DEVELOPMENT OF CLIMATE AND AIR POLLUTION CHARACTERISTICS AND THEIR IMPACT ON MINING OPERATIONS AND RECLAMATION WORK IN THE REGION OF NORTHWESTERN BOHEMIA

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ABSTRACT

The Brown Coal Research Institute j.s.c. is currently conducting long-term research on the development of the Czech Republic's climate and its impacts on mining activities. The research deals with the overall assessment of climate change in the Czech Republic and the main attention is paid to the area of the Most Basin, which is known as the largest Czech brown coal deposit. In addition, the basic air pollution characteristics in this area are monitored for a long time and trends in relation to climate change are compared. The trend of climate change in the Czech Republic is taking place in the context of climate change in Europe. The Czech Republic is located in Central Europe. The location of the European continent is the main cause of significant regional climate variability. Due to the extremely dense network of long-term measuring stations in Europe, analyzes of trend trends (perhaps with the exception of North America) are significantly more accurate than anywhere else on the planet. The presented results of monitoring climate change and air pollution characteristics suggest that especially the development of air pollution characteristics (concentration of suspended particles fraction PM_{10} and $PM_{2.5}$, concentrations of SO_2, NO_2, NO, NO_X, O_3) is strictly regional and the connection with climate change affects practically O_3 concentration only. The research was realised with support of EU research program The impact of EXtreme weather events on MINing operations, project No 847250-TEXMIN-RFCS-2018.

Keywords: mining area, air pollution, climatic changes

INTRODUCTION

The main task of the international project TEXMIN is to identify and analyse the impacts of climate change on mining activities. It is important to identify and analyse the impact of climatic parameters on different mines. This can be studied under significant changes (e.g. wet - dry, hot - cold, high - low pressure, etc.) under normal meteorological conditions or under what can be called extreme climatic events affecting the mining industry. The purpose of this task is to identify significant climate-related events that have already affected mining activities (coal and non-coal) in order to (i) identify the main impacts of events, (ii) document responses to these events, and (iii) identify key lessons to be learned from this experience.

As part of the research project, data on the development of the main meteorological indicators - temperature and precipitation - for the Most Basin in the north western part of the Czech Republic were collected in the previous stage of the solution. In agreement with other participants in the international TEXMIN project (United Kingdom,

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Germany, Poland, Greece, Spain), it was confirmed that there is a trend of increasing average temperature in all monitored areas in the long term. In the Czech Republic, the Most Basin is a monitored area. It is the largest brown coal deposit. This area is one of the most burdened by poor air quality. As part of the research, basic meteorological data (temperature, precipitation, pressure) have been processed since 1960 [1].

The development of temperature and precipitation for the area of interest of the Czech Republic is shown in Figure 1 [2]

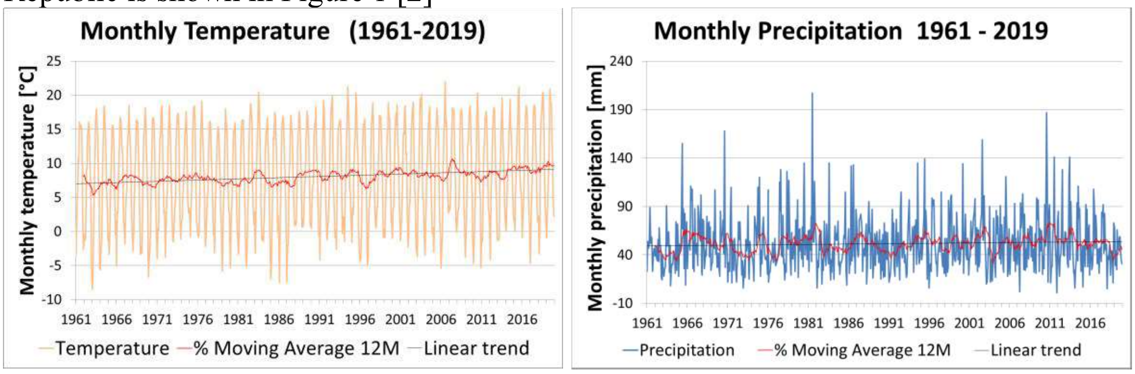

Figure 1: The development of temperature and precipitation in the North Western Bohemia

AIR POLLUTANTS - TIME DEVELOPMENT

Another part of the project was to draw up development of air quality characteristics. These were mainly air pollutants parameters of concentration of suspended particles fraction PM_{10} and $PM_{2.5}$, concentrations of SO_2, NO_2, NO, NO_X, O_3.

The whole area of the Most Basin was divided into the western and eastern parts. The western part occupies the districts of Chomutov, Most and Louny, the eastern part contains the districts of Teplice, Usti nad Labem, Decin and Litoměřice (see Figure 2).

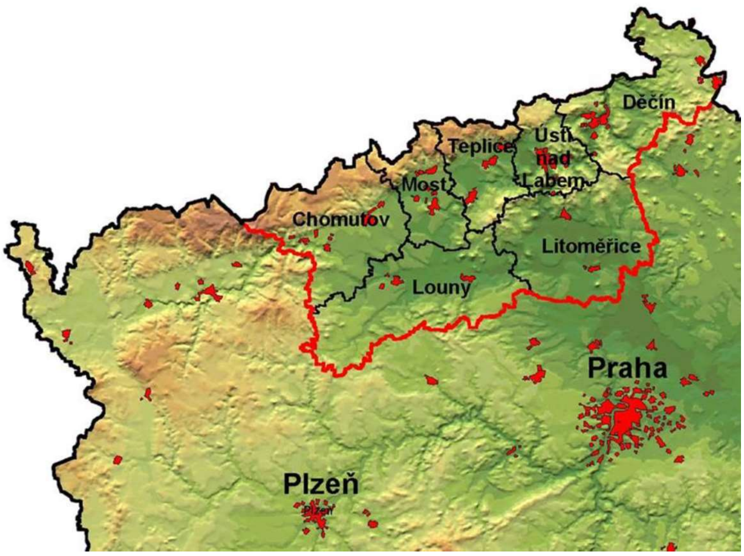

Figure 2: Most Coal Basin in the North Western Bohemia

In the western part of the basin there are brown coal open pit mines DNT, Vršany and ČSA, in the eastern part there is a open pit mine Bílina and other industrial companies. At the same time, there are 7 main large energy sources (power plants and heating plants) burning brown coal in the whole area.

Air quality in this area is monitored by a network of air pollutants monitoring measuring stations. For the analysis of the development of air pollutants characteristics in a long-term time series, measured data from the following air pollutants monitoring stations were used. In the western part it was the stations Chomutov, Měděnec, Most, Rudolice and Tušimice, in the eastern part it was the stations Krupka, Lom, Litoměřice, Teplice, Usti nad Labem - town and Usti nad Labem - Kočkov.

The time period from 2000 to 2019 was processed. The measured data for the relevant years were processed into annual average concentrations. Table and graphic outputs were compiled from individual air pollutants monitoring stations to evaluate the development of air pollutants characteristics. For the development of concentrations of suspended $PM_{2,5}$ particles, little measured data is available, as measurements are only gradually being introduced at individual stations [3].

Table 1: Suspended particles of fraction PM_{10} - western part ($\mu g.m^{-3}$)

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Chomutov	31,6	43,2	47,5	41,9	30,8	32,0	32,1	25,2	24,4	25,9	30,7	29,9	25,9	24,8	30,2	23,9	22,5	22,4	25,9	19,3
Měděnec	20,5	12,2	17,9	21,3	16,5	19,6	17,4	15,9	18,8	18,6	18,0	19,8	16,0	13,9	13,3	13,3	12,1	11,5	15,2	11,0
Most	23,8	23,7	22,6	36,9	39,0	43,0	40,9	30,8	29,2	31,5		38,0	32,9	31,4	32,5	28,1	26,3	25,8	31,3	23,6
Rudolice v Horách	15,9	12,5	19,4	22,2	16,1		15,7	14,0	12,8	13,5	15,0	14,0	15,2	15,3	14,9	12,7	10,6	10,5	14,6	10,6
Tušimice	19,2	24,2	27,3	44,8	32,6	36,5	30,7	24,5	23,5	25,8	28,8	28,2	23,9	23,3	26,8	25,8	22,3	20,5	26,1	19,4
Annual average	22,2	23,1	27,0	33,4	27,0	32,8	27,4	22,1	21,8	23,1	23,1	26,0	22,8	21,8	23,5	20,8	18,8	18,1	22,6	16,8

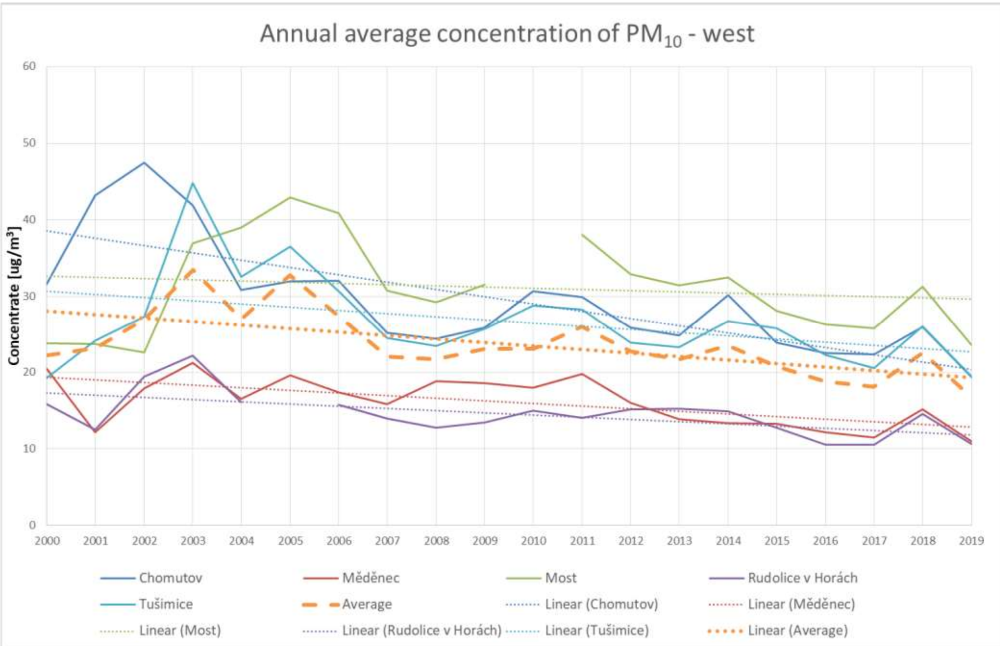

Figure 2: Annual average concentration of PM_{10} - western part

Table 2: Suspended particles of fraction PM_{10} - eastern part ($\mu g.m^{-3}$)

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Krupka	19,7	24,6	24,8	24,9	19,8	22,6	22,2	19,7	20,0	20,7	29,8	26,9	24,4	25,4	27,5	17,9	18,7	19,2	19,5	15,1
Lom						35,7	40,5	31,6	34,9	35,6	35,6	33,6	29,9	30,0	34,6	29,7	28,5	28,5	33,9	26,5
Litoměřice					31,3	34,1	38,4	26,9	27,6	28,8	30,6	31,9	28,1	27,0	28,9	25,4	25,0	24,9	25,5	20,7
Teplice										27,4		32,8	28,4	26,2	30,8	25,7	24,4	25,0	25,4	20,3
Ústí n.L.-Kočkov	30,5	30,6	51,8	37,1	31,9	27,7	28,6	22,6	22,8	23,5	24,4	26,6	22,4	22,5	25,0	24,0	18,7	19,4	20,6	16,1
Ústí n.L.-město						42,0	43,9	32,4	33,2	31,7	32,9	36,0	29,6	29,1	31,8	26,7	28,3	27,1	28,8	22,9
Annual average	25,1	27,6	38,3	31,0	27,7	32,4	34,7	26,6	27,7	27,9	30,7	31,3	27,1	26,7	29,8	24,9	23,9	24,0	25,6	20,3

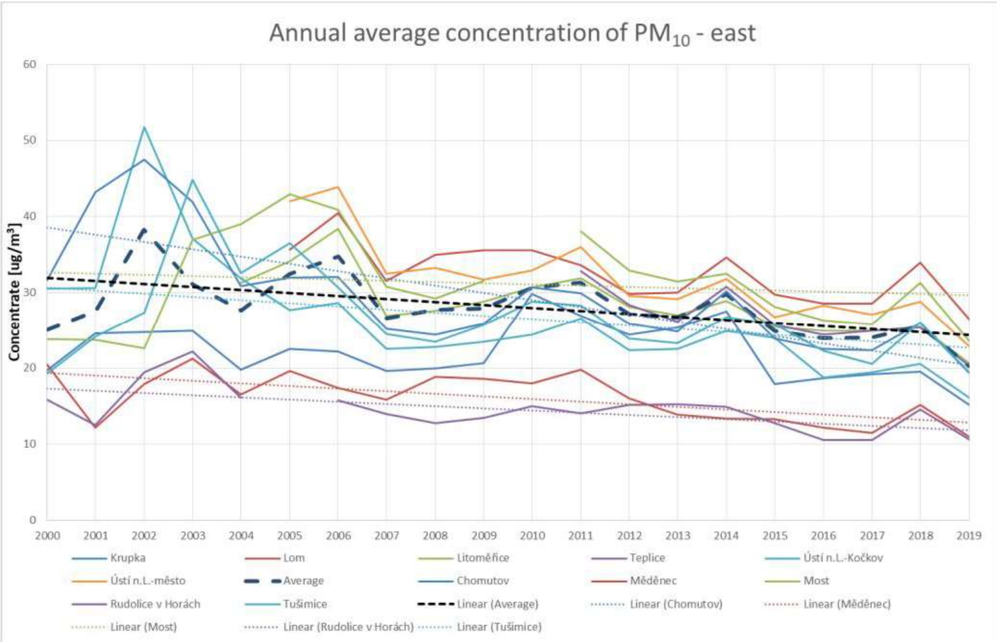

Figure 3: Annual average concentration of PM_{10} - eastern part

The measured data of the concentration of suspended particles fraction $PM_{2.5}$ were combined for both monitored areas of the Most Basin (west and east).

Table 3: Suspended particles of fraction PM_{10} - west and east ($\mu g.m^{-3}$)

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Most	24,3	24,0	25,6	16,8	17,3	18,0		24,7	23,2	21,8	22,4	18,7	18,4	18,3	21,7	15,1
Tušimice													15,5	14,6	18,7	12,8
Lom													19,1	18,8	20,7	15,6
Teplice						18,9		23,7	19,4	19,2	21,1	19,4	18,7	18,6	19,2	14,3
Ústí n.L.-Kočkov	21,0	22,5	23,0	15,4	15,5	17,5	19,3	18,1	18,2	18,1	18,7	15,4	14,7	15,7	15,9	11,4

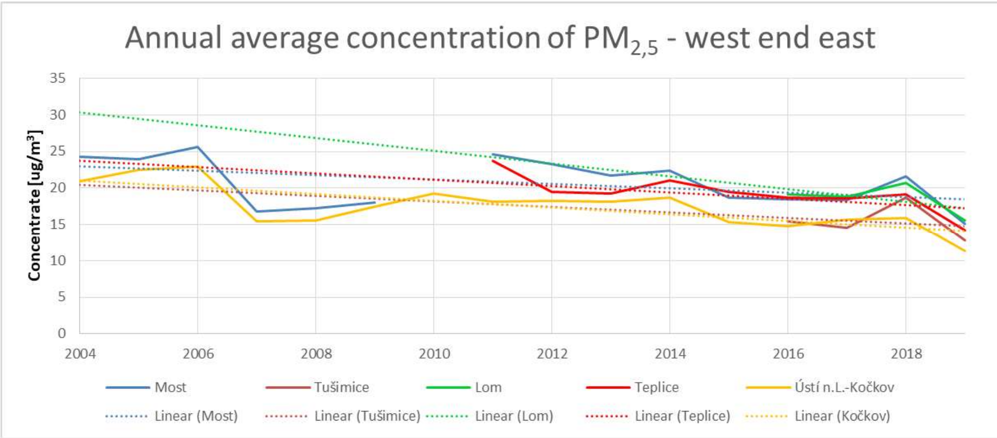

Figure 4: Annual average concentration of $PM_{2,5}$ **-** west and east

In the following view of the text will only include miniture graphical outputs of individual indicators monitored air quality to save space.

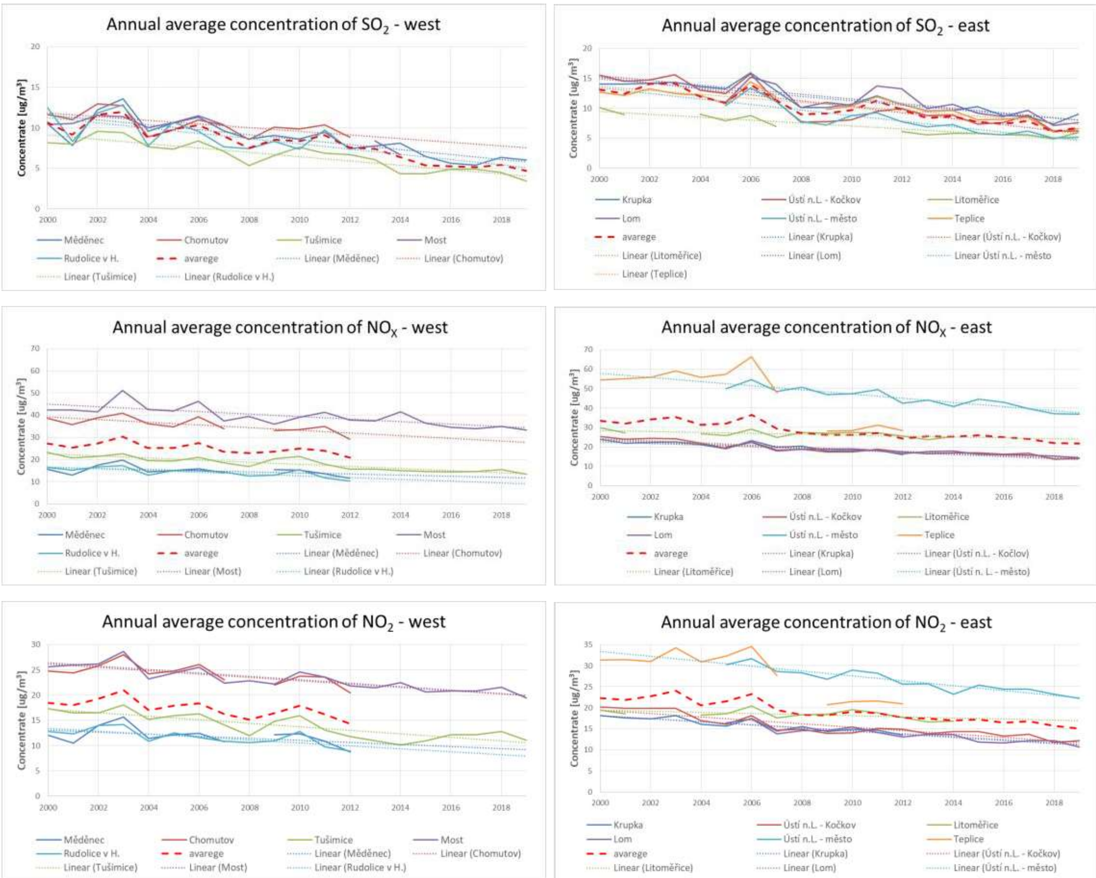

Figure 5: Annual average concentration of SO_2, NO_x, NO_2 **-** west and east

Table 4: Air pollutants characteristics - O_3 concentration - western part ($\mu g.m^{-3}$)

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Tušimice	44,5	51,1	50,9	57,1	56,7	57,1	55,6	53,7	50,3	47,8	49,0	52,0	52,5	53,1	47,8	54,3	53,9	55,3	60,0	58,5
Most	45,4	41,6	46,2	45,9	50,0	48,0	48,0	47,8	44,6	43,8	46,3	44,0	45,6	42,5	39,4	48,1	44,9	47,5	52,8	52,0
Rudolice v H.	44,5	51,1	50,9	57,1	56,7	57,1	55,6	53,7	50,3	47,8	49,0	52,0	52,5	53,1	47,8	54,3	53,9	55,3	60,0	58,5

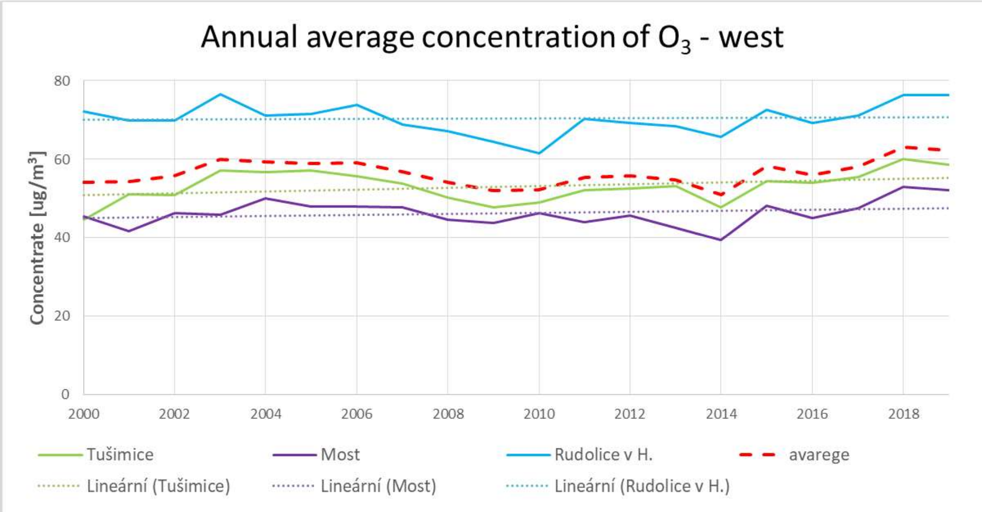

Figure 6: Annual average concentration of O_3 - west and east

Table 5: Air pollutants characteristics - O_3 concentration - eastern part ($\mu g.m^{-3}$)

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Litoměřice	-	-	-	56,4	47,5	53,2	52,0	50,9	45,7	45,8	48,7	45,2	47,8	47,1	43,4	50,4	47,4	50,0	58,2	52,7
Lom	-	-	-	-	-	51,1	51,4	49,1	44,1	42,3	44,5	41,9	46,1	46,3	40,5	47,7	43,2	46,3	52,1	49,8
Ústí n.L. - město	-	-	-	-	-	38,3	39,6	38,3	36,3	34,7	38,6	36,5	40,4	35,8	35,4	40,6	37,0	40,1	48,6	48,3
Teplice	40,6	34,0	40,8	43,5	42,3	41,7	41,8	41,8	-	47,6	50,4	47,2	49,7	49,9	46,9	53,8	48,2	52,2	59,0	56,0
Ústí n. l. - Kočkov	56,4	50,6	56,0	62,0	62,0	67,8	62,2	57,5	52,0	50,4	53,1	51,7	57,8	57,5	54,5	60,6	57,1	58,4	70,4	67,3

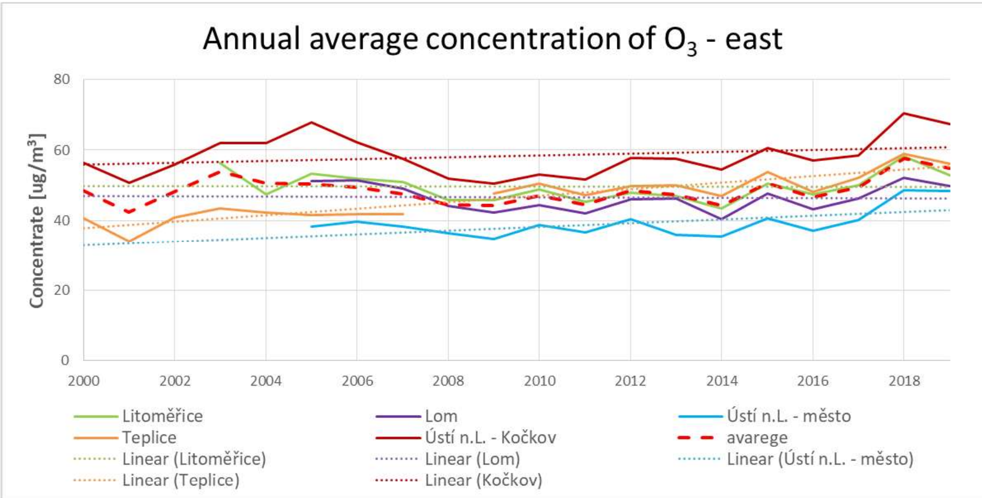

Figure 7: Annual average concentration of O_3 - west and east

BRIEF EVALUATION OF AIR POLLUTANTS TRENDS AT SELECTED STATIONS

The following text is a brief assessment of trends captured for individual pollution indicators.

PM_{10}

The trend is decreasing, at stations in the eastern region it is more than at stations in the western region. Here, a large effect of long-distance transmission is evident (very similar to the course of annual concentrations). At the same time, significant local emission sources can also affect the resulting concentration. Their activities create high short-term concentrations. If these high concentrations do not occur frequently, they are not visible in the annual course and appear only in the daily course of the concentration. Climatic influences also have a great influence on the value of PM10 concentration.

$PM_{2.5}$

Declining trend, but there is still a small number of stations, or short data series.

SO_2

Declining trend was observed, very similar to the course of SO_2 concentrations at individual stations. Air pollution concentrations are mainly caused by long-distance transmission (the main source - power plants) and also affected by other influences (mainly climatic).

NO

Slightly decreasing trend was observed. Higher concentrations at the Ústí n. L. station - town, Teplice and Most the city are probably influenced by roads with higher traffic. Other selected stations are located outside the direct influence of nearby sources of pollution.

NO_x

A slightly decreasing tendency is observed at all selected stations in both areas (West and East). The displayed average concentration at stations in the western area after 2012 is affected by a small number of stations with very different concentration levels.

NO_2

At stations in the eastern region, a very similar course is evident, the trend of which is decreasing. There is a very slight increase at stations in the western area after 2014 (mainly at the Tušimice station). Due to low concentrations and variance of values (15 ± 3 µg.m-3), we do not consider this increase to be significant.

O_3

After a short downward trend in 2005-2010, annual ground-level ozone concentrations are increasing. This trend is observed at all stations, it has been more pronounced since 2016.

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CONCLUSION

The Most Basin is one of the most polluted areas in the Czech Republic in terms of air quality. This area was affected by significant smog events especially at the end of the 20th century. In connection with the confirmed trend of climate change (especially the increase in average temperature), the development of air pollution characteristics in a long-term time series was processed. The trend of increasing average temperature could also predict certain changes in air quality. According to the evaluated data, the concentration of most air pollutants is gradually decreasing. The main reason for the decrease in concentration is the implemented ecological measures in the industrial area. Power plants and heating plants in the region have undergone significant modernization, "green" technologies have been implemented (cleaning combustion products, desulphurisation, denitrification). These measures have a clear effect on the gradual reduction of SO_2, NO_x, PM_{10} and $PM_{2.5}$ concentrations. Anti-dust measures were gradually implemented in surface mines, which have the largest share in reducing PM_{10} concentrations. The implementation of these measures seems to overlap with climate change. An exception is the ozone concentration, which has been rising in recent years. In this case, the main cause is a gradual increase in the average temperature, a greater proportion of warm and sunny days a year.

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