Population value
µg	Microgram

1. Introduction:

Kamp-Lintfort is a small town in Wesel district [1]. It has around 38,510 population mostly consists of old inhabitants and permanent residents. It is separated by green meadows, fields and forests mostly. It was considered as a mine town for more than 100 years. Friedrich Heinrich estate is one of the best known mine in this reason and was closed in 31st December 2012. Being a small town, many youngsters went to different place for studying so population was decreasing until the establishment of Hochschule Rhein-Waal in 2014. Kloster Kamp was founded in 1123 and as the first Cistercian foundation in the region, it has attracted great endowments and become a very wealthy and powerful and later it was converted to museum. Due to the museum and futuristic looking buildings of Hochschule Rhein-Waal with latest technology and special degree tends to attract the people here.

People in this place are unaware of environmental condition. Some people here believe that the air quality is bad over here due to coal mine. Until today, no any research has been conducted over air quality in this place and also there is no air data center in Kamp-Lintfort. There are data centers in the nearby cities but Kamp-Lintfort lacks that. But it is a right of the people to know about the environment where they are living. "A clean environment is a human right like any other. It is therefore part of our responsibility towards others to ensure that the world we pass on is as healthy, if not healthier, than we found it." (Dalai Lama, 2017)

Environment is surroundings of man, animal and all the living organism. It shows the interrelationship which exist between air, water, land, human beings and other living creatures such as plants, animals and microorganism. It consists of four interlinking systems the atmosphere, the hydrosphere, the lithosphere and the biosphere. Here, Lithosphere means the mantle of rocks constituting the earth's crust, atmosphere means the cover of the air, that envelopes the earth, Hydrosphere includes all water bodies such as lakes, ponds, rivers, streams and ocean and biosphere known as the life layer, refers to all organisms on the earth's surface and their interaction with water and air [14]. Environment pollution is the most serious problem in our planet in today's condition. It is defined as the contamination of physical and biological components of earth/atmosphere system, adversely affecting the normal environmental process. Extreme use of natural resources at higher rate than nature's capacity to restore itself can result in pollution of air, water, and land. [13]

1.2 Motivation:

Environmental awareness is not an option it's a duty. It is also the human rights to know about the environment where they are living. Also due to the lack of air quality data station and no any research done before in Kamp-Lintfort, one idea strike our mind about letting people know about the environment where they are living. People are still living with full of doubts and suspense about how the environment is and if it is better than other cities or healthy enough. Considering all these aspects, we came with the idea of doing this project so that it makes clear to the people about the actual air quality of Kamp-Lintfort.

1.3 State of the Art:

This methodology has a great impact on both Kamp-Lintfort inhabitants and environment. People of the Kamp-Lintfort need to know the environmental condition of their city. For a long time, so many approaches have been run to find the actual quality of the air of this city but so far not a single research has been successful to achieve the actual data and fulfil the goal. Even if they were able to find the actual air quality data, those applications don't exist now. The most two common approaches were to build an environmental monitoring station in Kamp-Lintfort and to gather data from the nearby city stations of Kamp-Lintfort. While the first approach could measure the actual air quality, the second approach were totally built on hypothesis.
Generally, one of the two approaches are used to get the actual environmental data throughout the world. With the help of various sensors (temperature and humidity sensor, gas sensors), the quality is measure and the data is collected and stored in database. Then the data is analyzed. This is the most common and widely used approach till now.

Another approach is getting the data from different secondary sources near the city. This data is not reliable and based on hypothesis. Because of now there is no environmental monitoring research station here in Kamp-Lintfort, it can be assumed that the air quality of the city may be equal to the average quality of its nearby cities. This approach may somehow work but it is not fully reliable.

However, these two approaches are not complete if people do not get to know if the air quality is good or bad. People may always believe that the city has now better air quality since the shutdown of the coal mining. Again, some might think that due to the excessive vehicles and other industries, it is possible that the air quality is degrading day by day. People's belief and the actual fact; these are two different criteria which is the main goal of our research project which has never been done before for Kamp-Lintfort city.

1.4 Historical data:

The city of Kamp was founded through monks who built a monastery called Camp, from Campus (lat. field), in around 1128 which was one of the origins of the current city (Kamp-Lintfort., n.d.b). After the monastery lost its importance in 1802, it belonged to the cities Rheinberg, Geldern and Moers. The second part of the town, Lintfort was mainly unknown until its black coal mining site Friedrich Heinrich which was founded in October 1906. This led to a drastic increase in the city's importance from 1906 to 1930, and thus, a rise in population by 494% from 3.748 to 22.261 inhabitants. In 1934, the cities were combined and the name Kamp-Lintfort was established [15]. The former mine Friedrich Heinrich was closed in 1957 and the Ruhrkohle AG (RAG) took over operation of the mine as Bergwerk West (Kamp-Lintfort., n.d.b). Operation of the mine has ended in 2012 and new plans are developed to use the former mining area for the Landesgartenschau 2020.

1.5 Environmental Data

Kamp-Lintfort is part of the German Ruhrgebiet, an area which is known for its mining and industrial activities. In the past, this area was known for its high air pollution, as all industrial areas in Europe. A high number of factories and no policy about emission control led to exhaust gases being released to the environment untreated. The high concentration of contaminant in the air consisting of particulate matter (PM_{10}), nitrogen dioxide (NO_2), Carbon monoxide (CO) and particulate matter ($PM_{2.5}$) led to negative health effects in the population. This has gradually been changed by amendments of policies and regulations from 1975 to 2000 [15]. One important regulation was the Federal Emission Control Act which was established in 1990 and has then constantly been amended until 2017. This constantly changing standard results in the necessity to regularly modernize the facilities. Today, the regulation states that the "best available technique" [15] as stated by the BundesImmissionsschutzgesetz is to be used for emission control to prevent negative effects on air, water or soil. As Germany is part of the European Union, standards on environmental quality were decided on and have to be reported and implemented. These standards concern drinking water policy, noise and emissions from traffic, surface water regulations and chemical use and standardization of such as well [16]. This led to a constantly monitored environmental status of Germany, improving the environmental status to comply with the regulations. The environmental quality in NRW has thus improved and the government agency Landesamt für Natur Umwelt- und Verbraucherschutz Nordrhein-Westfalen (LANUV) measures and evaluates the status of media and publishes the data online for public information. Different local associations assure the quality of natural resources. In Kamp-Lintfort, the Linksniederrheinische Entwässerungs-Genossenschaft has been responsible for the regulation of water discharge and wastewater treatment as well as water maintenance, landscape planning, monitoring of water quality, regulation of groundwater levels, procurement and provision of water for drinking and industrial water supply and the disposal of waste generated during operation in the area of environmental protection since 2003. Compliance with all environmental protection regulations is a basic prerequisite for LINEG to fulfil these largely environmentally relevant tasks. It is LINEG's aim to use its environmental policy to minimize the environmental impact associated with the company and to achieve a continuous improvement in environmental performance [16].

2. Methods and Materials:

Air pollution refers to all those unwanted things that are found in the air like gases, particles, biological molecules and so on. It has an adverse effect on human, animals and also on vegetation and the ecosystem. There are different harmful pollutants around us in the air that are explained as follow.

2.1 Air Pollutants

Solid particles, liquid or gases, all these substances can be considered as air pollutants if they have adverse effect on the environment and the ecosystem. There is 2 type of pollution one is primary which are usually produced by ash from volcanic eruption, motor vehicle exhausts, factories and Secondary pollutants are not emitted directly rather they are formed due to the reaction of primary pollutants like ground level ozone [15]. Some of the pollutants are as follow:-

- Carbon dioxide(CO_2)

  It is the one of the major air pollutant and the worst climate pollution even though it is a natural component of atmosphere. It is also excessively formed due to burning of fossil fuels as gasoline and natural gas in cars, planes and power plants. This increases the temperature of earth since, earth temperature is excessively increasing so it is one of the major pollutants.

- Nitrogen oxide (NOx)

  Nitrogen oxides are nasty-smelling gas that may be formed naturally in the atmosphere by lightning, plants, soil and water which is only 1%. Other are produced by burning fossil fuels: coal, oil and gases i.e. about 80% are formed by motor vehicle exhaust. It has adverse effect on human respiration i.e. it can inflame the lining of the lungs causing lung infections, wheezing, coughing, colds, flu and bronchitis.

- Carbon Monoxide (CO):

  Colorless, odorless, toxic gas, produced by the combustion of natural gas, coal or wood and obviously vehicular exhaust. It creates a smog in air and causes lung diseases and disruptions to the natural environment and animals.

- Sulfur oxide(SOx)

  It is produced due to volcanic eruption and by various industrial processes. It gets oxidized in the presence of a catalyst like NO_2 and forms H_2SO_4 resulting acid rain.

- Particulate matter / particles (PM)

  Atmospheric fine or tiny particles of solid or liquid suspended in a gas are classified as particulate matter (PM). By naturally, induced from volcanoes, dust storms, forest and grassland fires, living vegetation, and sea spray. And along with that by human activities like burning of fossil fuel, power plant and various industrial processes. Currently, approximately 10 percent of particulate matter are present due to human activities that has direct impact on health such as heart disease, lung function alteration and lung cancer. With that peoples persisted with asthma will have respiratory infection due to particulate matter. Particulate matter is classified into two categories according to the side of the matter, diameter of less than 2.5 micrometers are $PM_{2.5}$ and diameter of less than 10 micrometers are PM_{10}.

- Ground level Ozone(O_3):

  It is created by the reaction of NOx and VOCs (Volatile Organic Compounds). Photochemical and chemical reactions involving it drive many of chemical processes that occurs in the atmosphere by day and by night. Abnormal presence of ozone makes it pollutant and a constituent of smog. It may cause chest pain, coughing, throat irritation and may lead to bronchitis, emphysema and asthma also repeated exposure may permanently scar lung tissue.

2.2 Air Quality Monitoring types

In general, air quality monitoring can be grouped into following types [2]:

i. **Emissions Monitoring:** Emission created by the nature itself or by the human kind is focused under this monitoring system.

ii. **Ambient Monitoring:** The accentuation is on surrounding air convergence of dangerous and additionally non-harmful contaminants.

iii. **Deposition Monitoring:** This type of network measures the dry and wet deposition of atmospheric contaminants.

iv. **Visibility Monitoring:** Ability to see things is primary focus of this type of monitoring.

v. **Upper Air Monitoring:** A glance at surrounding focuses in upper environment with the assistance of satellites, planes and so on.

vi. **Health Monitoring:** Public health importance and risk analysis and management is the main focus.

2.3 Device Details

For the analysis of the environment variable like carbon monoxide, nitro dioxide, and particulate matter, we used sensors and microcontroller boards as follows,

2.3.1 Board

Two boards consisting of microprocessor are implement for the connection to the sensors and extract the data form the sensors. Details about the boards are as below,

2.3.1.1 Arduino Uno Rev3

One of the well documented and ease of use board to deals with the electronic and coding and specification of the boards as follows,

Figure 1: Arduino Uno Rev3

Microcontroller	ATmega328p
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limit)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	6
Flash Memory	32 KB
SRAM	2 KB
EEPROM	1 KB
Clock Speed	16 MHz
LED_BUILTIN	13

Table 1: Specification of Arduino Uno Rev3

2.3.1.2 STM32 Nucleo-64 development board

STM32 Nucleo-64 boards are various combinations of performance, power consumption and features and along with that support connection with Arduino Uno rev3 & ST morpho connectors. Features and specifications as below,

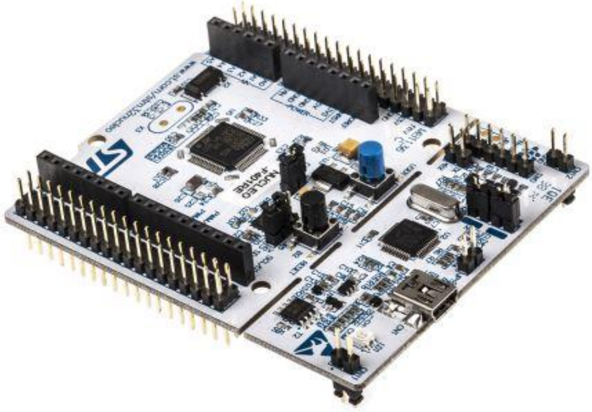

Figure 2: STM32F411RE

- STM32 microcontroller in LQFP64 package
- 1 user LED shared with Arduino™
- 1 user and 1 reset push-buttons
- 32.768 kHz LSE crystal oscillator
- Board expansion connectors:
  › Arduino™ Uno V3
  › ST morpho extension pin headers for full access to all STM32 I/Os
- Flexible power-supply options: ST-LINK USB VBUS or external sources
- On-board ST-LINK/V2-1 debugger/programmer with USB re-enumeration capability. Three different interfaces supported on USB: mass storage, Virtual COM port and debug port
- Comprehensive free software libraries and examples available with the STM32Cube MCU Package
- Support of a wide choice of Integrated Development Environments (IDEs) including IAR™, Keil®, GCC-based IDEs, Arm® Mbed™

2.3.2 Sensors

Three different sensors used for the measurement environmental data are as below,

2.3.2.1 Nova PM SDS 011

By using principle of laser scattering for the measurement of particulate matter present in the air, i.e. PM 2.5 and PM 10 and the specification as bellows,

Figure 3: Nova PM SDS 011

Laser PM2.5 Sensor--SDS011,
inovafitness.com/en/a/chanpinzhongxin/95.html.

- Measuring Range: 0.0-999.9μg/m3
- Input Voltage:5V
- Maximum Current: 100mA
- Sleep Current:2mA
- Response Time 1 second
- Serial Data Output Frequency: 1 time/second
- Particle Diameter Resolution:≤0.3μm
- Relative Error:10%
- Temperature Range:-20~50°C
- Size: 71mm*70mm*23mm

2.3.2.2 MQ-9

MQ-9 used for the measurement of the useful for gas leakage detection and along with that feature specification as below,

Figure 4: MQ-9

Bill. "Grove - Gas Sensor (MQ 9)." *Seeedstudio*, wiki.seeedstudio.com/Grove-Gas_Sensor-MQ9/.

- Sensitive for carbon monoxide
- Fast response and recovery
- Adjustable sensitivity
- Power: 5V ± 0.1
- Stable and long life

2.3.2.3 MICS 2714

The basic principle of SGX metal oxide sensors is that the resistance of the detecting layer in sensor changes in the presence of gas. Feature and specification as below,

Figure 5: Mics 2714

“MICS-2714.” *Component Distributors Inc.*, sgx.cdistore.com/Products/Detail/MICS2714-SGX-Sensortech/333416/.

- Nitrogen dioxide sensor
- Detection range 50 ppb to 5 ppm
- Surface Mounted Package
- Smallest footprint for compact designs (5 x 7 x 1.55 mm)
- Robust MEMS sensor for harsh environments
- High-volume manufacturing for low-cost applications

2.4 Device Implementation

Integrated Development Environment (IDE) helps to communicate the sensor to microcontroller and then with the help of Integrated Development Environment (IDE), microcontroller can be programmed and able to read the data from the sensor. On specific of Integrated Development Environment (IDE), Arduino IDE was used, which is an open-source software and makes easy to write the code and then upload to the board consisting of microcontroller. Arduino IDE supports multi-platform like Windows, Mac OS X and Linux, and environment is written in Java and based on processing.

Both the board, STM32F411RE and Arduino Uno Rev3 can be operated by Arduino IDE. First and foremost, things on implementation was to installation of the Arduino IDE software and then library package of the STM32F411RE board was installed, until and unless the library were not installed Arduino IDE not able to read the STM32F411RE board. After that Arduino IDE able to operate the STM32F411RE board, whereas in the case of Arduino Uno Rev3 board library was preinstalled by the time of installation of Arduino IDE.

Whereas in the case of MICS 2714 sensor, resistor is necessary to obtain the right temperature on the heater while using a single 5V power supply. For that 131-ohm resistance with the MICS 2714 sensor as below

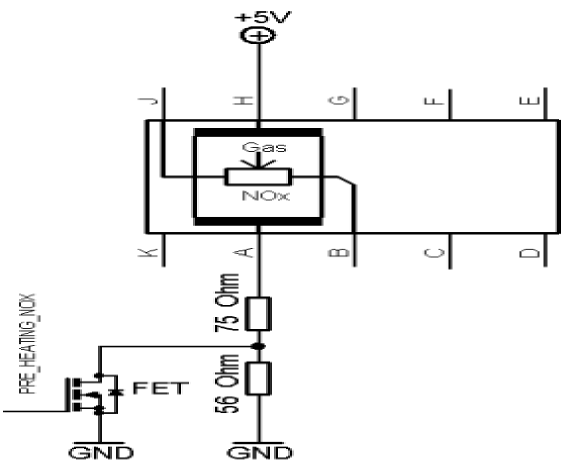

Figure 6: Resistor configurations for MICS 2714

After configuring the resistor on MICS 2714 and then it connects to STM32F411RE board and Nova PM SDS 011 and MQ-9 sensors are connected to Arduino Uno Rev3.

Then the Arduino IDE was able to access the both the board (STM32F411RE and Arduino Uno Rev3) alog, code was written in Arduino IDE in such the way that Arduino Uno Rev3 able to read the Nova PM SDS 011 and MQ-9, and STM32F411RE able to read the MICS 2714. And then sensor is connected to the board according to attribute like digital output, analog output, power supply and ground, which was predefine the written code on Arduino IDE.

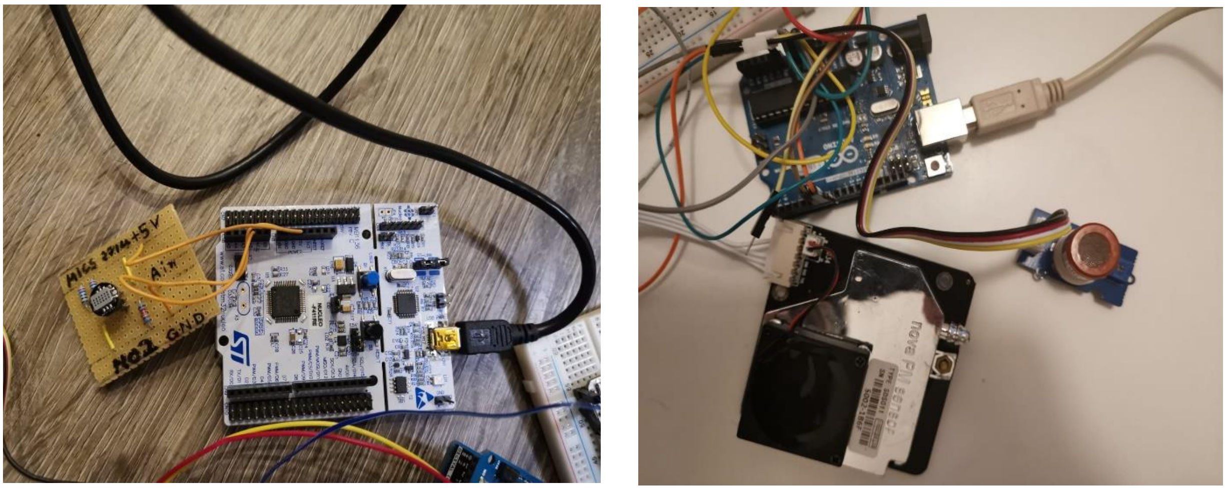

Figure 7: Implementation of device for construction of sensors

Then written code was execute on Arduino IDE and upload to microcontroller and with the help of Serial application, which is an application that help records the data follows from the microcontroller to the workstation, able the read the data and store on workstation.

2.5 Landesamt für Natur Umwelt- und Verbraucherschutz (LANUV)

LANUV is the official statement for collecting, preserving and analyzing nature and environmental data in North Rhine Westphalia. LANUV has so many environmental quality measuring data centers all around the NRW state. It collects air quality data, analyzes it then publishes it for the people so that people can check the condition of the environment and if needed, can further research and work with those data. LANUV works on environmental protection and supports for it. With the data already collected, it examines the condition of the environment of NRW. If the quality is not good, it helps in development of the situation. After informing the people about the environment, it welcomes the questions and feedbacks from them.

2.6 R Programming

R is a free and open source programming program. R is utilized for factual examination dependent on content language. The principle focal points of R are the way that R is freeware and there are a bunch of assistance accessible on the web. It is very like other programming bundles, for example, MatLab. RStudio is the open source IDE for R. Clients can unmistakably see charts, information tables, R code, and yield all in the meantime by utilizing Rstudio. Clients can import a few of document on this stage and examination like CSV, Excel, SAS (*.sas), SPSS (*.sav), and Stata (*.dta) records. RStudio have bunches of open source libraries. One can download and introduce libraries and work. It is accessible for windows, Mac and Linux client [11].

3. Data Collection and analysis

The main goal of this section was to collect the air quality data. For collecting those data, different approaches were taken for air quality data. For air quality data, it was difficult to collect those data as there is no measurement station in Kamp-Lintfort. To overcome this problematic situation, it was decided to collect the air quality data by sensors device. Keeping Kamp-Lintfort at the center, the nearby cities Krefeld, Duisburg and Wesel were chosen for the data collection and collected from LANUV.

3.1 Data measuring Station

In Kamp-Lintfort, data was collected from roadside area Prinzenstraße 64, Kamp-Lintfort,47475. Near this area local transport communication is available. Other cities like

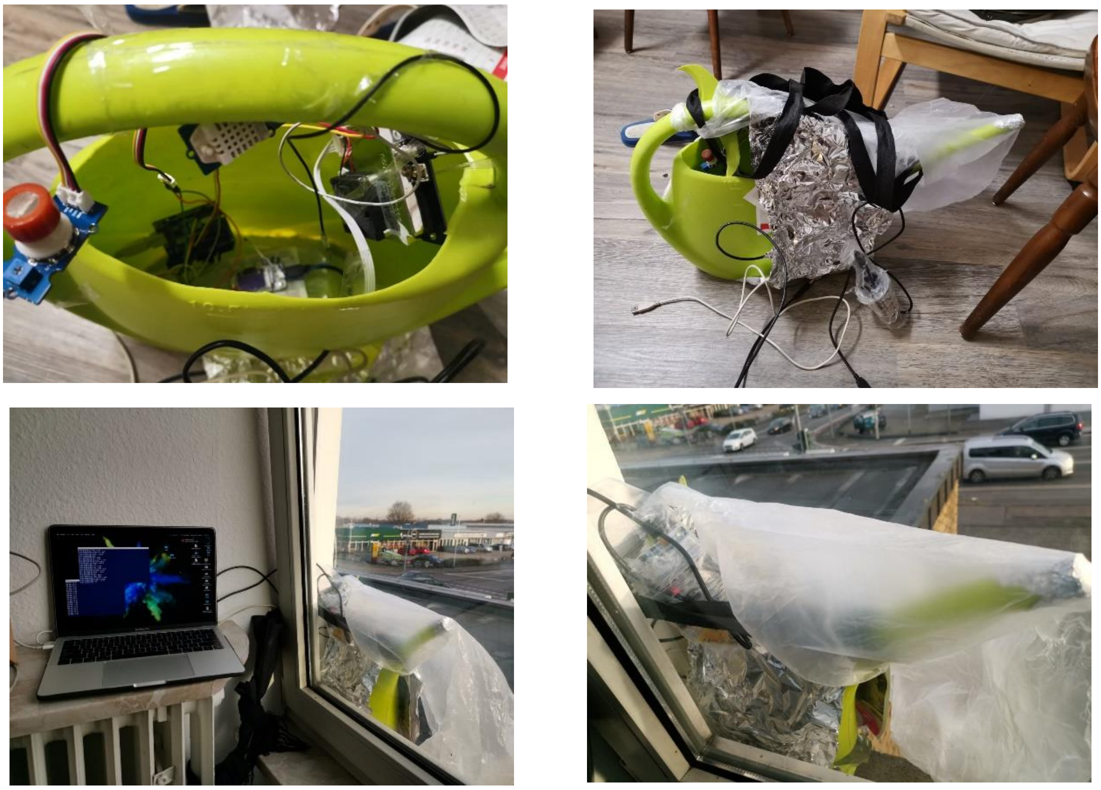

Figure 8: Kamp-Lintfort Data collection with implemented device

From figure 8, it's an overview picture of collecting Kamp-Lintfort air quality data. Duisburg, Krefeld and Wesel's data were collected from Rheinhausen, Marktstraße, 47158, Hentrichstraße, 47809 and Feldmark, 46485 respectively.

Bellow table 2 shows the specific address of all measuring station.

City	Measuring Point
Kamp-Lintfort	Prinzenstraße,64, Kamp-Lintfort,47475
Duisburg	Rheinhausen, Marktstraße, 47158
Krefeld	Hentrichstraße, 47809
Wesel	Feldmark, 46485

Table 2: Data measuring station

3.2 Data processing

Data preprocessing is a part of data mining technique. It builds the raw dataset into meaningful format. Data preprocessing is done to optimize unwanted, missing and inconsistent data which may give better results. Collecting raw datasets had lots of wanted attributes and missing values. Raw datasets were collected as text format from the device.

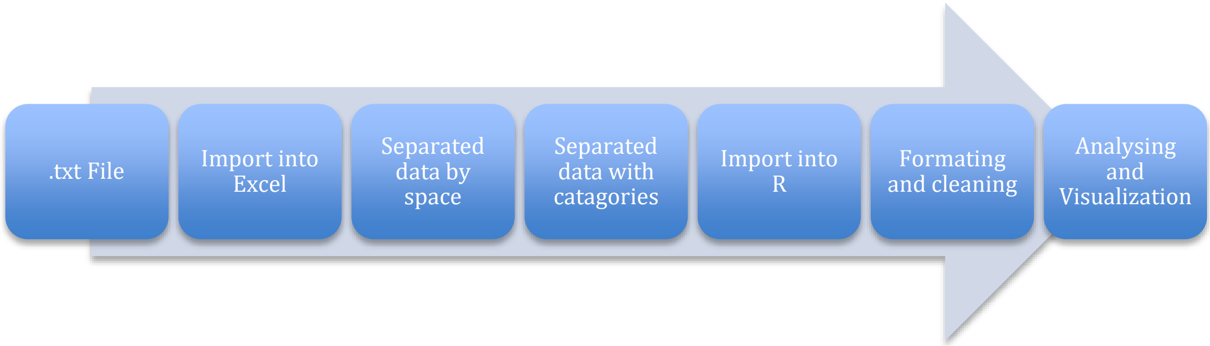

Figure 9: Data Processing steps

First, these datasets were imported into Microsoft excel and formatted text into data. All data were separated by space. Using excel advanced SQL format every pollutant was separated from each other. After separating the pollutants, all files were saved as csv format and imported into R. Before importing into R, NO_2 and CO data were converted mg/m^3 unit. Because these data were in ppm and ppb units. Concentrations of chemicals in air are typically measured in units of the mass of chemical (milligrams, micrograms, nanograms or picograms) per volume of air (cubic meter or cubic feet). However, concentrations may also be expressed as parts per million (ppm) or parts per billion (ppb) by using a conversion factor. The conversion factor is based on the molecular weight of the chemical and is different for each chemical. In R, these datasets were formatted by dates and time and removed unwanted attributes like voltage, radios and missing values.

3.3 Air quality monitoring results:

Air quality monitoring results are divided into two parts. One is for Kamp-Lintfort which data is collected from device and others is nearby cities Duisburg, Krefeld, Wesel where datasets are collected from LANUV data site.

3.3.1 Kamp-Lintfort monitoring result:

To analyze the air quality data, World Health Organization (WHO) and European Union (EU) threshold values were taken under consideration. PM_{10}, $PM_{2.5}$, NO_2 and CO are the substances collected and measured. The concentration of PM_{10} in Kamp-Lintfort from 22th December 2018 to 30th December 2018 are displayed in figure 10. It is visible that the concentration threshold values are under the EU and WHO threshold values for first six days. Although the concentration had exceeded the EU and WHO limit values from 27th December 2018 to 28th December 2018, it began to decrease after 26th December and since then it has been under the EU and WHO threshold value. In conclusion, the current concentration of PM_{10} in Kamp-Lintfort can be assessed as good.

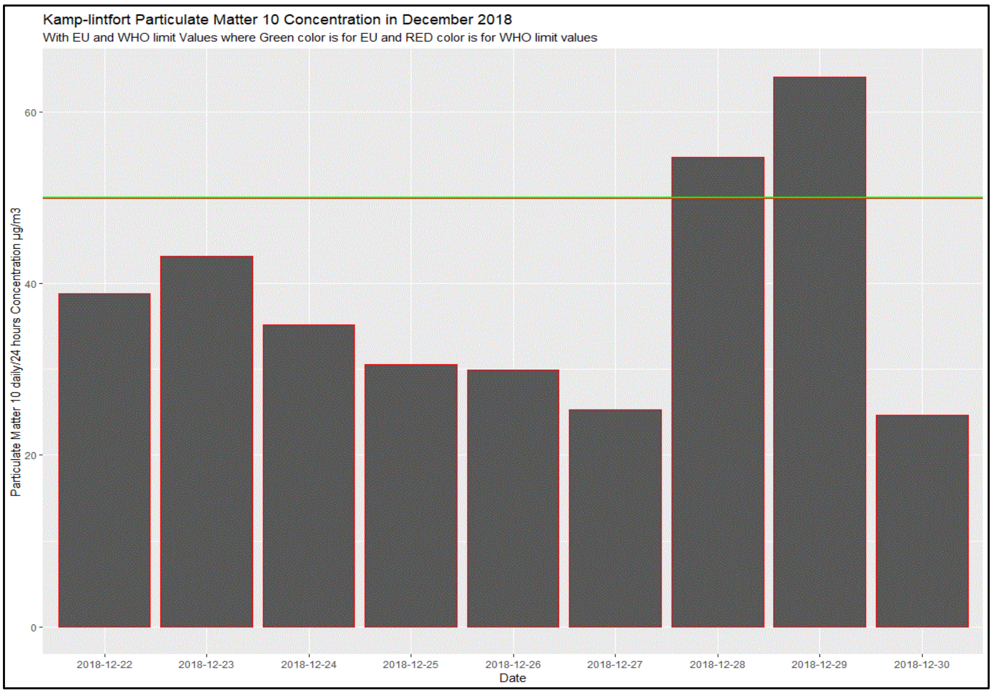

Figure 10: PM_{10} concentration in Kamp-Lintfort December 2018

Figure 11 shows the daily concentration of particulate matter 2.5 in Kamp-Lintfort from 22th December 2018 to 30th December 2018. The threshold value for $PM_{2.5}$ concentration is 25 $\mu g/m^3$. It is visible that the concentration of the particulate matter 2.5 is high in all those days concentration except 30th of December. In conclusion, the current concentration of $PM_{2.5}$ in Kamp-Lintfort can be assessed as bad because the mean values exceed the threshold value.

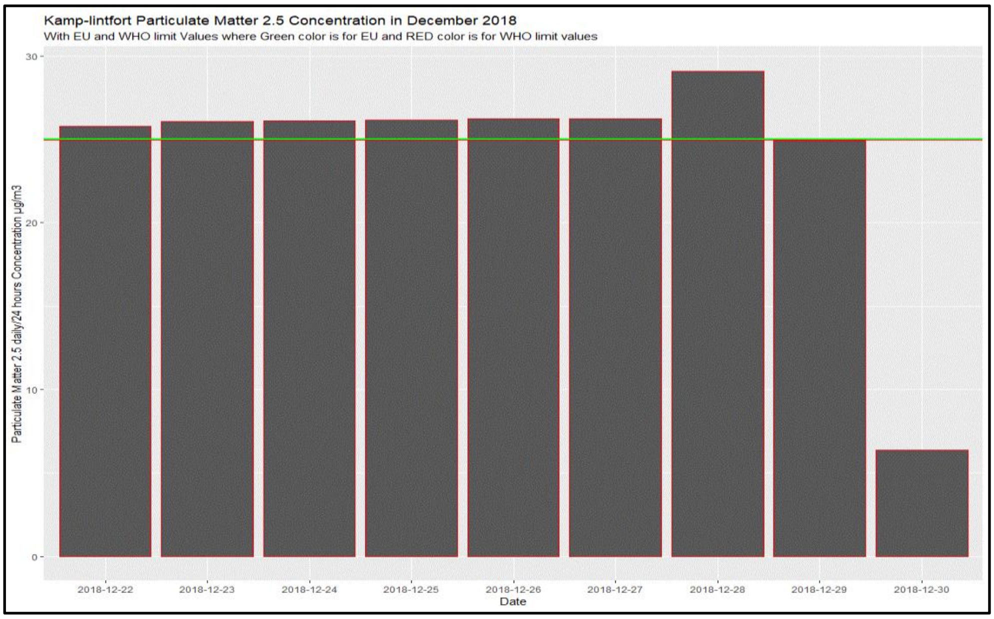

Figure 11: $PM_{2.5}$ concentration in Kamp-Lintfort December 2018

Figure 12 shows the hourly concentration of nitrogen dioxide in Kamp-Lintfort from 26th December 2018 to 4th January 2019. The threshold values for both EU and WHO is 200 µg/m^3 and these duration, the concentration of nitrogen dioxide has under both EU and WHO threshold values. In conclusion, the current concentration of NO_2 in Kamp-Lintfort can be assessed as good.

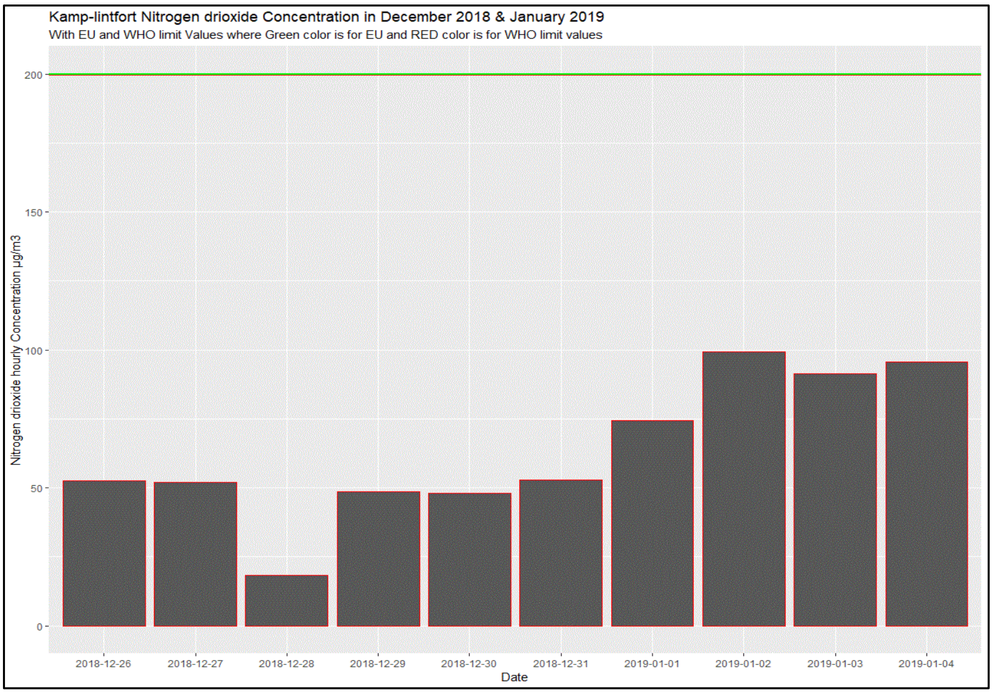

Figure 12: NO_2 concentration in Kamp-Lintfort December 2018.

Figure 13 shows the hourly concentration of carbon monoxide from 26th December 2018 to 30th January 2018. Over these days, the concentration of the CO gas is way below the threshold value of EU threshold value. In conclusion, the current concentration of carbon monoxide in Kamp-Lintfort can be assessed as good.

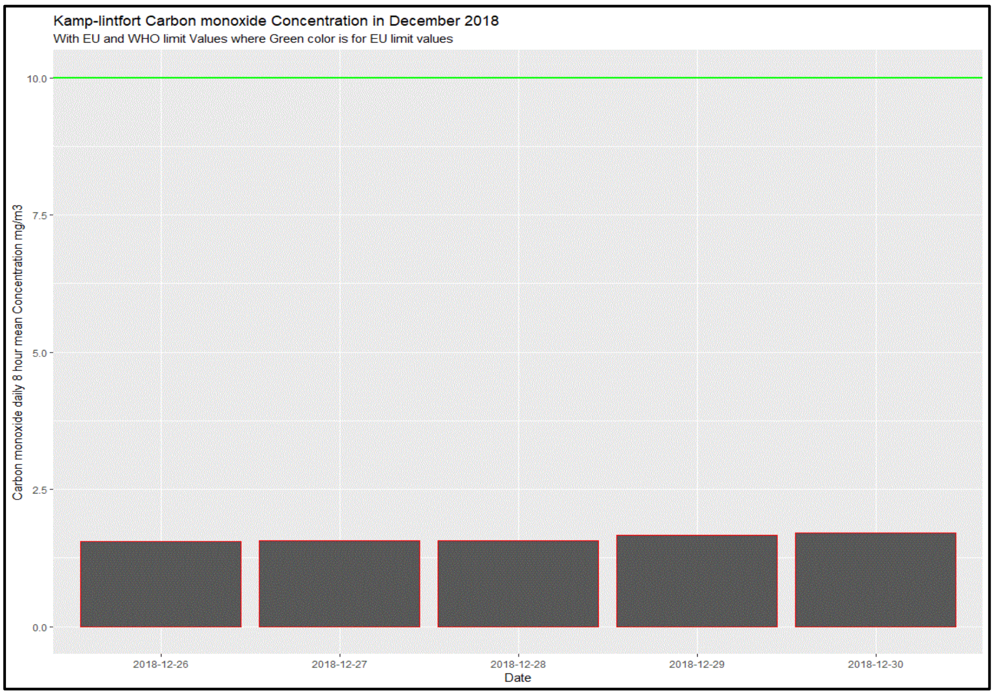

Figure 13: CO concentration in Kamp-Lintfort December 2018

3.3.2 Other Cities monitoring

Other cities Duisburg, Krefeld and Wesel concentrations are PM_{10}, and NO_2 are the substances collected from LANUV. The concentrations of PM_{10} in Duisburg, Krefeld and Wesel from 22th December 2018 to 30th December 2018 are displayed in figure 14. It is visible that the concentration threshold values are under the EU and WHO threshold values for every day. Although the concentration had ups and down, the concentrations were under the EU and WHO threshold values. In conclusion, the current concentration of PM_{10} in three cities can be assessed as good.

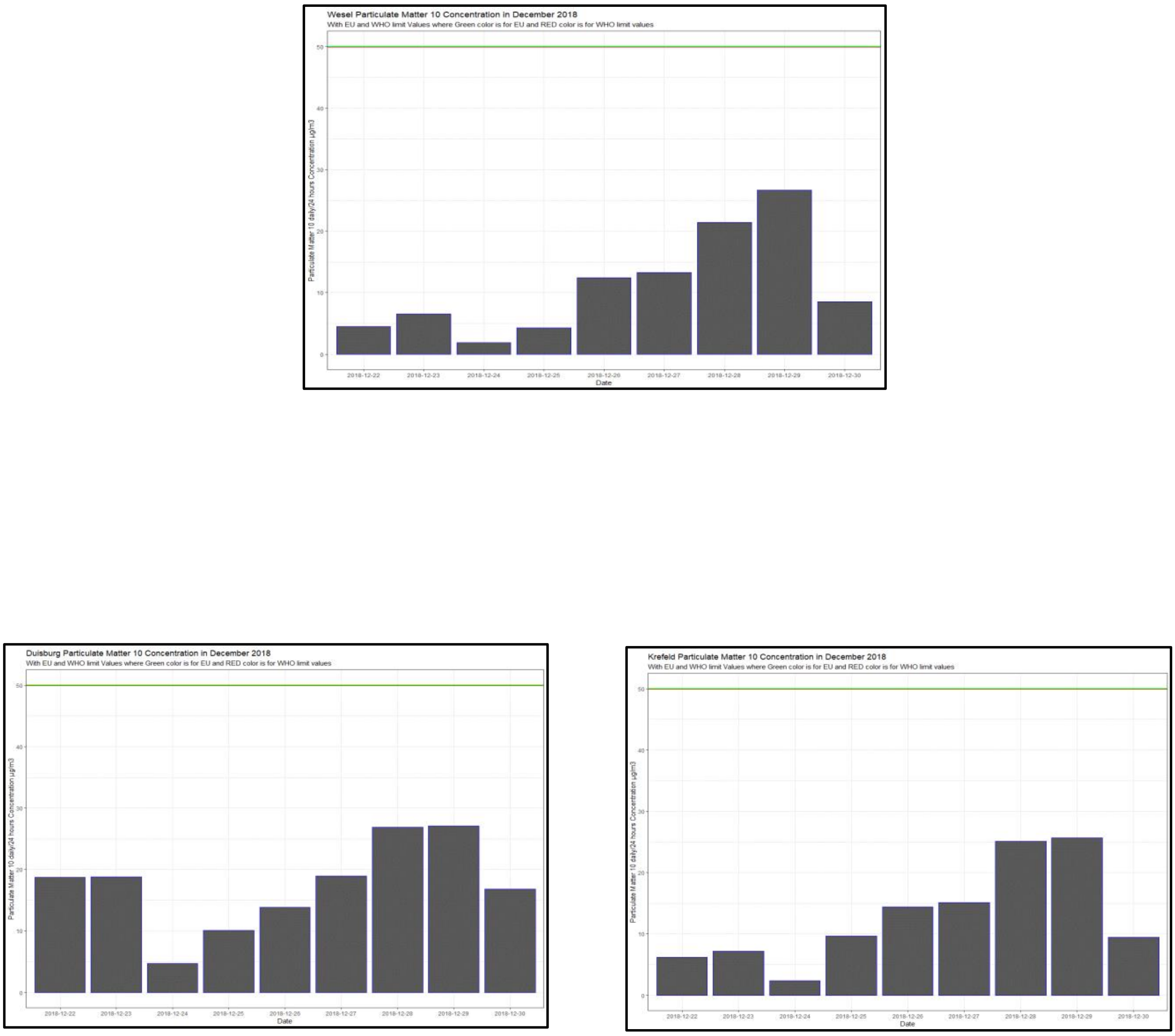

Figure 14: PM_{10} Concentration in Duisburg, Krefeld and Wesel

Figure 15 shows the daily concentration of NO_2 in Duisburg and Wesel from 22th December 2018 to 30th December 2018. The threshold value for NO_2 concentration is 200 µg/m^3. It is visible that the concentration of the NO_2 gas is under the threshold values in both cities. In conclusion, the current concentration of NO_2 in Kamp-Lintfort can be assessed as good because the mean values do not exceed the threshold value.

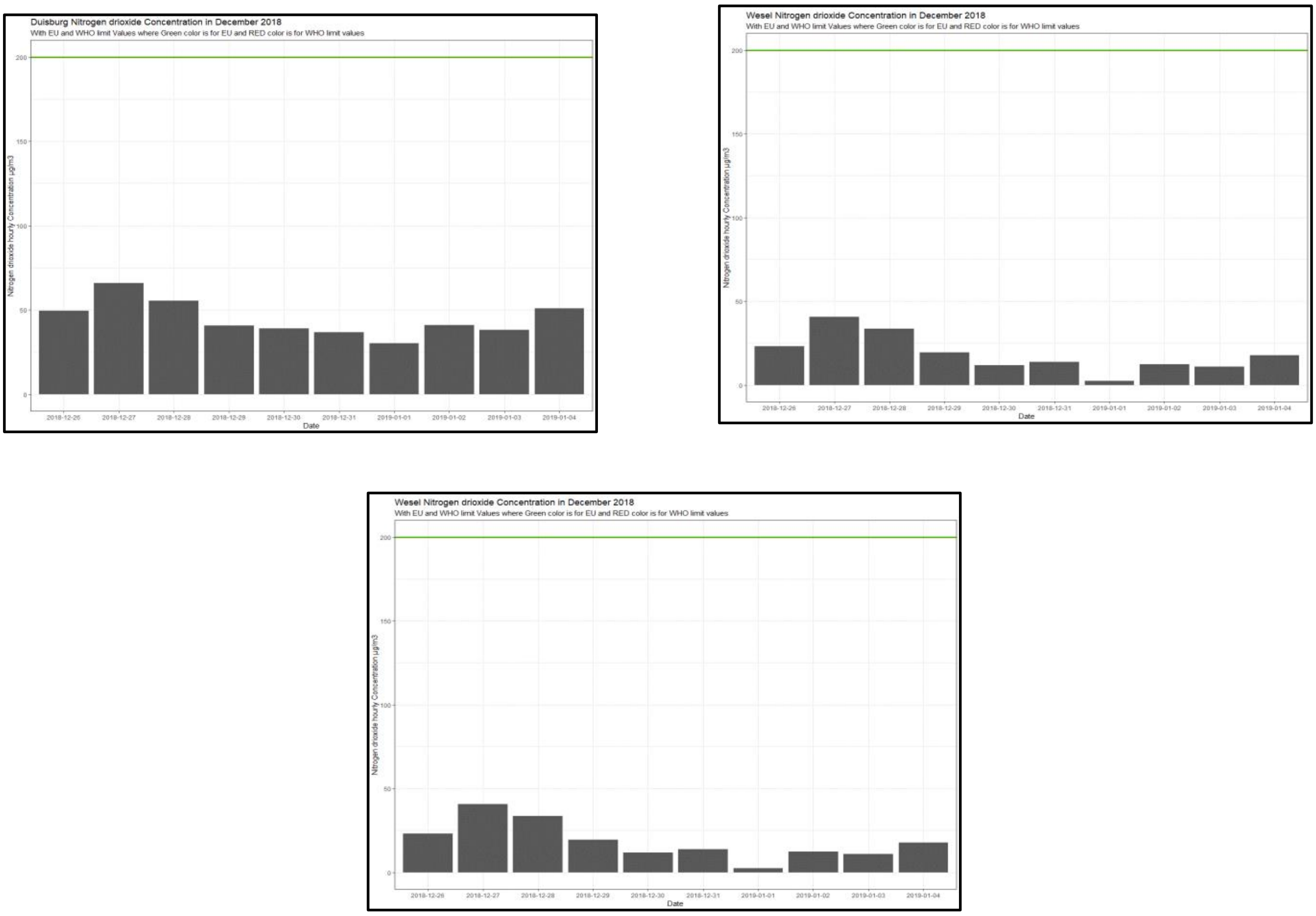

Figure 15: NO_2 Concentration in Duisburg, Krefeld and Wesel

3.4 Comparing with other cities

3.4.1 Comparing Kamp-Lintfort PM_{10} with other cities

Kamp-Lintfort particular Matter 10 pollutant is compared with nearby three cities. Figure 16 shows the concentration of PM_{10} in Duisburg, Kamp-Lintfort, Krefeld and Wesel from 22th December 2018 to 30th December 2018. Every concentration of Kamp-Lintfort is higher than other three cities where 29th December 2018 had most recorded concentration and 30th December 2018 had lowest concentration. The second position was in Duisburg where 29th December 2018 had most recorded concentration and 30th December 2018 had the lowest concentration.

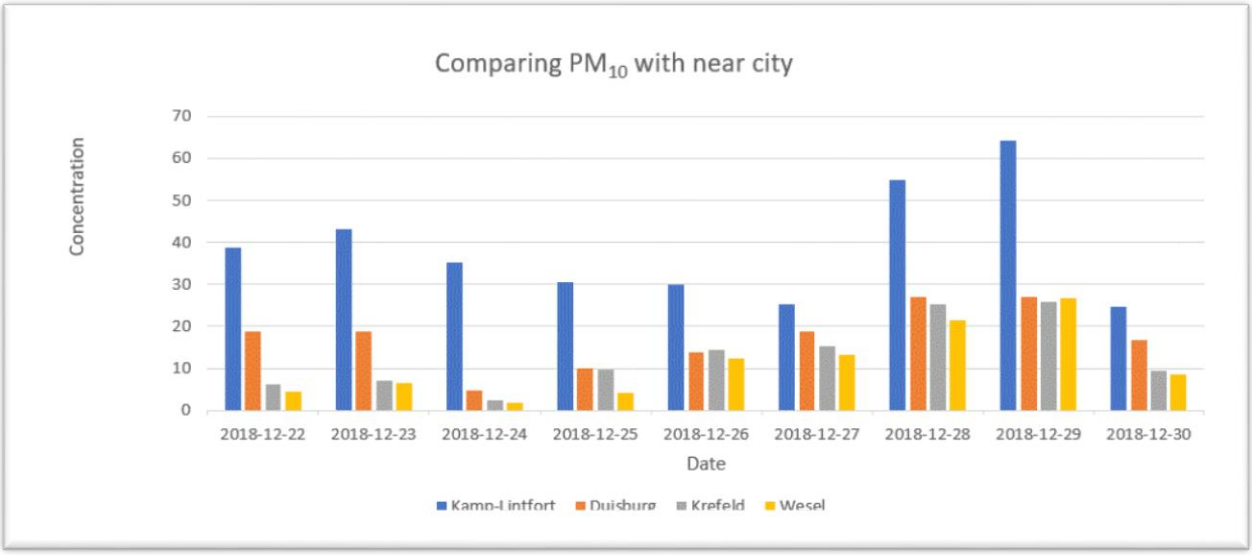

Figure 16: Comparing Kamp-Lintfort PM_{10} with other cities.

Other two cities Krefeld and Wesel had same concentration during that time frame. In conclusion, the current concentration of PM_{10} in Kamp-Lintfort cannot be assessed as good compared to other three cities.

3.4.2 Comparing Kamp-Lintfort NO_2 with other cities

Kamp-Lintfort NO_2 pollutant is compared with nearby two cities. Figure 17 shows the concentration of NO_2 in Kamp-Lintfort, Duisburg and Wesel from 26th December 2018 to 4th January 2019. Almost every concentration of Kamp-Lintfort is higher than other three cities except first three days where on the 2nd January 2019 had most recorded concentration and 28th December 2018 had lowest concentration. The second position was in Duisburg where on first three days, it had most recorded concentration and on 1st January 2019, it had the lowest concentration.

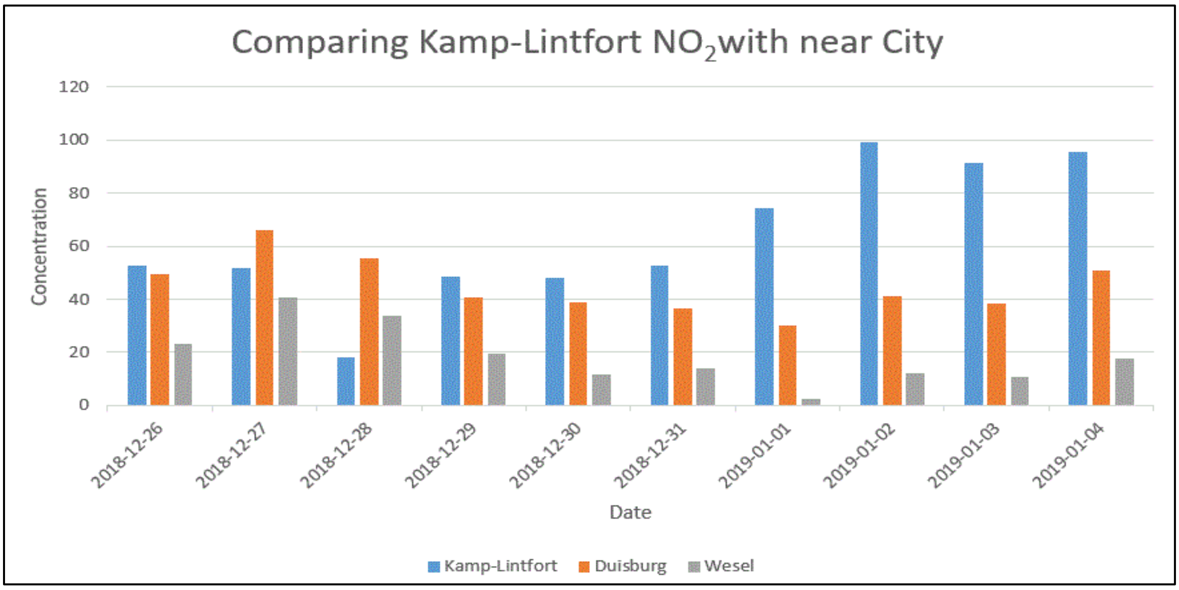

Figure 17: Comparing Kamp-Lintfort NO_2 with other cities

Wesel had the lowest concentration during that time frame. In conclusion, the current concentration of NO_2 in Kamp-Lintfort cannot be assessed as good compared to other two cities.

3.5 Health concern observation

All cities data were visualized according to health concern. European Environment Agency (EEA) has air quality index (AQI). How clean is the air and the breathing condition at the present time? How does the air in the city contrast and that of a neighboring city or area? Air contamination is the single biggest ecological wellbeing hazard in Europe. The European Environment Agency's European Air Quality Index enables clients to see increasingly about air quality where they live. Showing regularly updated information for the entire of Europe, clients can increase new experiences into the air nature of individual nations, districts and urban areas [17].

Pollutant	Index level (based on pollutant concentrations in µg/m3)				
	Good	Fair	Moderate	Poor	Very Poor
PM2.5	0-10	10-20	20-25	25-50	50-800
PM10	0-20	20-35	35-50	50-100	100-1200
NO2	0-40	40-100	100-200	100-400	400-1000

Table 3: Air quality index of European Environment Agency (EEA) [17].

Figure 18 shows the health concern of PM_{10} in Kamp-Lintfort. The maximum days PM_{10} was fair according to health concern and it's almost 55%. Other 45% is moderate and poor. In conclusion, the PM_{10} in Kamp-Lintfort is good there is nothing to worry.

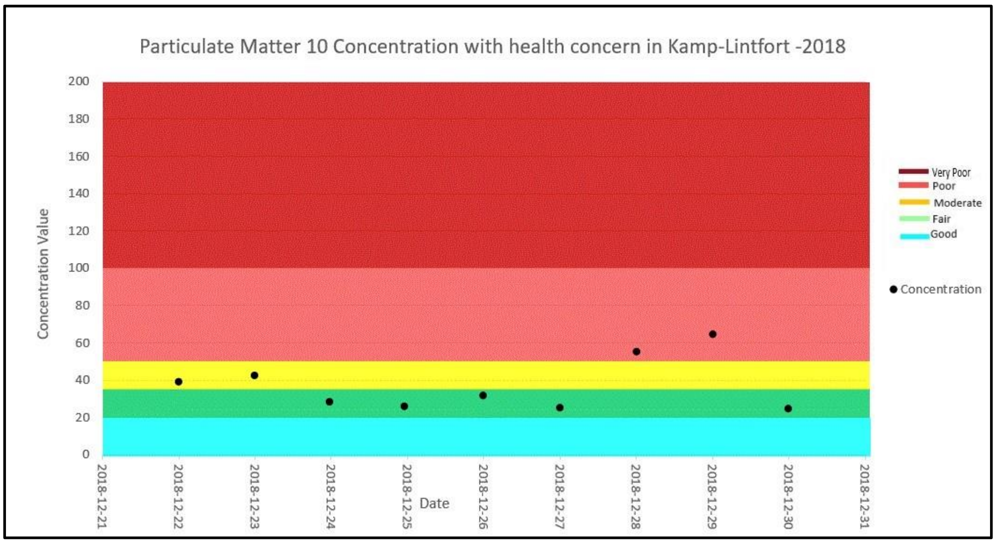

Figure 18: Health concern of PM_{10} in Kamp-Lintfort

Figure 19 shows the health concern of $PM_{2.5}$ in Kamp-Lintfort. The maximum days PM_{10} was moderate according to health concern and it's almost 66%. Other 34% is good and poor. In conclusion, the $PM_{2.5}$ in Kamp-Lintfort is good there is nothing to any serious concern.

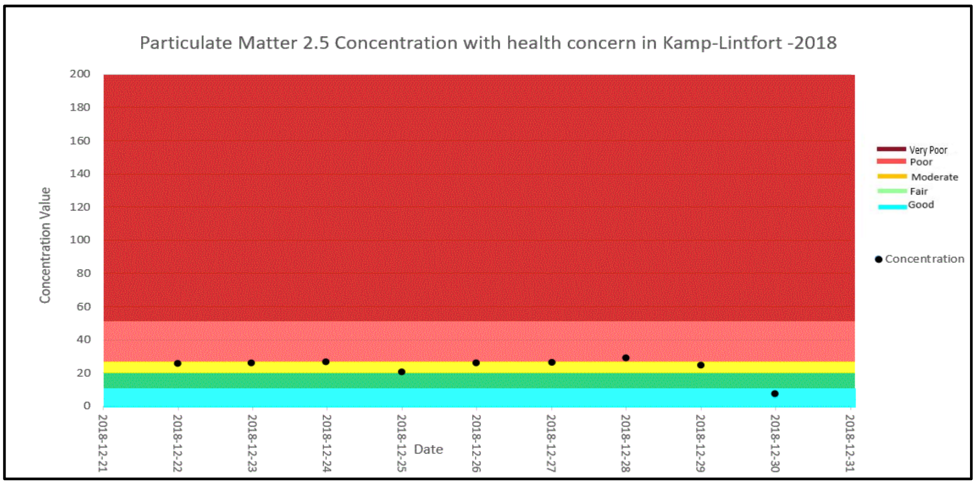

Figure 19: Health concern of PM2.5 in Kamp-Lintfort

Figure 20 shows the health concern of NO_2 in Kamp-Lintfort. The maximum days NO_2 was fair according to health concern and it's almost 83%. Other 17% is good. In conclusion, the NO_2 in Kamp-Lintfort is very good there has no serious health concern.

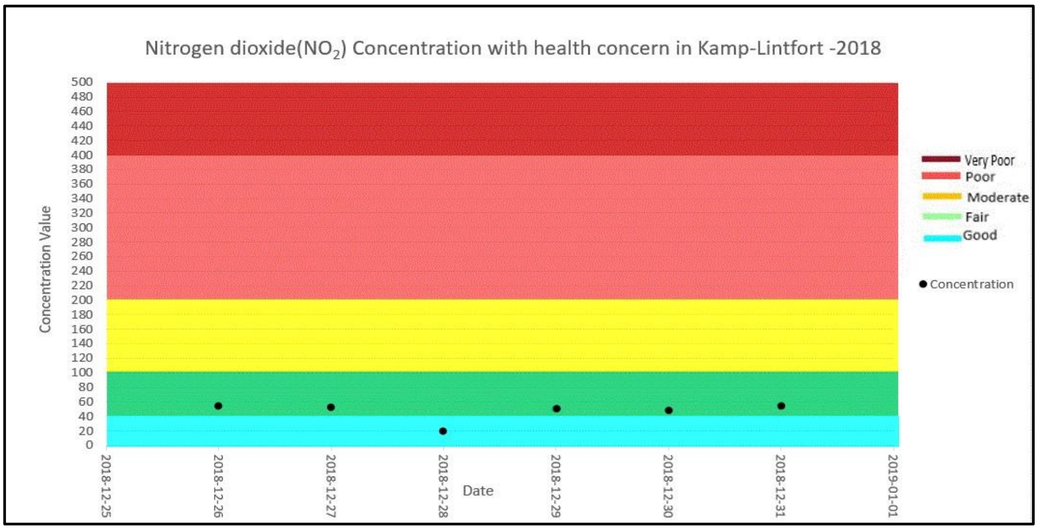

Figure 20: Health concern of NO_2 in Kamp-Lintfort

4. Findings, Results and Limitation:

4.1 Findings and results

The environmental quality of Kamp-Lintfort is measured carefully using different types of gas sensors. With the help of those particular gas sensors, Arduino as IDE and different types of Arduino microcontroller boards, the air quality measurement was quite a success. There were few special criteria and findings of this project. Comparing to the World Health Organization (WHO) and EU threshold values, the environmental quality of this city is moderately good. Surprisingly, the amount of the particles matters are quite high in the air of Kamp-Lintfort which may cause lung diseases, asthma attacks or even premature death. Comparing to other nearby cities of Kamp-Lintfort, the air quality is not at satisfied level. All the concentration values are comprehensively the highest among all these cities. But when it comes to health concern by European Environmental Agency (EEA), the quality of the environment if this city is still under satisfactory level.

4.2 Limitation

The primary goal of this project was to find the actual air quality of Kamp-Lintfort so that people can be aware of the environment quality of this city. Finding suitable devices and the suitable places as measuring stations were the most difficult challenges those were faced during the applicable time. The goal was to setup different measuring station points in different areas such as residential area, roadside area and greenspace area and collecting data from those individual points and after that, an average quality data which would represent the actual environmental quality of the city.

4.3 Future work

There is no existing air quality measuring station in Kamp-Lintfort city. It has been several years' people are unaware of the environment of this city. If sufficient fund, time and efforts are given to this work, it could be possible to build few measuring stations around the city which will provide the remote environmental quality data in real time as well as the data of previous months and years and then with those data, further prediction about how the environment will behave in the future.

5. Conclusion

This project aims to measure the actual environmental quality of Kamp-Lintfort, compare it with other nearby cities and make the people aware of it. In order to get the environmental information, it is necessary to get the data and then extract the information from the data. Unlike depending on other secondary sources for the environmental data, this project aims to build a mechanism which provides and shows the quality of the environment of Kamp-Lintfort. The whole mechanism is based on electronic devices combined of microcontrollers, gas sensors, and timer and so on. This project work can be extended for future development which may help the people to be more conscious and careful of the environment. Although the result show that the quality of the environment is still considerably good, it is everyone's duty to be kind towards environment and take care of it. Steps have already been taken to preserve the good environmental quality of the city such as “Landesgartenschau Kamp-Lintfort 2020”.

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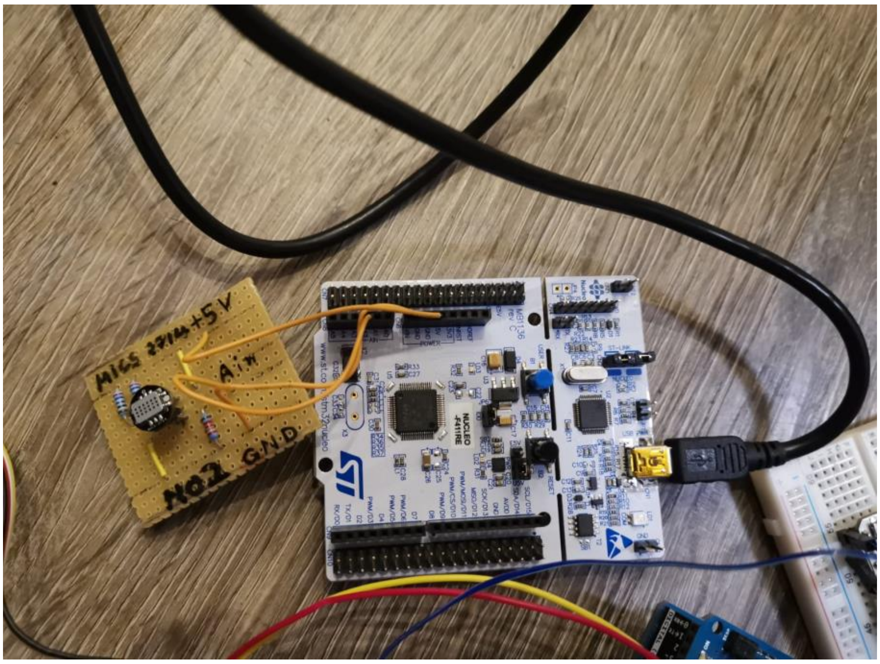
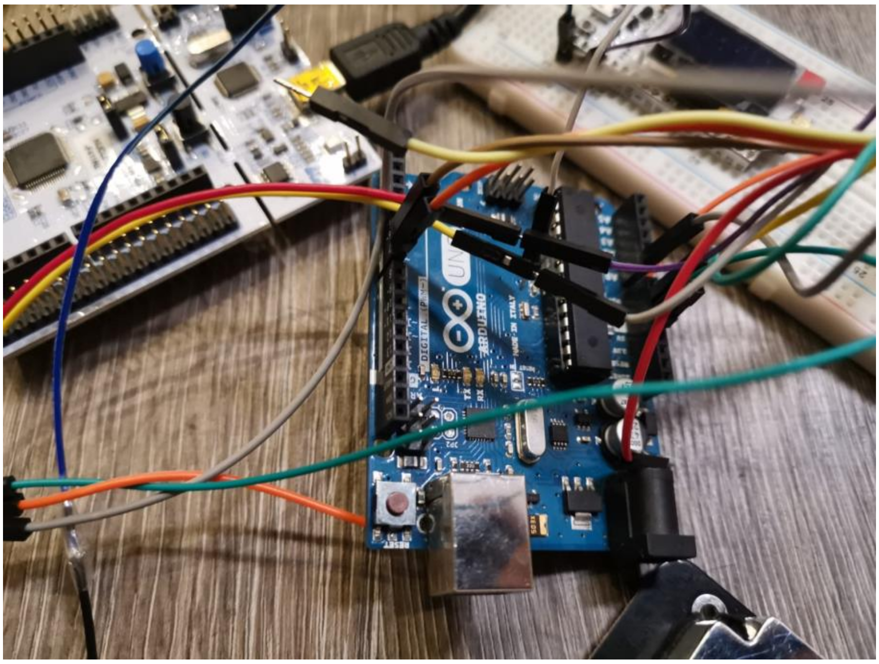
Appendix

All the data and codes are externally attached with Reports.

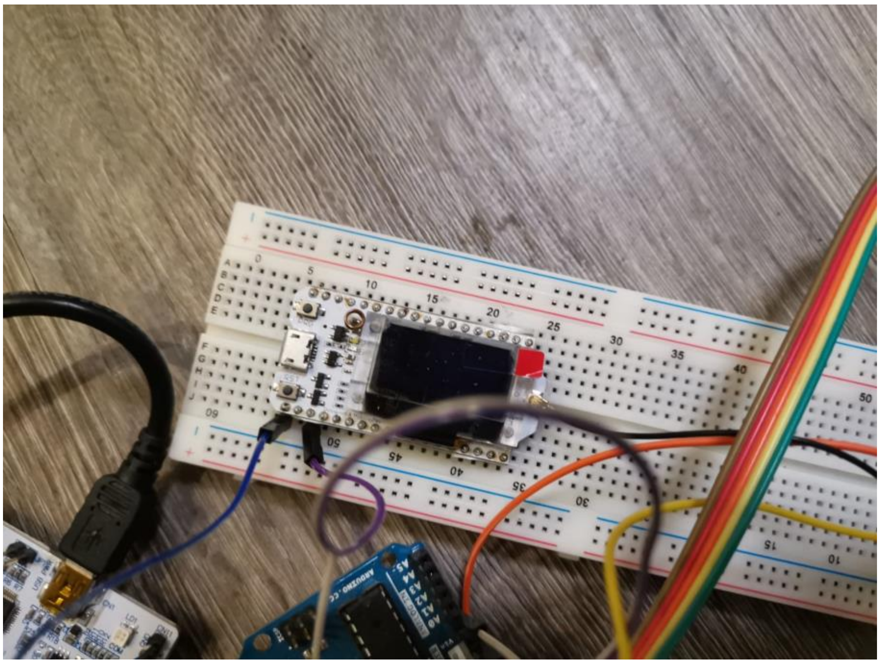
Data Collection Photo



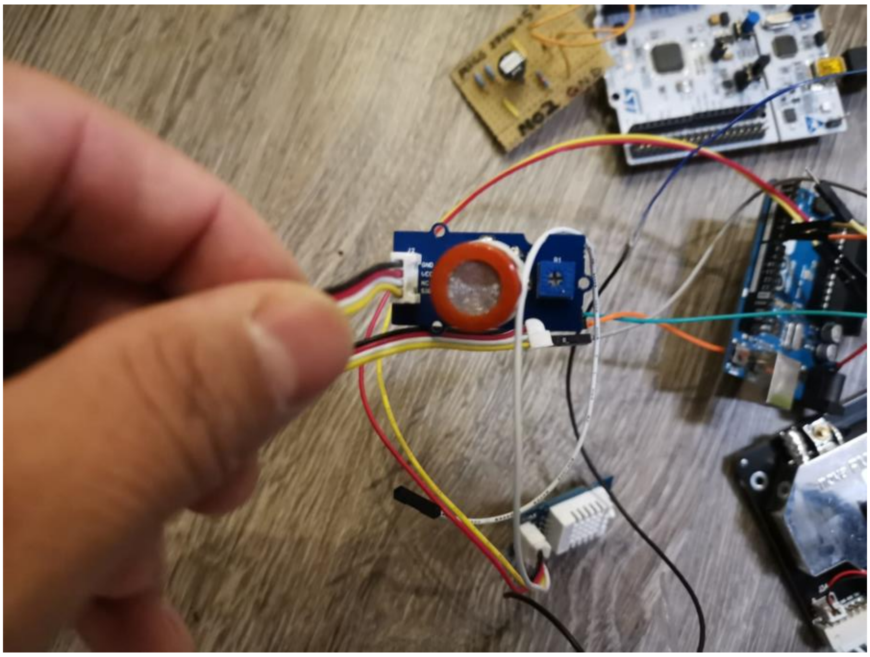
(1)



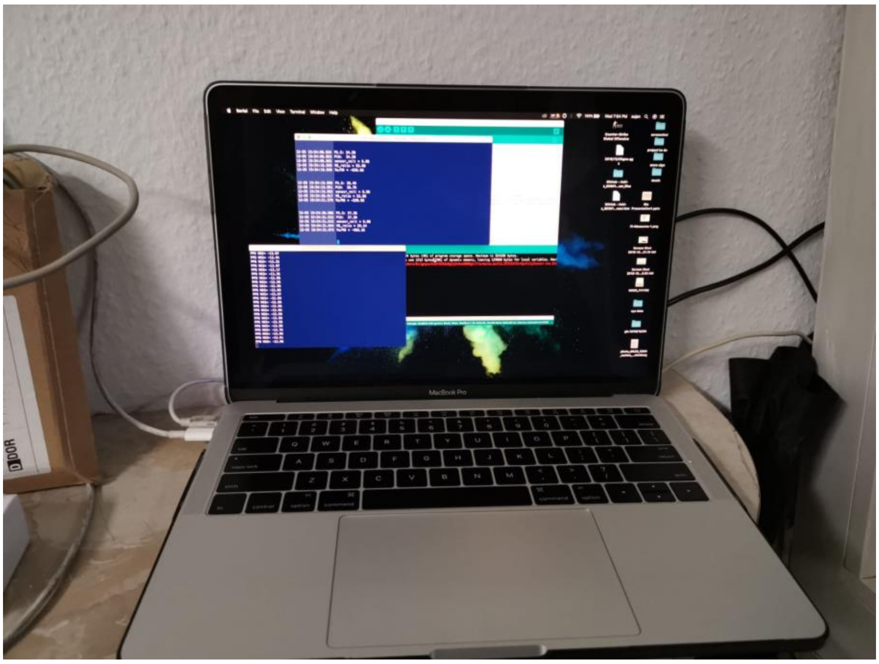
(2)



(3)



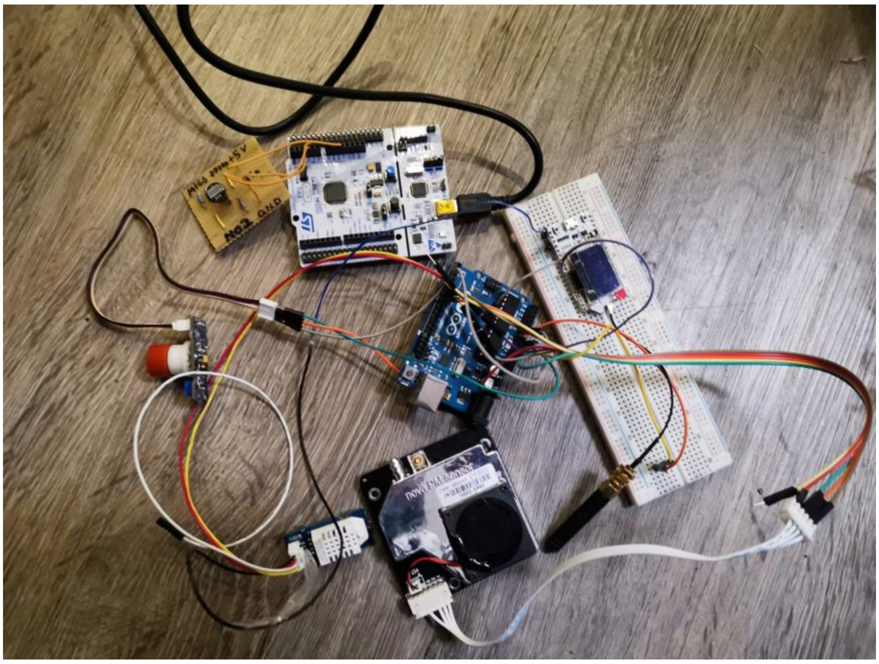
(4)



(5)

(6)

(7)



(8)

Code:

```r
library(ggplot2)
library(tidyverse)
library(dplyr)
library(plotly)

PM10<-read.csv("C:/Users/proth/Desktop/Winter 2018-19/ARP B/Data/Data/PM10.csv")
View(PM10)

PM10$Value <- as.numeric(PM10$Value)

PM10$Date <- as.Date(PM10$Date, format= "%d-%m-%Y")


PM101<-mean(PM10$Value[PM10$Date == "2018-12-22"])
PM1023<-mean(PM10$Value[PM10$Date == "2018-12-23"])
PM1024<-mean(PM10$Value[PM10$Date == "2018-12-24"])
PM1025<-mean(PM10$Value[PM10$Date == "2018-12-25"])
PM102<-mean(PM10$Value[PM10$Date == "2018-12-26"])
PM103<-mean(PM10$Value[PM10$Date == "2018-12-27"])
PM104<-mean(PM10$Value[PM10$Date == "2018-12-28"])
PM105<-mean(PM10$Value[PM10$Date == "2018-12-29"])
PM106<-mean(PM10$Value[PM10$Date == "2018-12-30"])

PM10_f<-data.frame("Date"=c('2018-12-22','2018-12-23','2018-12-24','2018-12-25','2018-12-26','2018-12-27','2018-12-28','2018-12-29'


View(PM10_f)

ggplot(PM10_f, aes(x=Date, y=Value)) +
  #theme_bw() +
  geom_bar(stat = "identity",color = "red") +
  geom_hline(yintercept=50, color = "red",size=1.2)+
  geom_hline(yintercept=50, color = "green", size=1)+
  labs(y="Particulate Matter 10 daily/24 hours Concentration µg/m3",
       title = "Kamp-lintfort Particulate Matter 10 Concentration in December 2018",
       subtitle = "With EU and WHO limit Values where Green color is for EU and RED color is for WHO limit values")



#line graph

ggplot(PM10, aes(x=Date, y=Value)) +
```

(1)

```r
#line graph

ggplot(PM10, aes(x=Date, y=Value)) +
  theme_bw() +
  geom_line(stat = "identity") +
  geom_hline(yintercept=50, color = "red",size=1.2)+
  geom_hline(yintercept=50, color = "green", size=1)+
  labs(y="Particulate Matter 10 daily/24-hours Concentration µg/m3",
       title = "Kamp-Lintfort Particulate Matter 10 Concentration in December 2018",
       subtitle = "With EU and WHO limit Values where Green color is for EU and RED color is for WHO limit values")




#--------------------------------------------------------------------------------------------------------#

NO2<-read.csv("C:/Users/proth/Desktop/Winter 2018-19/ARP B/Data/Data/NO2.csv")
View(NO2)

NO2<-na.omit(NO2)

NO2$Value <- as.numeric(NO2$Hourly)

NO2$Date <- as.Date(NO2$Date, format= "%d-%m-%Y")



NO21<-mean(NO2$Hourly[NO2$Date == "2018-12-26"])
NO22<-mean(NO2$Hourly[NO2$Date == "2018-12-27"])
NO23<-mean(NO2$Hourly[NO2$Date == "2018-12-28"])
NO24<-mean(NO2$Hourly[NO2$Date == "2018-12-29"])
NO25<-mean(NO2$Hourly[NO2$Date == "2018-12-30"])
NO26<-mean(NO2$Hourly[NO2$Date == "2018-12-31"])
NO27<-mean(NO2$Hourly[NO2$Date == "2019-01-01"])
NO28<-mean(NO2$Hourly[NO2$Date == "2019-01-02"])
NO29<-mean(NO2$Hourly[NO2$Date == "2019-01-03"])
NO210<-mean(NO2$Hourly[NO2$Date == "2019-01-04"])

NO2_f<-data.frame("Date"=c('2018-12-26','2018-12-27','2018-12-28','2018-12-29','2018-12-30','2018-12-31','2019-01-01','2019-01-02',
View(NO2_f)
```

(2)

```r
ggplot(NO2_f, aes(x=Date, y=Value)) +
 # theme_bw() +
  geom_bar(stat = "identity",color = "red") +
  geom_hline(yintercept=200, color = "red",size=1.2)+
  geom_hline(yintercept=200, color = "green", size=1)+
  labs(y="Nitrogen drioxide hourly Concentration µg/m3",
       title = "Kamp-lintfort Nitrogen drioxide Concentration in December 2018 & January 2019",
       subtitle = "With EU and WHO limit Values where Green color is for EU and RED color is for WHO limit values")



#line graph

ggplot(NO2_f, aes(x=Date, y=Value)) +
  theme_bw() +
  geom_line(stat = "identity") +
  geom_hline(yintercept=200, color = "red",size=1.2)+
  geom_hline(yintercept=200, color = "green",size=1)+
  labs(y="Nitrogen drioxide hourly Concentration µg/m3",
       title = "Kamp-Lintfort Nitrogen drioxide Concentration in December 2018",
       subtitle = "With EU and WHO limit Values where Green color is for EU and RED color is for WHO limit values")




#---------------------------------------------------------------------------------------------------------------------#


CO<-read.csv("C:/Users/proth/Desktop/Winter 2018-19/ARP B/Data/Data/CO.csv")
View(CO)

CO<-na.omit(CO)

CO$Value <- as.numeric(CO$Value.in.ug.m3)
CO$Value <- as.numeric(CO$eighthours)

CO$Date <- as.Date(CO$Date, format= "%d-%m-%Y")

CO1<-mean(CO$eighthours[CO$Date == "2018-12-26"])
CO2<-mean(CO$eighthours[CO$Date == "2018-12-27"])
CO3<-mean(CO$eighthours[CO$Date == "2018-12-28"])
```

(3)

```r
CO1<-mean(CO$eighthours[CO$Date == "2018-12-26"])
CO2<-mean(CO$eighthours[CO$Date == "2018-12-27"])
CO3<-mean(CO$eighthours[CO$Date == "2018-12-28"])
CO4<-mean(CO$eighthours[CO$Date == "2018-12-29"])
CO5<-mean(CO$eighthours[CO$Date == "2018-12-30"])
View(CO1)

CO_f<-data.frame("Date"=c('2018-12-26','2018-12-27','2018-12-28','2018-12-29','2018-12-30'),"Value"=c(CO1,CO2,CO3,CO4,CO5))
View(CO_f)

ggplot(CO_f, aes(x=Date, y=Value)) +
  #theme_bw() +
  geom_bar(stat = "identity",color = "red") +
  #geom_hline(yintercept=20, color = "red",size=1.2)+#
  geom_hline(yintercept=10, color = "green", size=1)+
  labs(y="Carbon monoxide daily 8 hour mean Concentration mg/m3",
       title = "Kamp-lintfort Carbon monoxide Concentration in December 2018",
       subtitle = "With EU and WHO limit Values where Green color is for EU limit values")


#line graph

ggplot(CO_f, aes(x=Date, y=Value)) +
  theme_bw() +
  geom_line(stat = "identity",color = "red") +
  #geom_hline(yintercept=100, color = "red")+#
  geom_hline(yintercept=10, color = "green")+
  labs(y="Carbon monoxide 8h mean Concentration mg/m3",
       title = "Kamp-Lintfort Carbon monoxide Concentration in December 2018",
       subtitle = "With EU and WHO limit Values where Green color is for EU limit values")

#-----------------------------------------------------------------------------------#


PM2.5<-read.csv("C:/Users/proth/Desktop/Winter 2018-19/ARP B/Data/Data/PM2.5.csv")
View(PM2.5)

PM2.5$Value <- as.numeric(PM2.5$Value)

PM2.5$Date <- as.Date(PM2.5$Date, format= "%d-%m-%Y")
```

(4)

```r

PM2.512<-mean(PM2.5$Value[PM2.5$Date >= "2018-12-22"])
PM2.523<-mean(PM2.5$Value[PM2.5$Date >= "2018-12-23"])
PM2.524<-mean(PM2.5$Value[PM2.5$Date >= "2018-12-24"])
PM2.525<-mean(PM2.5$Value[PM2.5$Date >= "2018-12-25"])
PM2.51<-mean(PM2.5$Value[PM2.5$Date >= "2018-12-26"])
PM2.52<-mean(PM2.5$Value[PM2.5$Date >= "2018-12-27"])
PM2.53<-mean(PM2.5$Value[PM2.5$Date >= "2018-12-28"])
PM2.54<-mean(PM2.5$Value[PM2.5$Date >= "2018-12-29"])
PM2.55<-mean(PM2.5$Value[PM2.5$Date >= "2018-12-30"])

PM2.5_f<-data.frame("Date"=c('2018-12-22','2018-12-23','2018-12-24','2018-12-25','2018-12-26','2018-12-27','2018-12-28','2018-12-2



View(PM2.5_f)

#Bar graph

ggplot(PM2.5_f, aes(x=Date, y=Value)) +
  #theme_bw() +
  geom_bar(stat = "identity",color = "red") +
  geom_hline(yintercept=25, color = "red",size=1.2)+
  geom_hline(yintercept=25, color = "green", size=1)+
  labs(y="Particulate Matter 2.5 daily/24 hours Concentration µg/m3",
       title = "Kamp-lintfort Particulate Matter 2.5 Concentration in December 2018",
       subtitle = "With EU and WHO limit Values where Green color is for EU and RED color is for WHO limit values")


#line graph

ggplot(PM2.5_f, aes(x=Date, y=Value)) +
  theme_bw() +
  geom_line(stat = "identity") +
  geom_hline(yintercept=25, color = "red",size=1.2)+
  geom_hline(yintercept=25, color = "green",size=1)+
  labs(y="Particulate Matter 2.5 daily/24-hours Concentration µg/m3",
       title = "Kamp-Lintfort Particulate Matter 2.5 Concentration in December 2018",
       subtitle = "With EU and WHO limit Values where Green color is for EU and RED color is for WHO limit values")
```

(5)

```r
       subtitle = "With EU and WHO limit Values where Green color is for EU and RED color is for WHO limit values")


#-----------------------------------------------------------------------------------------------#


allcocentration<- read.csv("C:/Users/proth/Desktop/Winter 2018-19/ARP B/Data/Data/allconcentration.csv")
View(allcocentration)

ggplot(allcocentration, aes(x=Date, y=Concentration, group=factor(Pollutants), colour=Pollutants)) +
  theme_bw() +
  geom_line(stat = "identity") +
  labs(y="Pollutants Concentration",
       title = "Kamp-lintfort Pollutants Concentration in December 2018")


#---------------------------------------CITY-----------Duisburg-----------------------------------------#

PM10_Dui<-read.csv("C:/Users/proth/Desktop/Winter 2018-19/ARP B/Data/Data/PM10_Dui.csv")

View(PM10_Dui)


PM10_Dui<-na.omit(PM10_Dui)
View(PM10_Dui)

PM10_Dui$PM10 <- as.numeric(PM10_Dui$PM10)

PM10_Dui$Date <- as.Date(PM10_Dui$Date, format= "%d.%m.%Y")


PM101_Dui<-mean(PM10_Dui$PM10[PM10_Dui$Date == "2018-12-22"])
PM1023_Dui<-mean(PM10_Dui$PM10[PM10_Dui$Date == "2018-12-23"])
PM1024_Dui<-mean(PM10_Dui$PM10[PM10_Dui$Date == "2018-12-24"])
PM1025_Dui<-mean(PM10_Dui$PM10[PM10_Dui$Date == "2018-12-25"])
PM102_Dui<-mean(PM10_Dui$PM10[PM10_Dui$Date == "2018-12-26"])
PM103_Dui<-mean(PM10_Dui$PM10[PM10_Dui$Date == "2018-12-27"])
PM104_Dui<-mean(PM10_Dui$PM10[PM10_Dui$Date == "2018-12-28"])
PM105_Dui<-mean(PM10_Dui$PM10[PM10_Dui$Date == "2018-12-29"])
PM106_Dui<-mean(PM10_Dui$PM10[PM10_Dui$Date == "2018-12-30"])
```

(6)

```r
PM106_Dui<-mean(PM10_Dui$PM10[PM10_Dui$Date == "2018-12-30"])


PM10_f1<-data.frame("Date"=c('2018-12-22','2018-12-23','2018-12-24','2018-12-25','2018-12-26','2018-12-27','2018-12-28','2018-12-2


View(PM10_f1)

ggplot(PM10_f1, aes(x=Date, y=Value)) +
  theme_bw() +
  geom_bar(stat = "identity",color = "blue") +
  geom_hline(yintercept=50, color = "red",size=1.2)+
  geom_hline(yintercept=50, color = "green", size=1)+
  labs(y="Particulate Matter 10 daily/24 hours Concentration µg/m3",
       title = "Duisburg Particulate Matter 10 Concentration in December 2018",
       subtitle = "With EU and WHO limit Values where Green color is for EU and RED color is for WHO limit values")

#line graph

ggplot(PM10_Dui, aes(x=Date, y=PM10)) +
  theme_bw() +
  geom_line(stat = "identity") +
  geom_hline(yintercept=50, color = "red",size=1.2)+
  geom_hline(yintercept=50, color = "green", size=1)+
  labs(y="Particulate Matter 10 daily/24-hours Concentration µg/m3",
       title = "Duisburg Particulate Matter 10 Concentration in December 2018",
       subtitle = "With EU and WHO limit Values where Green color is for EU and RED color is for WHO limit values")

#-----------------------------------------------------Krefeld------------------------------------------------#

PM10_KRE<-read.csv("C:/Users/proth/Desktop/Winter 2018-19/ARP B/Data/Data/PM10_KRE.csv")

View(PM10_KRE)


PM10_KRE<-na.omit(PM10_KRE)
View(PM10_KRE)

PM10_KRE$PM10 <- as.numeric(PM10_KRE$PM10)

PM10_KRE$Date <- as.Date(PM10_KRE$Date, format= "%d.%m.%Y")
```

(7)

```r

PM101_KRE<-mean(PM10_KRE$PM10[PM10_KRE$Date == "2018-12-22"])
PM1023_KRE<-mean(PM10_KRE$PM10[PM10_KRE$Date == "2018-12-23"])
PM1024_KRE<-mean(PM10_KRE$PM10[PM10_KRE$Date == "2018-12-24"])
PM1025_KRE<-mean(PM10_KRE$PM10[PM10_KRE$Date == "2018-12-25"])
PM102_KRE<-mean(PM10_KRE$PM10[PM10_KRE$Date == "2018-12-26"])
PM103_KRE<-mean(PM10_KRE$PM10[PM10_KRE$Date == "2018-12-27"])
PM104_KRE<-mean(PM10_KRE$PM10[PM10_KRE$Date == "2018-12-28"])
PM105_KRE<-mean(PM10_KRE$PM10[PM10_KRE$Date == "2018-12-29"])
PM106_KRE<-mean(PM10_KRE$PM10[PM10_KRE$Date == "2018-12-30"])


PM10_f2<-data.frame("Date"=c('2018-12-22','2018-12-23','2018-12-24','2018-12-25','2018-12-26','2018-12-27','2018-12-28','2018-12-2


View(PM10_f2)

ggplot(PM10_f2, aes(x=Date, y=Value)) +
  theme_bw() +
  geom_bar(stat = "identity", color = "blue") +
  geom_hline(yintercept=50, color = "red",size=1.2)+
  geom_hline(yintercept=50, color = "green", size=1)+
  labs(y="Particulate Matter 10 daily/24 hours Concentration µg/m3",
       title = "Krefeld Particulate Matter 10 Concentration in December 2018",
       subtitle = "With EU and WHO limit Values where Green color is for EU and RED color is for WHO limit values")


#line graph

ggplot(PM10_KRE, aes(x=Date, y=PM10)) +
  theme_bw() +
  geom_line(stat = "identity") +
  geom_hline(yintercept=50, color = "red",size=1.2)+
  geom_hline(yintercept=50, color = "green", size=1)+
  labs(y="Particulate Matter 10 daily/24-hours Concentration µg/m3",
       title = "Krefeld Particulate Matter 10 Concentration in December 2018",
       subtitle = "With EU and WHO limit Values where Green color is for EU and RED color is for WHO limit values")
```

(8)

```r
#------------------------------Wesel-------------------------------------------------#

PM10_Wes<-read.csv("C:/Users/proth/Desktop/Winter 2018-19/ARP B/Data/Data/PM10_WES.csv")

View(PM10_Wes)


PM10_Dui<-na.omit(PM10_Wes)
View(PM10_Wes)

PM10_Wes$PM10 <- as.numeric(PM10_Wes$PM10)

PM10_Wes$Date <- as.Date(PM10_Wes$Date, format= "%d.%m.%Y")




PM101_Wes<-mean(PM10_Wes$PM10[PM10_Wes$Date == "2018-12-22"])
PM1023_Wes<-mean(PM10_Wes$PM10[PM10_Wes$Date == "2018-12-23"])
PM1024_Wes<-mean(PM10_Wes$PM10[PM10_Wes$Date == "2018-12-24"])
PM1025_Wes<-mean(PM10_Wes$PM10[PM10_Wes$Date == "2018-12-25"])
PM102_Wes<-mean(PM10_Wes$PM10[PM10_Wes$Date == "2018-12-26"])
PM103_Wes<-mean(PM10_Wes$PM10[PM10_Wes$Date == "2018-12-27"])
PM104_Wes<-mean(PM10_Wes$PM10[PM10_Wes$Date == "2018-12-28"])
PM105_Wes<-mean(PM10_Wes$PM10[PM10_Wes$Date == "2018-12-29"])
PM106_Wes<-mean(PM10_Wes$PM10[PM10_Wes$Date == "2018-12-30"])


PM10_f3<-data.frame("Date"=c('2018-12-22','2018-12-23','2018-12-24','2018-12-25','2018-12-26','2018-12-27','2018-12-28','2018-12-2


View(PM10_f3)

ggplot(PM10_f3, aes(x=Date, y=Value)) +
  theme_bw() +
  geom_bar(stat = "identity", color = "blue") +
  geom_hline(yintercept=50, color = "red",size=1.2)+
  geom_hline(yintercept=50, color = "green", size=1)+
  labs(y="Particulate Matter 10 daily/24 hours Concentration µg/m3",
       title = "Wesel Particulate Matter 10 Concentration in December 2018",
```

(9)

```r

#line graph

ggplot(PM10_Wes, aes(x=Date, y=PM10)) +
  theme_bw() +
  geom_line(stat = "identity") +
  geom_hline(yintercept=50, color = "red",size=1.2)+
  geom_hline(yintercept=50, color = "green", size=1)+
  labs(y="Particulate Matter 10 daily/24-hours Concentration µg/m3",
       title = "Wesel Particulate Matter 10 Concentration in December 2018",
       subtitle = "With EU and WHO limit Values where Green color is for EU and RED color is for WHO limit values")


#---------------------------------NO2-------------------------------------------------------------------------#


NO2_Dui<-read.csv("C:/Users/proth/Desktop/Winter 2018-19/ARP B/Data/Data/NO2_DUI.csv")
View(NO2_Dui)

NO2_Dui<-na.omit(NO2_Dui)

NO2_Dui$Hourly <- as.numeric(NO2_Dui$Hourly)

NO2_Dui$Date <- as.Date(NO2_Dui$Date, format= "%d.%m.%Y")



NO21_Dui<-mean(NO2_Dui$Hourly[NO2_Dui$Date == "2018-12-26"])
NO22_Dui<-mean(NO2_Dui$Hourly[NO2_Dui$Date == "2018-12-27"])
NO23_Dui<-mean(NO2_Dui$Hourly[NO2_Dui$Date == "2018-12-28"])
NO24_Dui<-mean(NO2_Dui$Hourly[NO2_Dui$Date == "2018-12-29"])
NO25_Dui<-mean(NO2_Dui$Hourly[NO2_Dui$Date == "2018-12-30"])
NO26_Dui<-mean(NO2_Dui$Hourly[NO2_Dui$Date == "2018-12-31"])
NO27_Dui<-mean(NO2_Dui$Hourly[NO2_Dui$Date == "2019-01-01"])
NO28_Dui<-mean(NO2_Dui$Hourly[NO2_Dui$Date == "2019-01-02"])
NO29_Dui<-mean(NO2_Dui$Hourly[NO2_Dui$Date == "2019-01-03"])
NO210_Dui<-mean(NO2_Dui$Hourly[NO2_Dui$Date == "2019-01-04"])

NO2_f5<-data.frame("Date"=c('2018-12-26','2018-12-27','2018-12-28','2018-12-29','2018-12-30','2018-12-31','2019-01-01','2019-01-02'
View(NO2_f5)
```

(10)

```r
NO2_f5<-data.frame("Date"=c('2018-12-26','2018-12-27','2018-12-28','2018-12-29','2018-12-30','2018-12-31','2019-01-01','2019-01-02'
View(NO2_f5)


ggplot(NO2_f5, aes(x=Date, y=Value)) +
  theme_bw() +
  geom_bar(stat = "identity") +
  geom_hline(yintercept=200, color = "red",size=1.2)+
  geom_hline(yintercept=200, color = "green", size=1)+
  labs(y="Nitrogen drioxide hourly Concentration µg/m3",
       title = "Duisburg Nitrogen drioxide Concentration in December 2018",
       subtitle = "With EU and WHO limit Values where Green color is for EU and RED color is for WHO limit values")



#line graph

ggplot(NO2_f5, aes(x=Date, y=Value)) +
  theme_bw() +
  geom_line(stat = "identity") +
  geom_hline(yintercept=200, color = "red",size=1.2)+
  geom_hline(yintercept=200, color = "green",size=1)+
  labs(y="Nitrogen drioxide hourly Concentration µg/m3",
       title = "Duisburg Nitrogen drioxide Concentration in December 2018",
       subtitle = "With EU and WHO limit Values where Green color is for EU and RED color is for WHO limit values")


#------------------------------------------------------------------------------------------#



NO2_Wes<-read.csv("C:/Users/proth/Desktop/Winter 2018-19/ARP B/Data/Data/NO2_WES.csv")
View(NO2_Wes)

NO2_Wes<-na.omit(NO2_Wes)

NO2_Wes$Hourly <- as.numeric(NO2_Wes$Hourly)

NO2_Wes$Date <- as.Date(NO2_Wes$Date, format= "%d.%m.%Y")
```

(11)

```r
NO21_Wes<-mean(NO2_Wes$Hourly[NO2_Wes$Date == "2018-12-26"])
NO22_Wes<-mean(NO2_Wes$Hourly[NO2_Wes$Date == "2018-12-27"])
NO23_Wes<-mean(NO2_Wes$Hourly[NO2_Wes$Date == "2018-12-28"])
NO24_Wes<-mean(NO2_Wes$Hourly[NO2_Wes$Date == "2018-12-29"])
NO25_Wes<-mean(NO2_Wes$Hourly[NO2_Wes$Date == "2018-12-30"])
NO26_Wes<-mean(NO2_Wes$Hourly[NO2_Wes$Date == "2018-12-31"])
NO27_Wes<-mean(NO2_Wes$Hourly[NO2_Wes$Date == "2019-01-01"])
NO28_Wes<-mean(NO2_Wes$Hourly[NO2_Wes$Date == "2019-01-02"])
NO29_Wes<-mean(NO2_Wes$Hourly[NO2_Wes$Date == "2019-01-03"])
NO210_Wes<-mean(NO2_Wes$Hourly[NO2_Wes$Date == "2019-01-04"])

NO2_f6<-data.frame("Date"=c('2018-12-26','2018-12-27','2018-12-28','2018-12-29','2018-12-30','2018-12-31','2019-01-01','2019-01-02'
View(NO2_f6)


ggplot(NO2_f6, aes(x=Date, y=Value)) +
  theme_bw() +
  geom_bar(stat = "identity") +
  geom_hline(yintercept=200, color = "red",size=1.2)+
  geom_hline(yintercept=200, color = "green", size=1)+
  labs(y="Nitrogen drioxide hourly Concentration µg/m3",
       title = "Wesel Nitrogen drioxide Concentration in December 2018",
       subtitle = "With EU and WHO limit Values where Green color is for EU and RED color is for WHO limit values")



#line graph

ggplot(NO2_Wes, aes(x=Date, y=Hourly)) +
  theme_bw() +
  geom_line(stat = "identity") +
  geom_hline(yintercept=200, color = "red",size=1.2)+
  geom_hline(yintercept=200, color = "green",size=1)+
  labs(y="Nitrogen drioxide hourly Concentration µg/m3",
       title = "Wesel Nitrogen drioxide Concentration in December 2018",
       subtitle = "With EU and WHO limit Values where Green color is for EU and RED color is for WHO limit values")
```

(12)

```r
#line graph

ggplot(NO2_Wes, aes(x=Date, y=Hourly)) +
  theme_bw() +
  geom_line(stat = "identity") +
  geom_hline(yintercept=200, color = "red",size=1.2)+
  geom_hline(yintercept=200, color = "green",size=1)+
  labs(y="Nitrogen drioxide hourly Concentration µg/m3",
       title = "Wesel Nitrogen drioxide Concentration in December 2018",
       subtitle = "With EU and WHO limit Values where Green color is for EU and RED color is for WHO limit values")




#----------------------------------------COMPARE-----------------------------------------#
data<- read.csv("C:/Users/proth/Desktop/Winter 2018-19/ARP B/Data/Data/allconcentration.csv")


r <- plot_ly(data, x = ~Date, y = ~Concentration,type = 'scatter', mode = 'markers', color=as.factor(data$Pollutants),
             size = ~Concentration) %>%
  layout(title = 'All Pollutants Concentration in Kamp-Linfort ',
         xaxis = list(showgrid = FALSE),
         yaxis = list(showgrid = FALSE))
r


Compare<-read.csv("C:/Users/proth/Desktop/Winter 2018-19/ARP B/Data/Data/Compare/Compare_PM10.csv")
View(Compare)

barplot(Compare, beside = TRUE, legend= rownames(Compare), ylab = "Concentration")
```

(13)

Declaration of Authenticity

We hereby declare that the work presented herein is our own work completed without the use of any aids other than those listed. Any material from other sources or works done by others has been given due acknowledgement and listed in the reference section. Sentences or parts of sentences quoted literally are marked as quotations; identification of other references with regard to the statement and scope of the work is quoted.

The work presented herein has not been published or submitted elsewhere for assessment in the same or a similar form. We will retain a copy of this assignment until after the Board of Examiners has published the results, which We will make available on request.

Bhuwan Acharya (Matriculation Number: 26129)

Bikash Paudel (Matriculation Number: 26192)

Ashikul

Md. Ashikul Islam (Matriculation Number: 24387)

Md. Monsur Ali (Matriculation Number: 24547)