Analysis of air quality and meteorological conditions in Warsaw

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1. Meteorological conditions in Legionowo the period of 28 – 30 March 2020

Day	Hour	Air temperature at 100 m [°C]	Wind speed at 100 m [m/s]	Inversion layer occurrence*	Inversion layer height** [m]	Ventilation coefficient*** [m^2/s]
28/03/2020	00:00	2.4	2.315	YES	300	1095
	12:00	16.7	3.087	NO	1500	4630
29/03/2020	00:00	2.8	2.058	YES	234	482
	12:00	9.9	5.247	YES	900	4722
30/03/2020	00:00	-0.53	2.264	NO	1500	3396
	12:00	2.68	3.190	NO	1500	4785

Table 1 – meteorological conditions in Legionowo on28th – 30th March

* YES/NO

** If inversion layer does not occur assume that mixing layer height is equal to 1 500 m

*** Assume that mixing layer height is equal to inversion layer height

Ventilation coefficient =the product of the height of the mixing layer and the average wind speed in that layer.

Vc1=300x2.315=695 [m2/s]

Vc2=1500x3.087=4630 [m2/s]

Vc3=234x2,058=482 [m2/s]

Vc4= 900x5,247=4722 [m2/s]

Vc5=1500x2,264=3396 [m2/s]

Vc6=1500X3,190=4785 [m2/s]

From the table above, we can see that typically, the air near the surface of the earth is warmer in the daytime because of the absorption of the sun's energy.

The low temperature and low wind speed (such as in 28th 00:00 and 29th 00:00) may maintain a stable atmospheric condition and cause the form of the inversion layer, this layer occurs when warm air is above cool air and the mixing depth is significantly restricted. During this time, air pollutants can release into the atmosphere's lowest layer can trap there, which cause severe air pollution.

2. Air quality in Warsaw in the period of 28 – 30 March 2020

Analyze the hourly concentrations of PM2.5 and PM10 observed at Warszawa-Targówek air quality monitoring site against the meteorological conditions from point #1.

Legionowo-Zegrzyńska		
Unit	**PM2.5 g / m^3**	**PM10 g / m^3**
2020-03-28 00:00	138.5	151.3
2020-03-28 12:00	59.2	69.7
2020-03-29 00:00	197.3	211.9
2020-03-29 12:00	61.7	69.3
2020-03-30 00:00	4.8	6.1
2020-03-30 12:00	2.4	5.3

Table 2 – concentrations of PM2.5 and PM10 in Legionowo on28th – 30th March

Warsaw-Targówek		
Unit	**PM2.5 g / m^3**	**PM10 g / m^3**
2020-03-28 00:00	60.7	73.6
2020-03-28 12:00	61.5	76.5
2020-03-29 00:00	111.8	153.9
2020-03-29 12:00	66.3	79.5
2020-03-30 00:00	5.0	6.5
2020-03-30 12:00	1.4	4.2

Table 3 – concentrations of PM2.5 and PM10 in Targówek on28th – 30th March

The tables above show the PM2.5 and PM10 from 28th to 30th March in two stations (Legionowo and Targówek) in Warsaw.

When we compare these two places, we can find that the trends in the concentration of PM2.5 and PM10 is similar. Generally, the concentration in the daytime is slightly higher than in the night, the concentration of PM10 is relatively higher than the concentration of PM2.5. When we look at time scale, we observe that the PM is in a moderate state at 28th, but when at 00:00 29th, it increased significantly to a dangerous level, then at 12:00 29th, the PM turn back to the similar concentration as in 28th, while after 12hour, the PM drop to a very low concentration and keep this healthy level for the whole day in 30th March.

When we compare the PM concentrations to the Meteorological conditions in Warsaw, we can find some patterns between the two. As for the 29th 00:00, the highest PM concentrations correspond to the lowest ventilation coefficient, which causes by the form of the low height inversion layer. Then after 12hours, when the temperature is rising and the wind speed up, we can see the effect of the inversion layer is decreasing, and the ventilation coefficient comes back to a daily level.

But on the 30th, you can see a sharp drop in PM concentration, this phenomenon can correspond to the rapid cooling on the 30th, in the meantime, the relatively strong wind which may eliminate the effect of the inversion layer and able to remove the trapped air pollutants.

3. Conclusions

Briefly describe the reasons of poor air quality in Warsaw in the period of 28 – 30 March 2020.

AQI	Air Pollution Level	Health Implications	Cautionary Statement (for PM2.5)
0 - 50	Good	Air quality is considered satisfactory, and air pollution poses little or no risk	None
51 -100	Moderate	Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people who are unusually sensitive to air pollution.	Active children and adults, and people with respiratory disease, such as asthma, should limit prolonged outdoor exertion.
101-150	Unhealthy for Sensitive Groups	Members of sensitive groups may experience health effects. The general public is not likely to be affected.	Active children and adults, and people with respiratory disease, such as asthma, should limit prolonged outdoor exertion.
151-200	Unhealthy	Everyone may begin to experience health effects; members of sensitive groups may	Active children and adults, and people with respiratory disease, such as asthma, should avoid prolonged outdoor exertion; everyone else,
201-300	Very Unhealthy	Health warnings of emergency conditions. The entire population is more likely to be affected.	Active children and adults, and people with respiratory disease, such as asthma, should avoid all outdoor exertion; everyone else, especially children, should limit outdoor exertion.

Table 4 - the Air Quality Index scale as defined by the US-EPA 2016 standard [3]

On the whole, according to the standards in table 4, the air pollution level in Legionowo on the 28th is between “unhealthy for sensitive groups” and “moderate” level; And on 29th the PM increasing significantly reach to the “unhealthy” or even “very unhealthy” level; But on 30th, the air quality back to the “good” level.

The causes of air pollution in Legionowo will be analyzed from two main aspects of weather and geography.

Weather: The main reason for the weather has been mentioned before, cold air is under the warm air with low wind speeds form a reversal layer above the surface, thereby capturing and retaining pollutant particles that are emitted into the atmosphere, the long residency over an urban (industrial) area usually results in episodes of severe smog. From the left of fig 1, we can see that the temperature in 29th and 30th is obviously lower than 28th, which create the conditions for the reversion layer.

The mitigation of the pollution situation on the 30th can be understood as a sudden drop in temperature to minus zero and a strong wind breaking the inversion layer, so that the polluted particles no longer accumulate above the surface, but settle to the surface or continue to move upward with the airflow. In addition, there is 0.3mm rainfall on this day (see right of figure 1), which also helps the sedimentation of pollutants particles.

Fig 1 –highest and lowest temperatures in March 2020(left); b. Temperature and rainfall on March 30(right)

Geography: As we all know, Poland is a large coal consuming country, coal supports more than 70% of Poland 's energy supply, so when heating in winter, the incomplete combustion of fossil fuels and biomass can form more black carbon and other air pollutants, the release of them with vehicle exhaust, factory emissions, etc., it is the main cause of the serious and repeated air pollution problems in Warsaw in winter.

But when we compare two areas in Warsaw from table 2 and table 3, we can find that even they have a similar trend of PM, but the concentrations of PM2.5 and PM10 have a big difference, the Legionowo was more polluted than Targówek.

In fig 2, it shows the location of Legionowo, which is located 23 kilometers to the north-east of the center of Warsaw, this distraction have many industrials, and the heating contractor PEC is only three blocks far from the air monitoring station, therefore, there is reason to believe that this station's data have a greater magnitude of change than other stations in Warsaw.

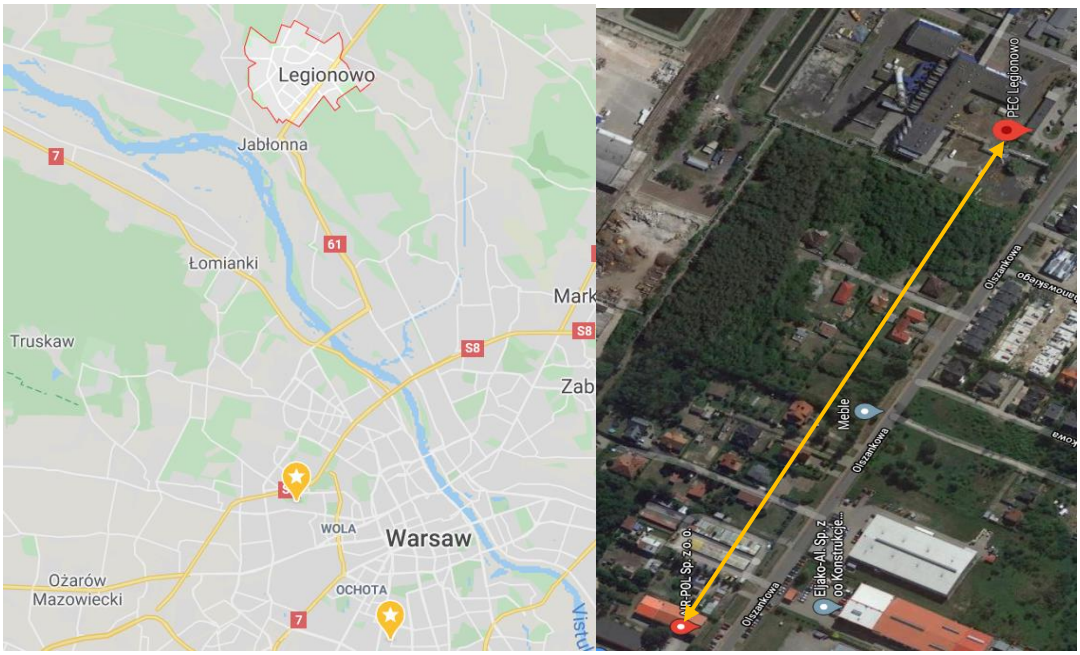

Fig 2 –the location of Legionowo in Warsaw(left); b. the location of air monitor and heat contractor(right)

Source of data:

[1]Atmospheric Soundings: http://weather.uwyo.edu/upperair/sounding.html

[2]Air quality data: http://powietrze.gios.gov.pl/pjp/home?lang=en

[3] https://aqicn.org/scale/