



HARMO19

**19th International Conference on
Harmonisation within Atmospheric Dispersion Modelling for Regulatory
Purposes 3-6 June 2019, Bruges, Belgium**

Impact of the NEC Directive on Air Quality in Poland

Jacek W. Kaminski^{1,2}, Joanna Struzewska^{2,3}, Grzegorz Jeleniewicz², Paulina Jagiełło²,
Paweł Durka², Aneta Gienibor², Marcin Kawka²

¹) Institute of Geophysics, Polish Academy of Science, ²) Institute of Environmental Protection – National Research Institute, ³) Warsaw University of Technology

Abstract:

Air pollution remains as one of the most important civilisation problems. High concentrations of atmospheric pollutants have a negative impact on human health, ecosystems and infrastructure. Implementation of the Directive 2016/2284 on the reduction of national emissions of specific atmospheric pollution (National Emissions Ceilings Directive - NEC) aims to reduce air pollution and human health and environmental exposure further. The NEC Directive sets national emission reduction commitments for individual Member States with regard to SO₂, NO_x, NMVOC, NH₃ and PM_{2.5}.

In Poland, there is an ongoing effort to prepare the National Air Pollution Control Programme. A modelling study was undertaken to assess the impact of emission reduction according to the NEC directive on the pollution concentrations level over Poland.

The GEM-AQ air quality model (Kaminski et al., 2008) was used as a computational tool. EMEP emission inventory with the resolution 0.1deg was used over Europe. For the base run, we have used emission dataset reported for 2016. To prepare scenarios for 2025 and 2030 a proportional emission reduction for all SNAP sectors was applied based on emissions reported for 2005. Six simulations were carried out for one-year period – scenarios with 2016, 2025 and 2030 emissions as well as three additional simulations with zero anthropogenic emissions over Poland, in order to assess the contribution from the transboundary transport.

Modelling results in terms of annual concentrations of PM₁₀, PM_{2.5}, SO₂, NO₂, NO_x and ozone, showed that implementation of the NEC Directive would improve the air quality in Poland for primary as well as secondary pollutants. Also, the number of premature deaths related to air quality as well as areas exposed to excessive concentrations of pollutants would be significantly reduced.

Key words: NEC Directive, emission reduction, air quality modelling, air pollution exposure.

INTRODUCTION

The NEC Directive constitutes part of “The Clean Air Policy Package”. In its framework, other legal acts were adopted, including the Directive 2015/2193 of the European Parliament and of the Council of 25 November 2015 on the limitation of emissions of certain pollutants into the air from medium combustion plants. The system of

national emission ceilings laid down in the Directive 2001/81/EC was amended to align the international obligations of the Union and the Member States. The NEC Directive, therefore, defined national emission reduction commitments for particular pollutants in reference to the year 2005 for years 2020-2029 under the revised Gothenburg Protocol, and for 2030 and beyond, it defined a range of individual pollutant reductions based on the estimated reduction potential of each Member State.

In order to support analyses related to the implementation of the NEC Directive, the IOŚ-PIB conducted a modelling study of the impact of the assumed reduction of emissions on the level of pollutant concentrations in Poland.

EXPERIMENT SETUP

Emission data

With regard to anthropogenic emissions, the latest available data reported by the Member States under the LRTAP Convention were used for Europe. In 2018, the EMEP emission base was spatially condensed to the resolution of $0.1^\circ \times 0.1^\circ$ (approx. 10 km)¹. Emissions of non-methane volatile organic species (NMVOC) were disaggregated into substances and groups of substances relevant to the modelling of chemical transformations. Outside Europe, ECLIPSE emissions prepared by IIASA were used².

In order to prepare emission scenarios, emission data for all the countries included in the reduction strategy were modified according to the NEC Directive coefficients. Based on the emissions reported for 2005 the reduction level was applied proportionally to all sectors of activity (Fig.1). For countries not included in the NEC Directive, it was assumed that the emission load in 2025 and 2030 is the same as reported in 2016. In the case of the PMcoarse fraction, the reduction factor was assumed to be the same as for PM2.5. Due to the lack of references in the NEC Directive to carbon monoxide, no emission reduction was assumed.

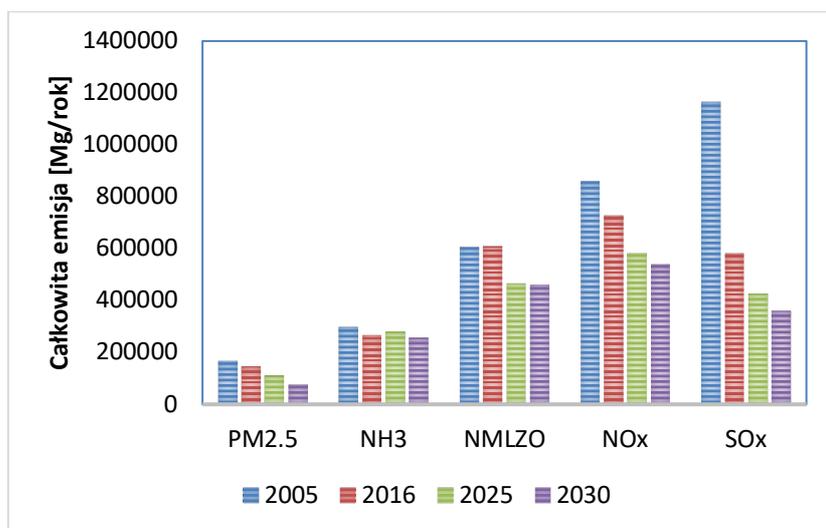


Figure 1. Total pollutant emission load reported for years 2005 and 2016 and forecasted according to the assumptions of the NEC Directive for 2025 and 2030 in Poland

Model configuration

The air quality model GEM-AQ (Kaminski et al., 2008) was used to calculate the concentrations of pollutants at the surface. Calculations with the GEM-AQ model were performed on a variable resolution global grid, with approximately 10 km resolution over Central Europe (Fig. 2). This configuration ensures a proper reconstruction of the cross-border inflow. The time step used in the calculations was 600 seconds. For the purpose of this analysis, the 2017 meteorological fields were used for all model simulations.

¹ http://www.ceip.at/new_emep-grid/01_grid_data

² <http://www.iiasa.ac.at/web/home/research/researchPrograms/air/ECLIPSEv5.html>

Six simulations covering a period of one calendar year were performed:

- Three simulations reflected subsequent emission reduction scenarios - 2016 - current status and 2025 and 2030 - as a forecast based on the guidelines of the NEC Directive;
- In order to determine the share of domestic emissions in the development of ozone concentration levels in Poland and the impact on pollution in neighbouring countries, as well as to estimate the impact of pollutants from cross-border transport on the excessive values over the limits, three additional simulations were performed with all anthropogenic emissions over Poland excluded. All other elements of model configuration and input data remained unchanged (so-called brute force for sensitivity analysis method for source-oriented models).

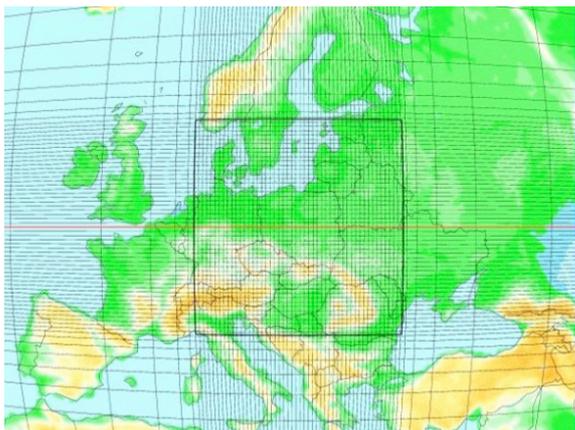


Figure 2. Variable resolution global grid configuration: the black square covers a 10 km resolution area, the red line represents the equator in a rotated coordinate system.

RESULTS

In the northern, eastern and western parts of the country, in 2016, the annual average concentration values of PM_{10} ranged from 20 to 30 $\mu\text{g}\text{m}^{-3}$. On the other hand, in central and southern parts of Poland higher concentrations, from 30 to 40 $\mu\text{g}\text{m}^{-3}$, were recorded, and in small areas, they were as high as 52 $\mu\text{g}\text{m}^{-3}$. Simulations for 2025 and 2030 show a decrease in PM concentration. In 2030, over Poland, the concentration values of PM_{10} will not exceed 30 $\mu\text{g}\text{m}^{-3}$, except for small areas in the south of the country, where concentrations of up to 15 $\mu\text{g}\text{m}^{-3}$ were predicted.

In 2016, the highest concentrations of $PM_{2.5}$ were recorded in Silesian, Małopolskie, Podkarpackie Opolskie and Świętokrzyskie Voivodships and the centre of Poland (Fig. 3). Concentration values ranged from 25 to 40 $\mu\text{g}\text{m}^{-3}$. In the remaining part of Poland, $PM_{2.5}$ concentrations ranged from 20 to 25 $\mu\text{g}\text{m}^{-3}$ except for the north of the country, where concentrations were 15 – 20 $\mu\text{g}\text{m}^{-3}$. In 2025 a significant improvement can be seen. Highest concentrations are predicted for the Silesian, Opolskie and Małopolskie Voivodships. However, in 2030, the annual average concentration of $PM_{2.5}$ will remain in a range 15- 20 $\mu\text{g}\text{m}^{-3}$ throughout the country, except for the parts of Silesian, Małopolskie and Opolskie Voivodships where the values are predicted for 20-25 $\mu\text{g}\text{m}^{-3}$.

In 2016, the highest average annual concentrations of sulphur dioxide, even up to 20 $\mu\text{g}\text{m}^{-3}$, were predicted in the Silesian and Małopolskie Voivodships, as well as the centre of the country and the Bay of Gdańsk. Lower values, up to 5 $\mu\text{g}\text{m}^{-3}$, were recorded in the north-east and north-west parts of the country. The forecast for 2030 shows a decrease in concentrations of sulphur dioxide. In 2030, almost all over the country, SO_2 concentrations will not exceed 5 $\mu\text{g}\text{m}^{-3}$, except for the Silesian Voivodship, where concentrations were up to 10 $\mu\text{g}\text{m}^{-3}$.

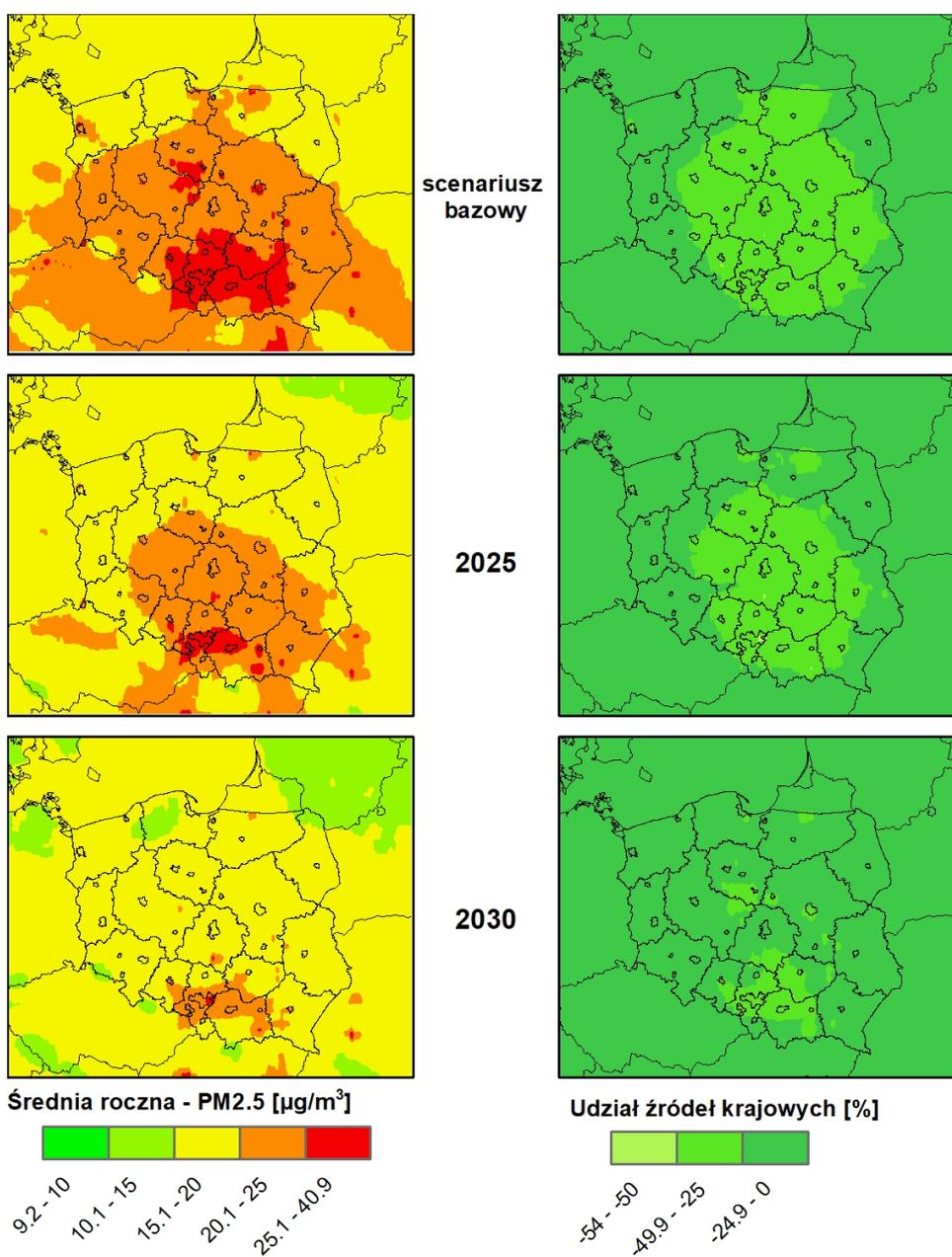


Figure 3. Spatial distribution of annual average PM2.5 dust concentration (left side) and TAYR indicator distribution for PM2.5 dust concentration (right side) in 2016, 2025 and 2030.

In 2016, the highest concentrations of nitrogen dioxide were recorded in the central and southern parts of the country, particularly in the Silesian, Małopolskie and Wielkopolskie Voivodships. Concentrations in these areas ranged from 10 to 20 $\mu\text{g}/\text{m}^3$, but there are also regions where predicted concentrations reached 40 $\mu\text{g}/\text{m}^3$. The lowest concentrations, up to 10 $\mu\text{g}/\text{m}^3$, were predicted in the coastal areas and the north-eastern part of the country. In other parts of Poland, NO_2 concentrations ranged from 5 to 10 $\mu\text{g}/\text{m}^3$. In the following years, a decrease in NO_2 concentration can be seen. In 2025, the predicted values will not exceed 10 $\mu\text{g}/\text{m}^3$ in the most of the northern part of the country: West Pomeranian and Pomeranian Voivodships and in the eastern and southern parts of the country. On the other hand, in areas of the country with the highest predicted concentrations, the values will reach maximum levels of 20 $\mu\text{g}/\text{m}^3$. In 2030, in the eastern and western part of Poland, the predicted values of NO_2 concentrations will not exceed 5 $\mu\text{g}/\text{m}^3$. A

significant reduction of nitrogen dioxide is predicted throughout the country.

In 2016, the AOT40 index reached its highest values in the south of the country - the values ranged from 10 001 to 18 000 $\mu\text{g}\cdot\text{m}^{-3}\cdot\text{h}$. In the remaining part of the country, the index values ranged from 2 000 to 10 000 $\mu\text{g}\cdot\text{m}^{-3}\cdot\text{h}$. The lowest values, up to 1 000 $\mu\text{g}\cdot\text{m}^{-3}\cdot\text{h}$, were predicted in the north of the country and the lake district. The results of modelling show that the value of the analysed indicator will decrease in the following years. The highest values will still be in the Silesian Voivodship; however, in 2025 the highest values will reach 18 000 $\mu\text{g}\cdot\text{m}^{-3}\cdot\text{h}$, and in 2030 only up to 10 000 $\mu\text{g}\cdot\text{m}^{-3}\cdot\text{h}$ in a small area of the voivodship. In the remaining part of the country, AOT40 will not exceed 5 000 $\mu\text{g}\cdot\text{m}^{-3}\cdot\text{h}$.

SUMMARY

Model simulations lead to a conclusion that the implementation of the NEC Directive in the horizon of 2025 and 2030, air quality in Poland will significantly improve, for both primary and secondary pollutants.

- Ozone is the only secondary pollutant subject to the analysis

Exposure to excessive ozone concentrations for plant protection expressed as the AOT40 index, decreases significantly with the assumption of emission reduction to the level specified in the Directive by 2025, with a further decrease in exposure taking place in 2030. A significant decrease in this index is also seen in neighbouring countries.

- Nitrogen dioxide

The highest annual average nitrogen dioxide concentrations predicted by the model based on 2016 emissions in the central and southern parts of the country were decreased significantly in subsequent calculation horizons. Significant reductions in concentrations are also expected in neighbouring countries except for the areas along the Baltic Sea, where no emission reductions were applied, due to the lack of guidelines in the text of the Directive.

- Sulphur dioxide

The average annual concentrations of sulphur dioxide indicate a significant decrease in both the highest values and the area covered by the elevated concentrations of this species.

- Particulate matter pollution

The annual average concentration of $\text{PM}_{2.5}$ in 2025 show a significant decrease in concentrations as compared to the current situation. The average annual concentrations of PM_{10} calculated for 2016 emissions indicate the highest concentrations in the central and southern part of Poland. Calculated concentrations for 2025 and 2030 show a significant decrease.

Impact of cross-border emissions depend on the pollutant, emission reductions and source distribution in Poland:

- For the AOT40 indicator, the contribution of ozone precursor concentrations from Poland exceeds 50% in most of the country. This fraction is slightly lower along the western and north-western borders. National emissions of precursors are also primarily responsible for the values exceeding the target value for health protection reasons.
- The contributions of pollutants from Poland in annual average concentrations of NO_2 exceeds 50%. A slightly higher cross-border contribution is predicted along the western and south-western borders.
- For SO_2 , emissions from Poland account for more than 50% in the annual average concentration. For the horizon of 2030, in the western part of the country, the transboundary inflow has the main contribution, which indicates a significant reduction in concentrations of this pollutant in Poland.
- Emissions from outside of Poland contribute over 50% to the annual average concentrations of $\text{PM}_{2.5}$ and PM_{10} over large areas of Poland. In the horizon 2030, as a result of a significant reduction of PM emissions in Poland, the contribution of concentrations from outside Poland increased.

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