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# DEPENDENCE OF AIR QUALITY CONDITIONS IN CITIES IN NORTH-WESTERN POLAND ON THE DIRECTION OF AIR INFLOW

**Abstract:** This paper presents the dependence of air pollution with sulphur dioxide and nitrogen dioxide on wind direction in Szczecin, Łeba, Elbląg and Zielona Góra in the period 1993-1999. It has been shown that the most disadvantageous air quality conditions in the cities listed above are on the days with air inflow from south-east, and the most advantageous on the days with advection from north-west. This dependence is particularly evident in the case of pollution with sulphur dioxide, especially in the cold half-year.

**Key words:** North-western Poland, air pollution, sulphur dioxide, nitrogen dioxide, wind direction.

In tracing large-scale directions of pollutant movement, of particular importance are analyses of the influence of wind conditions on air quality situation in regions with small emission of pollutants originating locally. In such regions, air pollution is due to a large extent to the inflow of harmful substances from remote areas. One of such regions is the north-western part of Poland.

This paper investigates the dependence of air pollution in Szczecin, Elbląg, Zielona Góra and Łeba on the direction of the inflow of air masses. Results of daily measurements of concentration of sulphur dioxide and nitrogen dioxide from the years 1993-1999 (the first three places listed above) and 1994-999 (Łeba) have been used. The wind direction in individual days in each of the points listed has been determined based on data from the Institute of Meteorology and Water Management (Instytut Meteorologii i Gospodarki Wodnej), by means of analysis of observation results in main synoptic times.

Compared to other regions of Poland, the area in question is distinguished by relatively small air pollution. In the four analysed measurements points the mean annual concentration of sulphur dioxide in 1993-1999 was in the range from 4.6 to 8.4 $\mu g/m^3$, while that of nitrogen dioxide, from 5.8 to

22.4 μg/m$^3$. In both cases, distinct seasonal changes of the mean concentration have been observed. Higher values occur in the cold half-year, especially in the winter, while lower values occur in the warm half-year, especially in the summer. Such well-defined rhythm is characteristic primarily for air pollution with sulphur dioxide. This results from the significant seasonal increase of emission of this pollutant: in the winter, especially during a very cold one, apart from the basic sources of $SO_2$ emission (large power plants), many additional sources are active (local boiler plants, house burners). The concentration of the nitrogen dioxide during each year also shows a winter peak, although a significantly weaker one. This is understandable, because public transportation is the main source of this pollutant in cities, and the intensity of traffic does not changes very much during the year.

Apart from changes in emission, seasonal changes of weather conditions strongly influence air pollution with sulphur and nitrogen dioxides during the year. In the warm half-year, quicker conversion of harmful primary pollutants and more effective removal of pollutants from the atmosphere are conducive to the decrease of their concentration. These processes result mainly from the more advantageous thermodynamic and precipitation conditions.

The strength of the correlation of the mean daily concentration of sulphur dioxide and nitrogen dioxide with wind conditions in each point considered has been estimated by means of correlation methods. It has been ascertained that the correlation under investigation is statistically significant, although the values of correlation coefficients are not high (0.3-0.5). Wind conditions exert stronger influence on air pollution with sulphur dioxide than on that with nitrogen dioxide. This results probably from the fact that in the region in question there are no large local sources of $SO_2$ emission, therefore the $SO_2$ pollution is caused to a large extent by the inflow of polluted air from large distances. This dependence is much stronger in the cold half-year than in the warm one, which is related to the fact that in the winter, when conversion of primary pollutants is slower, sulphur dioxide can be moved to more distant places before it undergoes conversion or is removed from the atmosphere. In the case of nitrogen dioxide the situation is different. Due to the fact that a significant share of its emission comes from transportation sources, this pollutant is moved with air masses over large distances to a smaller extent than is sulphur dioxide, whose emission comes mostly from tall chimneys. Therefore, local, located close to the ground and dispersed emission sources influence greatly the concentration of $NO_2$. This exactly explains the weaker correlation of the concentration of nitrogen dioxide with wind conditions, as well as small differences between the correlation coefficients determined for the cold and warm half-years.

To illustrate the influence of the wind direction on air pollution in northwestern Poland, in certain measurement points mean values of concentration of sulphur dioxide and nitrogen dioxide have been determined, as well as the frequency of occurrence of certain specified values of concentration of

these gases in days with air inflow from individual directions. The calculations have been done both for the cold and the warm half-year. This part of the analysis demonstrated that general regularities of the dependence of air quality conditions on wind conditions are analogous in the case of each substance considered. It is clear that particularly poor air quality conditions in the region in question occur on days with air advection from the south-eastern sector, while the best ones, on days with advection from the north-western sector.

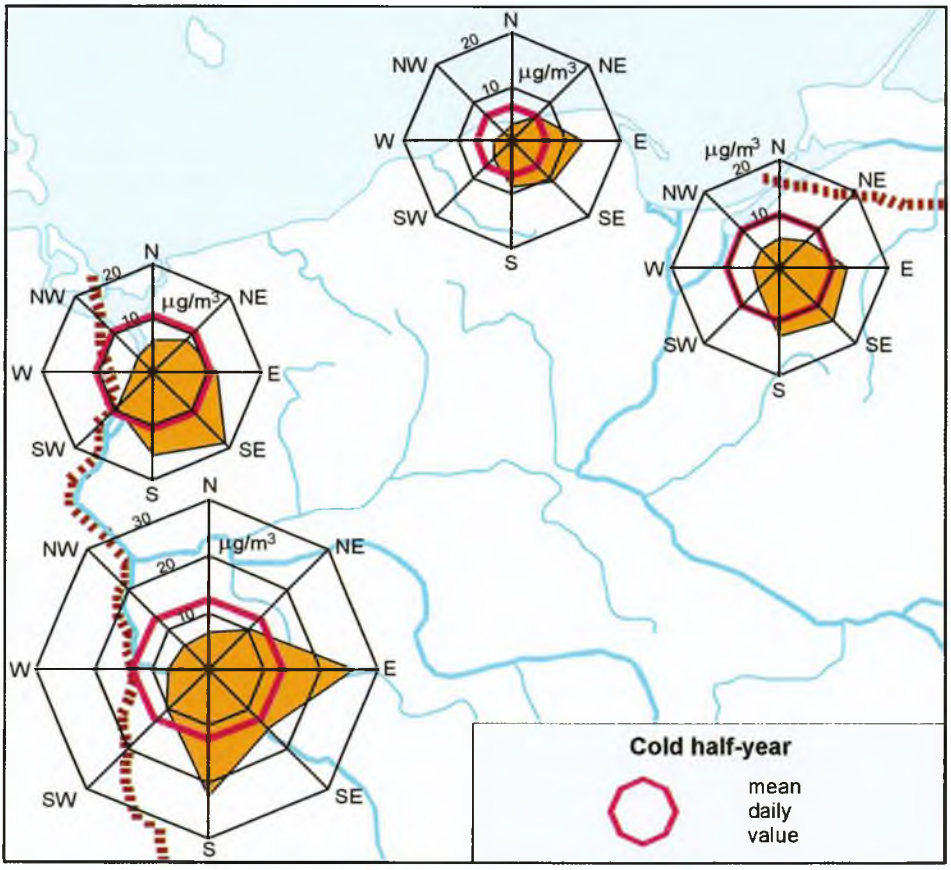


Fig. 1. The impact of the wind direction on the concentration of sulphur dioxide in north-western part of Poland

The strongest dependence of air pollution with sulphur dioxide on wind conditions occurs in the cold half-year (Fig. 1). It is characteristic that in all the measurement points considered here on days with air advection from the south-eastern sector the mean concentration of $SO_2$ is significantly greater than the mean concentration of $SO_2$ calculated for this half-year. In Łeba the mean concentration of sulphur dioxide on days with air inflow from

the east is twice as large as the mean value. Almost equally disadvantageous conditions predominate in Szczecin on days with air advection from southwest and in Zielona Góra on days with air advection from east or west. On days with air advection from the north-western sector, on the other hand, the mean concentration of $SO_2$ is usually less than half the average in individual points. In the warm half-year the dependence of the concentration of sulphur dioxide on wind conditions is clearly weaker, although the same wind directions are distinguished as advantageous or disadvantageous.

The dependence of the $NO_2$ concentration on the direction of air advection is much weaker marked (in particular in warm half-year). Also in this case, however, one can observe an advantageous influence of air advection from the north-western direction — it is best visible in Łeba in the cold half-year. The average concentration of $NO_2$ on days with air inflow from the south-eastern sector is usually somewhat larger than the mean concentration. Only in Zielona Góra the average air pollution with nitrogen dioxide seems almost independent from the direction of air advection.

The second part of the analysis allows for confirming and at the same time completing the conclusions reached so far. In this part of the analysis the numbers of days with specified values of sulphur dioxide and nitrogen dioxide concentration were considered, taking into account individual directions of air inflow. This stage of research made it possible to determine how often advection from directions regarded as advantageous or disadvantageous occurs in observation points considered, as well as to indicate what concentration values of the given gases are typical during such wind conditions (also, what are the greatest measured values of $SO_2$ and $NO_2$ concentration) (Fig. 2).

It was established that in the measurement points used here air advection from directions regarded as disadvantageous occurs fairly often (least often in Szczecin). It is unfortunately more frequent in the cold half-year. One can suppose that an exceptionally large inflow of sulphur dioxide over north-western Poland happens during very cold weather, caused by advection of the continental polar air from the eastern sector. It is on such days that the concentration of sulphur dioxide and nitrogen dioxide in cities of the region under consideration is relatively large (although in the period in question it did not exceed values acceptable by legal norms).

The identification of the dependence of air pollution in the given region on weather conditions, including wind conditions, makes it possible to increase the accuracy of the air quality forecast — for this reason such analyses are frequently done (a. o. Kuroś E., Morawska-Horawska M. 1989; Niedźwiedź T., Ustrnul Z., 1989; Niedźwiedź T., Olecki Z., 1994; Piwkowski H., Madany A., 1997). Moreover, the identification of directions of air inflow, during which air quality conditions in the given region can be regarded as deviating from the norm (positively or negatively) is a premise which allows to indicate, with great probability, the source areas of air pollution in this region. In the case of north-western Poland one can say that air pollution with sulphur

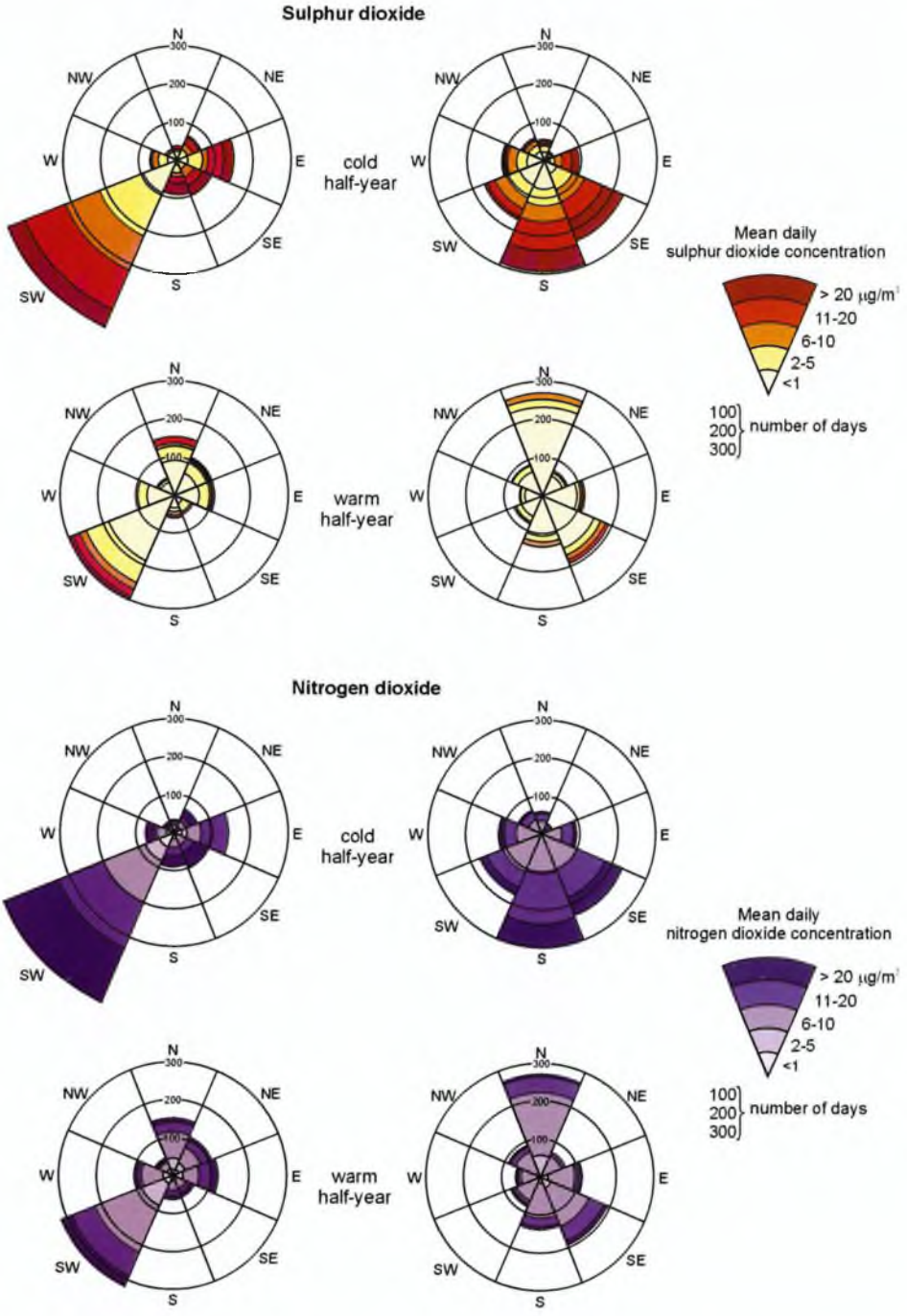


Fig. 2. Number of days with specified values of the sulphur dioxide and nitrogen dioxide concentration in Szczecin (left column) and in Elbląg (right column)

dioxide is to a large extent caused by emission sources localised in central and southern Poland (Kicińska, 2000). The same sources, although to a definitely smaller extent, increase air pollution with nitrogen dioxide in the same region.

Poland, just as other European countries, definitely restricts emission of harmful substances, including sulphur dioxide and — to a smaller extent — nitrogen dioxide. The effectiveness of these actions is not the same in various countries and their individual regions. For these reasons it would be profitable to perform analyses of the influence of wind conditions on air quality conditions in individual regions for longer observation periods, with break-up of the period into shorter periods, lasting a few years. Such research can illustrate very well the dynamics of changes of the spatial differentiation of air pollution on a large spatial scale.

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