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Emission of combustion gases during fires of large-scale commercial buildings and its impact on environment

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Abstract. The analysis of the large-scale commercial buildings fires was conducted. The study presents summary of large-scale fires in Mazovian Voivodship in 2015-2016 and its impact on environment. Location and dates of large-scale fires were compared with historical data of air monitoring available on State Inspectorate for Environmental Protection database. Impact of wildfires on environment was already described widely in literature, this approach is focused on commercial buildings fires. The substantial peaks were noticed at Inspectorate for Environmental Protection research stations when large-scale fires occurred, especially regarding fires with long duration. Large fires with short duration were not reflected significantly in air monitoring database.

1 Introduction

Large fires have significant impact on environment including water pollution as a result of using extinguishing foams [1,2], soil contamination caused by both the extinguishing agents and fire water [3,4]. Another influence of fires is an air pollution as a result of emission combustion products to the atmosphere. Several studies presented impact of wildfires on environment, especially PM2.5 concentration [5-10], as well as health effects of wildfires smoke [11-15].

Large-scale commercial buildings are usually low or medium-high buildings. Examples of such facilities are shopping centers, exposition buildings, railways, airports, as well as production and storage buildings. In this type of objects fires are mostly characterized by high speed of fire development [16].

The exact amount of combustion gases emission depends on fire duration, fire load density and type of combustible material. In comparison with wildfires, commercial buildings fires will cause different effect on environment. The most important difference is type of combustible material. In commercial buildings the variety of combustible materials are much wider, including wood, polyethylene, PCV, polystyrene, polyester, cotton as well as hazardous materials [17]. Due to higher possibility of oxygen deficit accompanying commercial buildings fires, the combustion products will depend on different fire conditions. Fire load density of commercial buildings will be also different for each fire incident. Fire duration is the most difficult variable to assess. In simplified approach fire duration is a result

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of fire load density, fire surface area and extinguishing intensity. In real, complex approach [18], fire duration will be determined by location of the building, more precisely distance from fire stations, organization of water supply, access to build extinguishing posts, presence of hazardous materials, ventilation and oxygen concentration and priorities of the action. What is more fire duration is consisting of 3 phases: fire growth phase, developed phase and extinguishing phase. Extinguishing phase is usually the longest one, however it has insignificant impact on environment. Fire growth phase and developed phase will result in highest emission of combustion products, therefore causing major pollution.

2 Methodology

In this study all the "very large" commercial buildings fires in Mazovian Voivodship in 2015–2016 were analyzed. According to the rules of registering fires in decision support system (SWD PSP) "very large" fire is defined as a fire where area of over 1001m^2 or volume of over 5001m^3 of the object have been burned or area over 100ha of forest, crops or grasses have been burned. The necessary data were obtained from decision support system database (SWD PSP). All the data, including starting time of each fire, precise coordinates and fire growth time are presented in table 1. In the analyzed period the "very large" fires of the forest did not appear in Mazovian Voivodship.

Table 1. List of "very large" fires in Mazovian Voivodship in 2015-2016.

No	Date	Start time	Fire growth time	Coordinates N	Coordinates E
1	06.01.2015	06:35:00	2:24:00	52°20'05.7"N	21°05'55.5"E
2	14.02.2015	17:33:00	7:17:00	52°13'32.8"N	21°03'04.4"E
3	05.03.2015	04:35:00	1:25:00	52°22'35.0"N	19°43'51.8"E
4	19.05.2015	15:18:00	1:49:00	53°02'43.1"N	20°18'42.7"E
5	12.06.2015	19:53:00	1:47:00	51°12'57.9"N	20°52'30.6"E
6	06.07.2015	07:32:00	1:06:00	53°04'18.4"N	19°52'03.2"E
7	23.08.2015	19:08:00	2:51:00	51°46'01.2"N	0°46'41.8"E
8	30.08.2015	16:11:00	3:56:00	52°23'24.4"N	20°37'52.8"E
9	29.10.2015	18:45:00	2:25:00	51°45'59.1"N	21°22'18.6"E
10	30.03.2016	05:49:00	0:48:00	52°34'43.8"N	19°48'16.4"E
11	25.04.2016	09:30:00	3:17:00	52°17'54.0"N	20°11'38.9"E
12	27.06.2016	04:08:00	4:39:00	52°49'27.4"N	21°12'51.2"E
13	28.07.2016	04:54:00	2:24:00	52°19'52.5"N	20°54'06.4"E
14	02.10.2016	15:12:00	3:34:00	51°52'48.9"N	21°36'46.4"E
15	27.10.2016	10:45:00	1:30:00	52°08'23.6"N	21°48'21.1"E

In the next step coordinates of "very large" fires in 2015 were compared with locations of air monitoring posts of State Inspectorate for Environmental Protection. Locations of air monitoring posts and "very large" fires in Mazovian Voivodship illustrates Figure 1. In the next step all data from air monitoring posts surrounding large fires in specific dates were analyzed. Firstly the 24 hours average measurements were analyzed, though major changes were not observed. Slight growths in concentration of matter particles were noticed, but it was not distinguishing from other peaks in longer, i.e. one week or one month period. Afterward 1 hour measurement were examined and results of the analysis are presented in the next section.

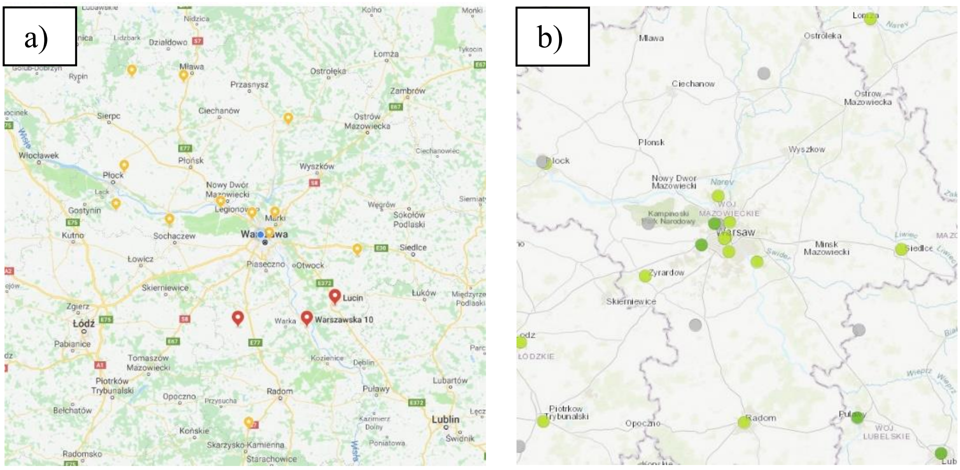

Fig. 1. Location of: a) "very large" fires in 2015-2016, b) air monitoring stations.

While evaluating large fires and its influence on air monitoring measurements NOAA Hysplit model was used to estimate movement of fire gases and particles in specific dates. For fires with short (less than 3 hours) fire growth phase, the influence on air monitoring measurements was not observed. Fire growth time in conducted research includes fire growth phase and developed fire phase. After the time given as fire growth time the fire was located, i.e. it was not spreading further. Detailed results are presented in next section.

3 Results

In this section detailed results of analysis are presented for two fires from 2015 in Mazovian Voivodship. Fire no 2 (from table 1) was the fire with the longest fire growth time, i.e. 7 hours 17 min. For this fire the most significant impact on air monitoring measurements was observed. Fire no 7 was characterized by shorter fire growth time, i.e. 2 hours 51 min. The difference in air monitoring for this fire was noticed, however it was less substantial than fire no 2.

3.1 Fire no 2 (14.02.2015)

This fire started in Warsaw on 14th February 2015 around 5.30 pm. The wooden technological bridge has been burned. Duration of this fire, i.e. fire growth time, was the longest in 2015. While analyzing the air monitoring measurements the most significant values were noticed in Legionowo. The peak was detected at 10pm. Estimation of movements particles conducted in NOAA Hysplit model confirmed that the highest concentration of particles and smoke gases should be around Legionowo post (figure 2).

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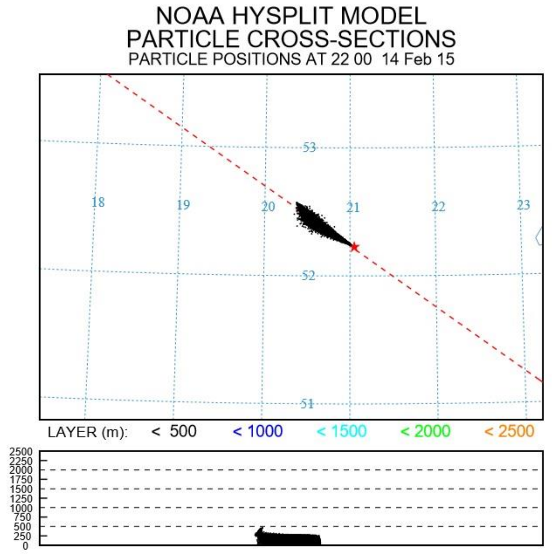

Fig. 2. Estimated movement of particles on the 14th Feb 2015.

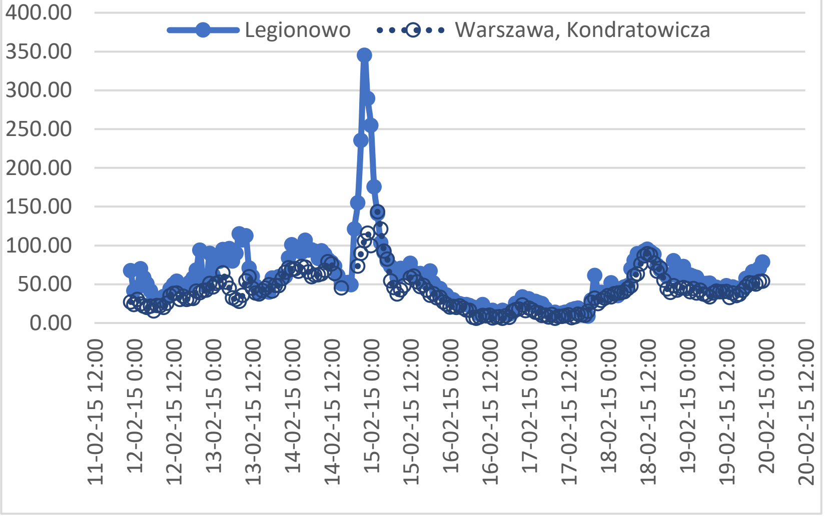

Fig. 3. PM2.5 concentrations [µg/m^3] from air monitoring stations in Legionowo and Warsaw, Kondratowicza street.

Figure 3 illustrates concentrations of PM2.5 in Legionowo and Warsaw, Kondratowicza stations from 11.02.2015 to 20.02.2015. In both air monitoring stations increase of PM2.5 concentration started on 14th February 2015 at around 6pm and reached a maximum value of 345µg/m^3 at 10pm. After that time the concentration started to decline till 8am on 15.02.2015. The long term impact on PM2.5 concentrations was not noticed. The fire duration time was evidently shorter than fire duration in wildfires already described in Quebec [5] or Baltimore City [8]. It explains the short term influence on air monitoring results and also very small changes in 24 hours average measurements results.

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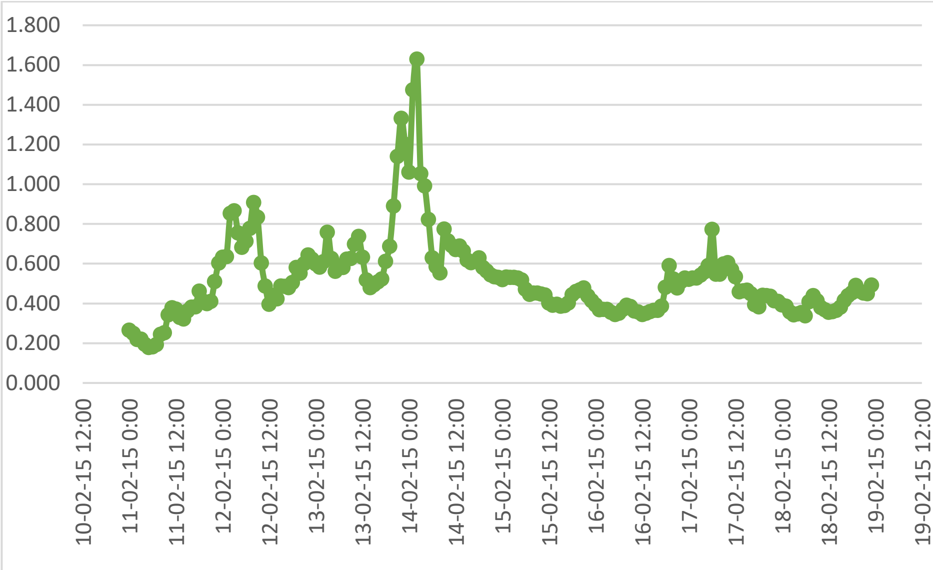

Fig. 4. CO concentration [mg/m^3] in Legionowo on the 14th Feb 2015.

Figure 4 shows concentrations of carbon monoxide in Legionowo from the same period as for PM2.5. The increase of CO concentration started exactly at the same time and reached a peak at 10pm and after small drop reached a maximum value at 2am. After that time the concentration started to decline similar as for PM2.5. The long term impact on CO measurement results was not remarked.

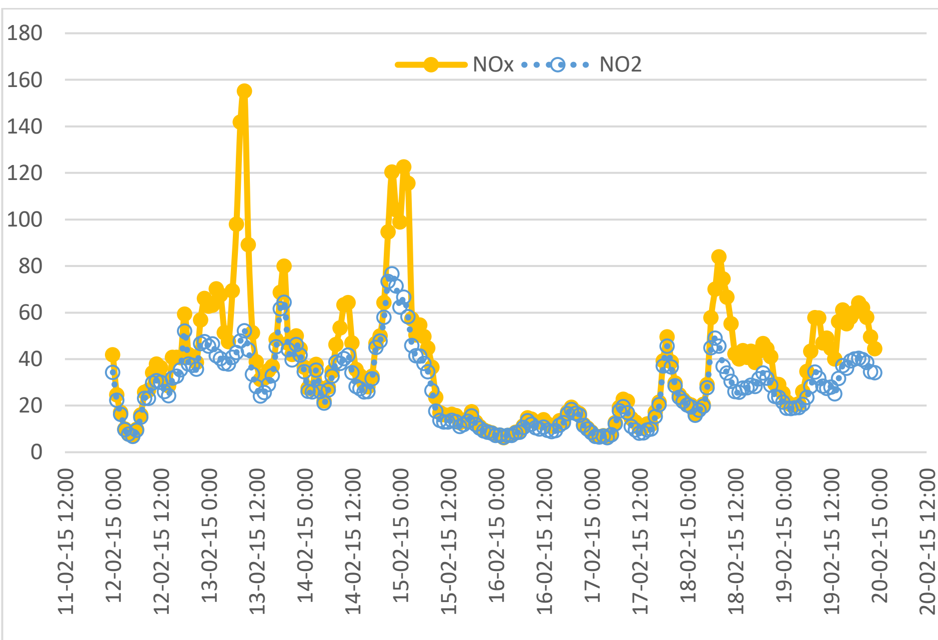

Fig. 5. NOx and NO_2 concentration [μg/m^3] in Legionowo on the 14th Feb 2015.

Figure 5 presents concentrations of NOx and NO_2 levels in Legionowo from the same period as for PM2.5 and CO. The increase of both NOx and NO_2 concentration started at the same time and reached a peak ad 10pm and 11pm respectively. After that time the concentration started to decline similar as for PM2.5 and CO. The long term impact on NOx and NO_2 measurement results was not noticed as well. While analyzing NOx levels in one week period the higher peak was noticed on 13th February at 9am, which was accompanied by slight increase of CO level, however not connected with PM2.5 rise.

3.2 Fire no 7 (23.08.2015)

This fire no 7 started in Warsaw on 23rd August 2015 around 7 pm. The wooden pallets and plastic boxes has been burned. Fire growth time was 2 hours 51 min. While analyzing the air monitoring measurements the most significant values were noticed in Żyrardów. The peak was detected at 10pm. Estimation of movements particles performed in NOAA Hysplit model confirmed that the highest concentration of particles and smoke gases should be around Żyrardów monitoring station (figure 6). Figure 7 illustrates concentrations of PM2.5 in Żyrardów station. In this example an increase of PM2.5 concentration was not remarkable in comparison with one week results.

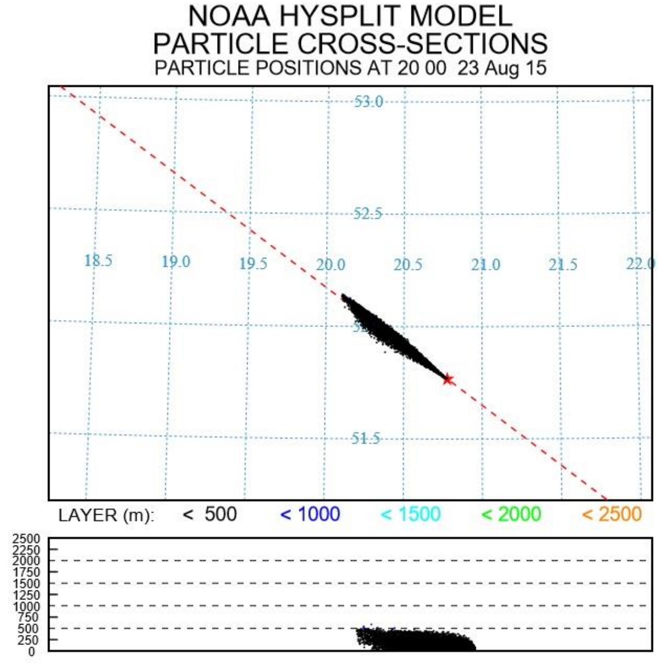

Fig. 6. Estimated movement of particles on the 23rd Aug 2015.

Figure 7 illustrates concentrations of PM2.5 in Żyrardów station from 20.08.2015 to 29.08.2015. The increase of PM2.5 concentration started on 23rd August 2015 at around 7pm and reached a maximum value of only 53µg/m^3 at 8-9pm. After that time the concentration started to decrease. The long term impact on PM2.5 concentrations was not noticed. The fire duration time was evidently shorter than in fire no 2 and results of PM2.5 concentration were much smaller than in Legionowo during the time of fire no 2.

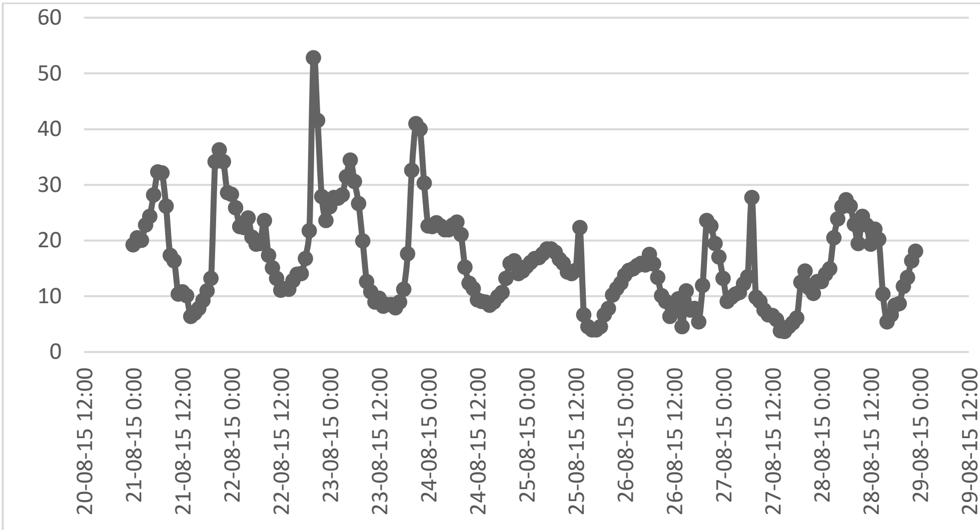

Fig. 7. PM2.5 concentrations [μg/m^3] from air monitoring stations in Żyrardów.

4 Conclusions

In summary, the study presents the analysis of PM2.5, CO and NOx concentrations obtained from air monitoring stations during “very large” fires in Mazovian Voivodship. During fires with long fire growth time, i.e. over 5 hours, significant rises of PM2.5, CO, and NOx were remarked. The increased results were noticed only while analyzing 1 hour measurements. The average 24 hours measurements were not substantially higher during the large fires in comparison to long term results. The impact of large fires on air monitoring results was lasting for few hours, similar to fire growth time which was not longer than 7 hours 17 min. It explains lack of influence on average 24 hours results. The results of air monitoring depends on dispersion, not only in terms of direction, but also in terms of concentration value.

For the large fire with the shorter growth time marginal increase for PM2.5 concentration was observed, however analysis of CO and NOx concentrations did not evident remarkable rises in comparison with one week measurement.

While analyzing "very large" fires it was important to study the detailed description of the fires, for the reason that not every fire registered as "very large" was in fact causing huge emission of fire gases and particles. Another limitation during the analysis was the location of monitoring stations. When distance between the place of the fire and monitoring station was large the rises in the particle concentrations were not observed.

Further analysis should be conducted to confirm results and acquire more conclusions, especially “very large” fires with longer fire growth time. For longer fires more significant changes should be noticed in air measurement results. Depending on conditions influencing dispersion of particles and gases rises in concentrations might be observed in few stations. Finally the analysis of results shall be confirmed by the experiment of monitoring concentrations of PM2.5, CO, NOx and others while controlled long duration fire.

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