The impact of weather on air quality

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Abstract

The research consisted of investigating the relationships between airborne black carbon and other weather data (temperature, barometric pressure, humidity and precipitation) in Kilingi-Nõmme, Estonia. Different types of GLOBE observations data have been used in the research, weather data and black carbon measurements data.

Research has shown that the concentration of black carbon in the air is most influenced by temperature. During periods of warmer weather, there is less black carbon in the air and during periods of colder weather, there is more black carbon in the air. The heating season during winter increases the concentration of airborne black carbon. All indicators are within the norm 0-12,0 μg/m^3, airborne black carbon concentration in the air can be considered good in Kilingi-Nõmme throughout the whole measurement period.

Keywords: airborne black carbon, weather, air and air quality.

Research Question and Hypothesis:

Based on the information gathered on the topic, we proposed research questions and hypotheses:

- Which weather parameters affect the concentration airborne of black carbon?
- How do seasonal weather changes affect airborne black carbon concentration?

Based on these questions we set up hypotheses:

- Airborne black carbon concentration depends mostly on temperature.
- There is less airborne black carbon during the warm season than during the cold season.

Introduction and Review of Literature

Kilingi-Nõmme Gymnasium has participated in the GLOBE program for 23 years. During this time different weather parameters have been measured. The aim of this study is to identify the relationships between the concentration of airborne black carbon and weather parameters (temperature, relative humidity, barometric pressure, precipitation). The research area is located in the city of Kilingi-Nõmme is in Saarde parish, Pärnu county. Kilingi-Nõmme is a small town in southwest Estonia with a population of 1650 (2019) (Statistics Estonia). Area is surrounded by mixed or pine forests and fields, there are many parks in the town. Kilingi-Nõmme has a transitional temperate climate. Kilingi-Nõmme is located in the transition area from Pärnu lowland to Sakala upland. Our climate is influenced by the proximity of the sea and the Sakala upland (Arold, 2005). The land here is natural sandy soil covered with pine forests (Figure 1).

High concentrations of black carbon in the air have negative impact on human health and the environment. In order to better understand the impact we need data about parameters during different years and seasons. Air and air quality are very important issues because in many big cities the air is already heavily polluted and people are experiencing health problems as a result. The measured and modelled values are better correlated during the heating period. Lower correlations in summer are expected, as the combustion emissions, responsible for most of BC, are lower. Somewhat surprisingly, the BC measurements are somewhat better correlated with model estimations than PM2.5 measurements. The reason may be in the database of emissions: no wind-blown dust neither from agricultural areas, nor from roads is included. Thus, combustion emissions are dominating (Reis, 2013).

Figure 1. Kilingi-Nõmme from space (Estonian Land Board).

Airborne black carbon is a component of fine particulate matter, PM2.5, and this is used as an indicator for assessing air quality (EPA United States). In the EU, the daily limit value for PM2.5 is 15 µg / m3 (micrograms per cubic meter) and the air quality 24-Hour PM2.5 Standard (µg/m3) 0-12,0 is considered good (Table 1).

Table 1. 24-Hour $PM_{2.5}$ Standard (µg/m^3) (European Environment Agency).

$PM_{2.5}$	Air quality
0-12,0	Good
12,1-35,4	Moderate
35,5-55,4	Unhealthy for sensitive groups
55,5-150,4	Unhealthy
150,5-250,4	Very unhealthy

About 50% of Estonia is covered by forests or woodlands. The population is over 1.3 million (1 328 360 by 1st of January 2020, Statistics Estonia). Estonia is sparsely populated.

Research Methods and Materials

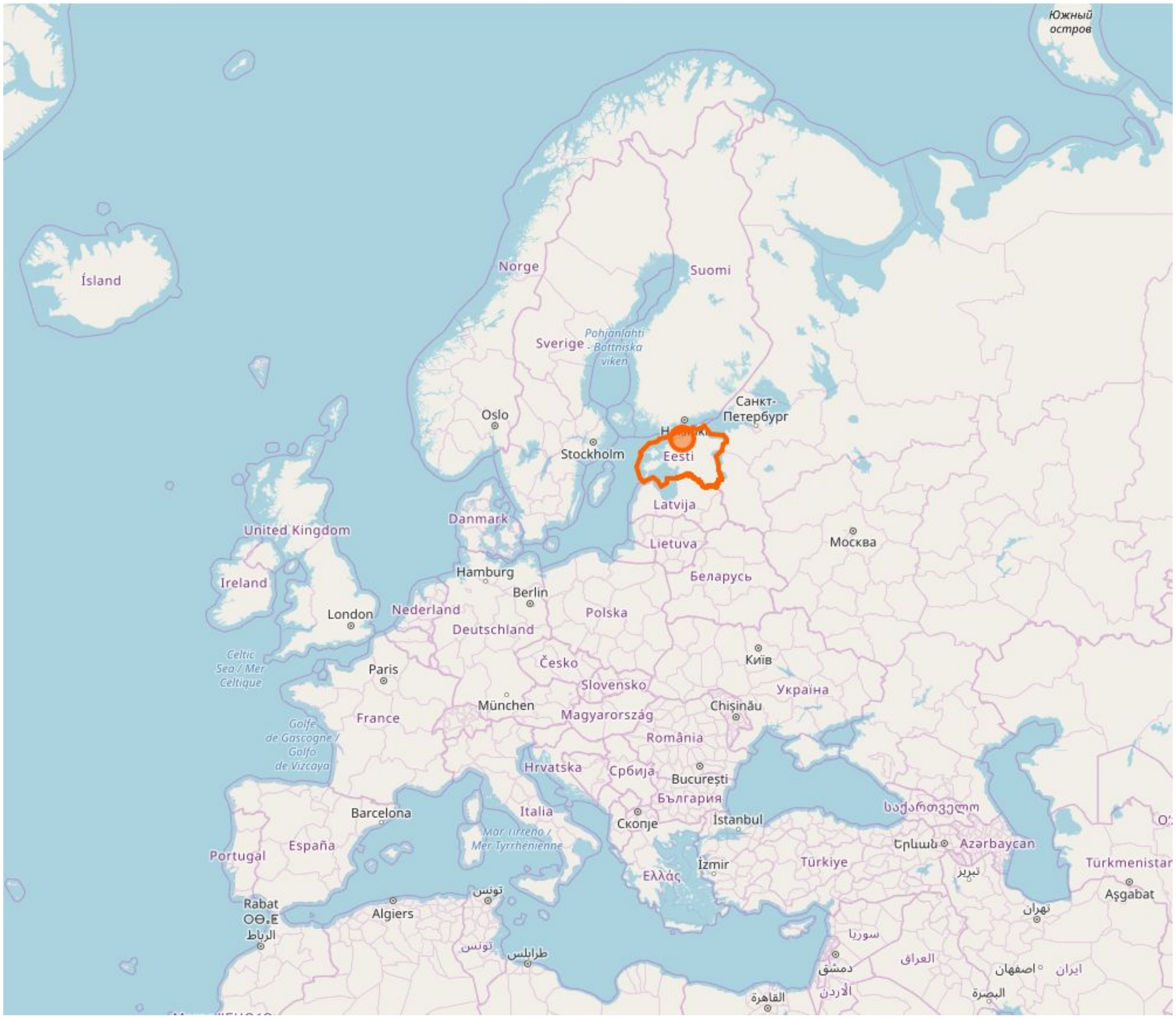

Figure 2. Location of Estonia in Europe (OpenStreetMaps).

Figure 3. Study site location. Weather observations are made at point A, black carbon measurements are made at point B (Estonian Land Board).

Weather measurements are made at the weather observation station next to the school. Measurements are taken daily, at noon, up to one hour before or after the astronomical noon (Figure 3). Atmospheric measurements are usually made by students who have at that time either a geography or a science lesson. During the weather observation, the average temperature, atmospheric pressure, precipitation and humidity are recorded, in addition, cloud types are viewed and photographed in every cardinal direction (N, E, S, W).

Our school has nearly 60 000 data entries in GLOBE. We have the most data on temperatures.

Daily atmospheric measurements (GLOBE protocols that we used) (Figure 4):

- temperature (^{0}C)
- precipitation (mm)
- relative humidity (%)
- barometric pressure (mb)

Figure 4. Weather measurements. Picture by Eliise Mändmets.

Daily measurements of the concentration of airborne black carbon (ng/m^3) were made during 14 measurement periods (Figures 7,8,9 and 10). Each period was 14 days. Measurements were made every morning between 8:05 a.m.- 8:45 a.m. Black carbon measurements were taken with a device that was installed outside the third-floor window. Measurements were taken between 2012 and 2017 (Figure 3).

Data analysis methods covered

- Descriptive statistics
- Correlation analysis
- Semi-structured interview (Figure 5)

We conducted a semi-structured interview with the environmental specialist of Saarde parish, our local municipal government. The interview covered several questions including:

- Which human activities affect the air quality in our area?
- What is the current state of our air quality?
- Are there any measurements on air pollutants in the area?

From that interview we found out that the main factors which affect our air quality are as follows:

- Local heating systems
- Burning trash/bonfires
- Air source heat pumps
- Old vehicles
- Forest fires
- Weather

Figure 5. Interview. Picture by Elli Altin.

From the government we received data about the businesses in the area that have polluter´s permits. Each company also has a certain black carbon limit that must not be exceeded.
There were a total of three companies in our municipality to which allowances were allocated. These are mainly companies in the metal and wood industries. According to information from the interview, all pollutants in our companies are within the limits allowed in Estonia.

Kilingi-Nõmme is green town surrounded by forests. Our weather measurements site's MUC code is 1121: "woodland, Mainly Evergreen, Needle-Leaved, Irregularly Rounded Crowns Dominated by trees (more than 50% of the canopy) with broad, irregularly rounded crowns (e.g., *Pinus sylvestris*)." (GLOBE MUC field codes, page 33).

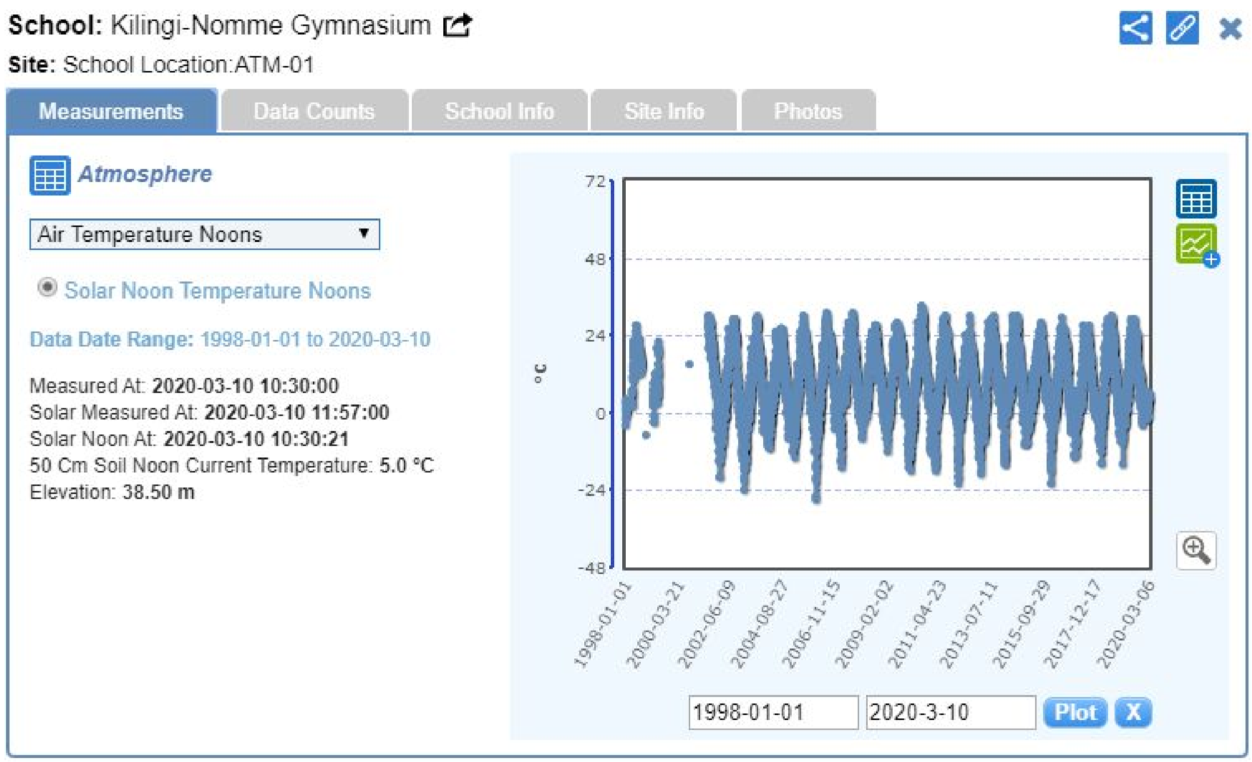

Figure 6. GLOBE data on air temperatures in our school (GLOBE visualization).

Results

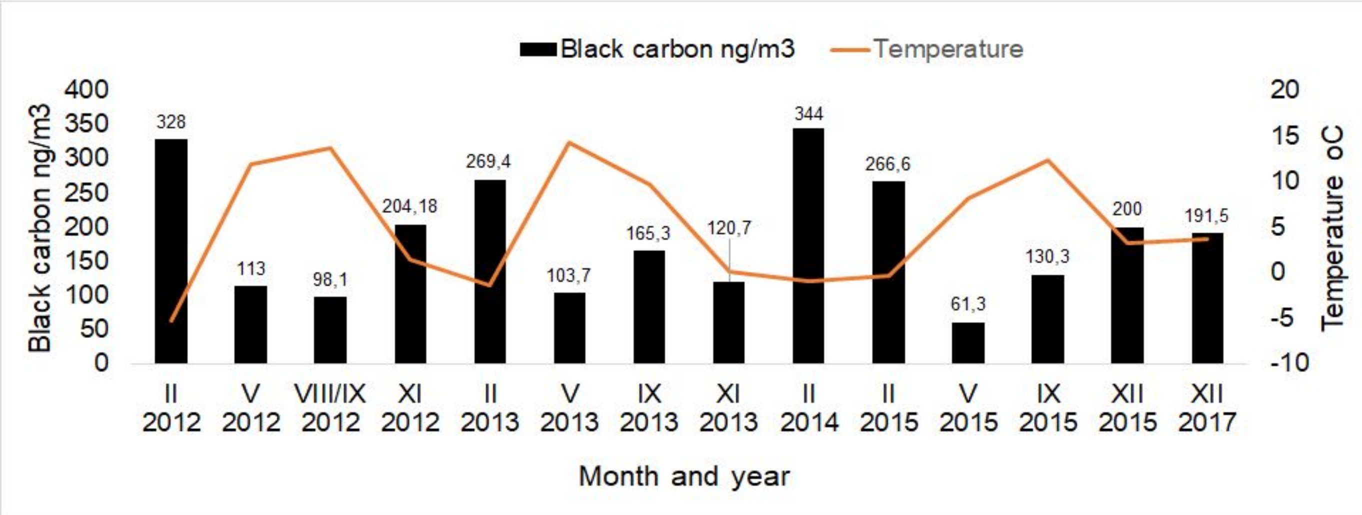

Figure 7. The concentration of airborne black carbon and temperature.

The highest measured value of airborne black carbon was 344 ng/m^3 and the lowest 61.3 ng/m^3. The highest value of airborne black carbon was measured in February 2014 and the lowest in May 2015. The highest temperature of 14.2 degrees was measured in May 2013. The minimum temperature of -5.3 degrees was measured in February 2012.

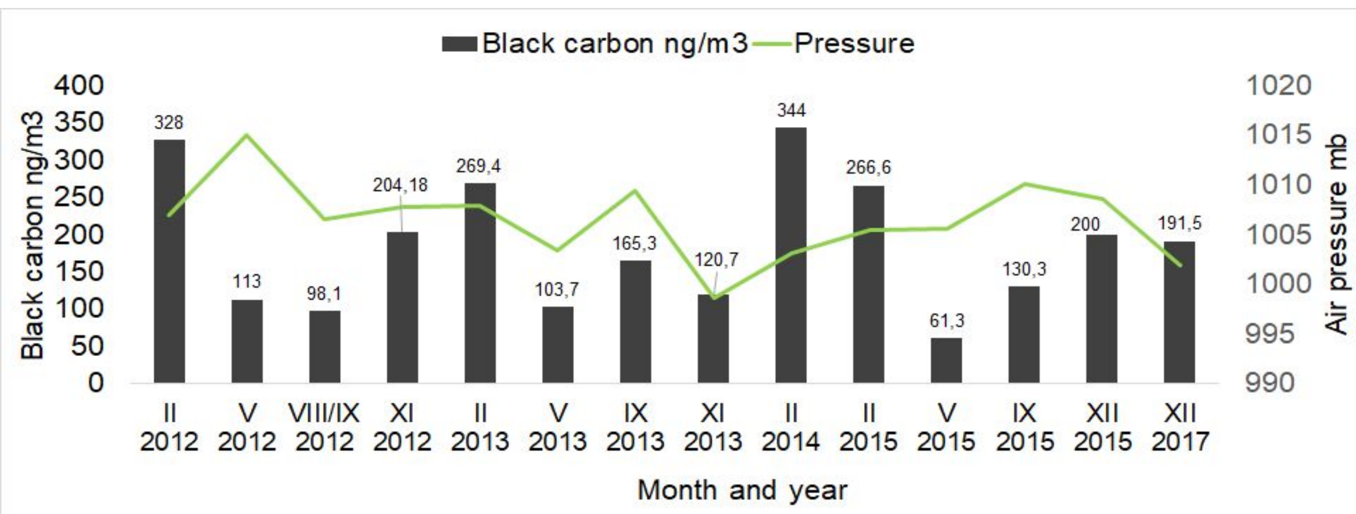

Figure 8. The concentration of black carbon and barometric pressure.

The lowest barometric pressure of 998.6 mb was measured in November 2013. The highest barometric pressure of 1015 mb was measured in May 2012. The correlation between barometric air pressure and the concentration of airborne black carbon is positive (0,2, low correlation). With higher barometric pressure there is more airborne black carbon in the air.

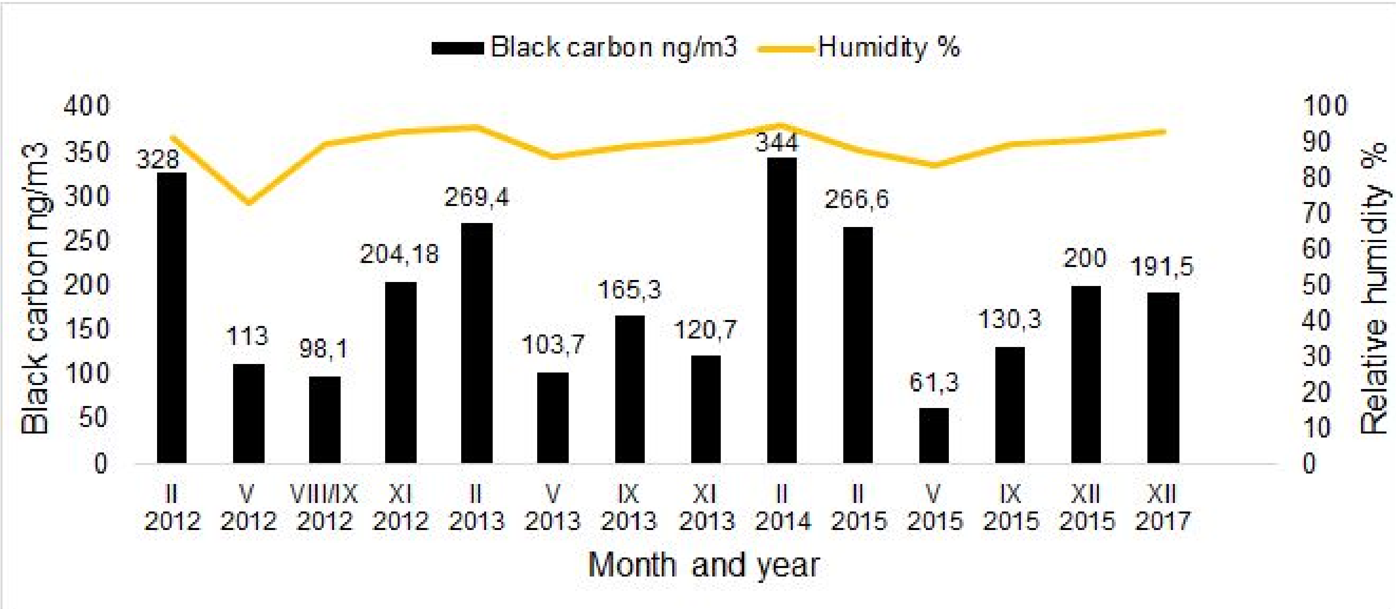

Figure 9. Airborne black carbon concentration and relative humidity.

The impact of air humidity on the concentration of black carbon is low, there is no correlation (0.05). The humidity measurement period with 95% humidity will remain in February 2014. The humidity measurement period with the lowest humidity - 73.5% will remain in 2012.

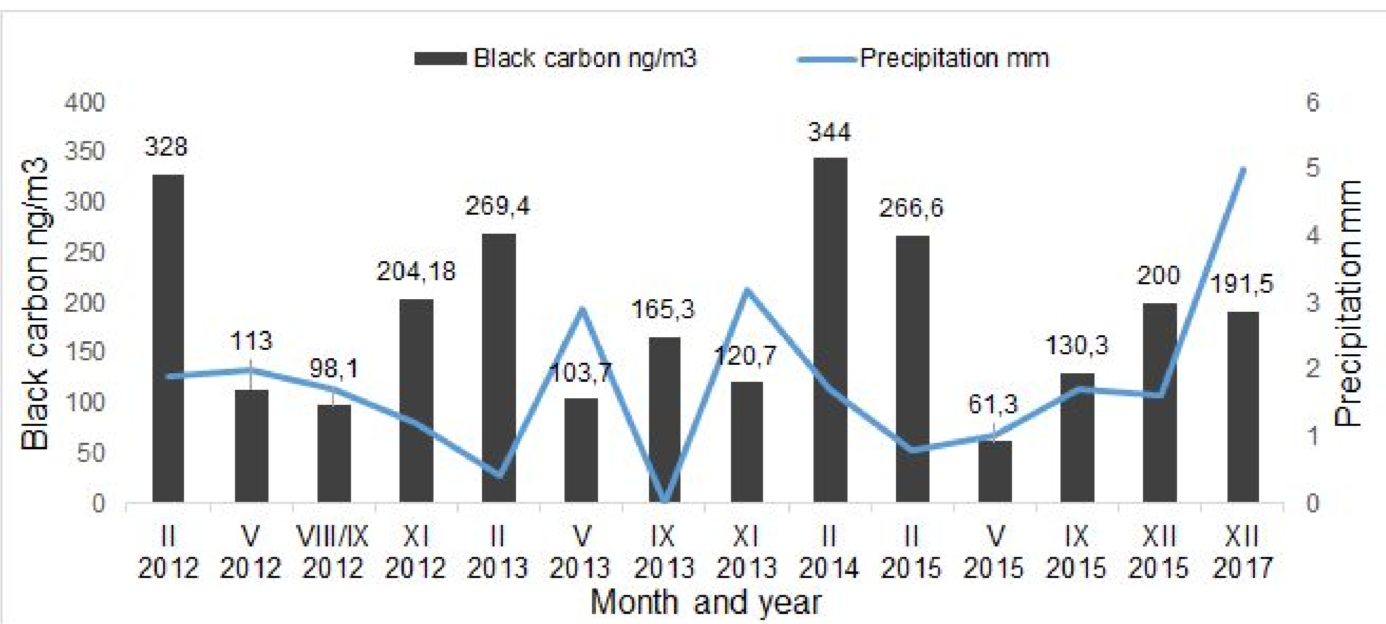

Figure 10. Airborne black carbon concentration and precipitation.

The impact of precipitation on airborn black carbon is very small, with a correlation of -0.02. The highest precipitation during the measurement period in December 2017 was 5mm. The lowest precipitation during the measurement period was in September 2013 with 0mm.

Table 2. Airborne black carbon concentration, $PM_{2.5}$ (particulate matter) and air quality in Kilingi-Nõmme 2012-2017.

Month	II	V	IX	XI	Average of all measurements
Black carbon concentration 24-hour µg/m^3	0,30	0,10	0,13	0,14	0,17
$PM_{2.5}$ 24-hour µg/m^3	2,4-7,2	0,8-2,8	1,1-3,3	1,1-3,3	1,3-4,0

PM2.5 can be considered good throughout the years. The value is lowest (the best quality) in May and highest in February (Table 1; 2). The highest concentration of black carbon 908,6 ng/m3 (0.908 µg/m3) in Kilingi-Nõmme was measured on 13.02.2012.

Discussion

Based on the report on activities related to ambient air pollution, all indicators are within the norm 0-12,0 µg/m^3 (Table 1). Firstly, we compared the concentration of airborne black carbon to the temperature measured during the same period. Our calculations indicated that the correlation between the temperature and the concentration of airborne black carbon is negative (-0,52, medium correlation, figure 7). During warmer periods there is less black carbon in the air. The heating season during winter increases the concentration of black carbon.

In the future, black carbon concentration can be investigated, not only in Kilingi-Nõmme but also in other areas. For example, other hazardous compounds in the air and their relationship to weather conditions could be explored too.

Conclusion

Air temperature affects the concentration of airborne black carbon in the air. The concentration of airborne black carbon is the highest in February and lowest in May. There is no correlation between the relative humidity and black carbon concentration in the air and between the precipitation and the concentration of black carbon in the air. Compared to the EU norms, the concentration of airborne black carbon in Kilingi-Nõmme is low throughout the whole year and the air quality can be considered good.

We also discovered that all weather parameters gave some influence on the black carbon concentration and air temperature have the most influence on black carbon concentrate in the air and values are correlated during the heating period (Reis, 2013). There is negative correlation between air temperature and black carbon concentration of -0.52. As the temperature rises, airborne black carbon concentration in the air decreases.

As we did not choose a set measurement periods, our observations were made during different months each year. Thus we cannot be completely sure of the results. To get accurate results, we need to take measurements over several years during the same months.

What we could investigate in the future?

The concentration of black carbon and the relationship between wood cutting could be further investigated. Although there are many trees in our city and the surrounding forests, it would be interesting to see if there is a relationship between large amount of trees in the area and the concentration of airborne black carbon. In recent years, the forests around the city have become mature, and there are less trees that bind carbon. The trees are planted back, but it would be fascinating to see if the change in carbon content can also be seen in the measurements.

In the future, a similar research project could certainly be repeated to see if the concentration of black carbon in the air has fallen or increased. Next time, repeating the research, we could choose the measurement periods so that they are at the same dates every year. This way we can get more accurate results. In addition to European Union standards, the results could be compared with worldwide limits as well.

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