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Ground Level Ozone Precursors: Emission Changes in Lithuania 1990–2006

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Lithuanian national strategy for sustainable development is aiming to reduce air pollution per GDP unit significantly and to ensure compliance with international commitments in the air pollution sphere. Ground-level ozone (O_3) is one of the most important secondary air pollutants, which is assigned to be harmful to environmental and human health and is one of the main problems of air pollution in cities. This paper aims to overview the changes in the emissions of ground level ozone precursors and their ozone forming potential as well as the achieved progress in foreseen goals. During the analysis period (1990 - 2006) emissions of ground-level ozone precursors declined twofold in Lithuania. After transitional decline intensity of ground level ozone precursors also significantly decreased due to advanced technologies, more efficient energy consumption and changes in fuel mix. However, intensity of ground-level ozone precursors in Lithuania was higher compared to the old EU member states on average, therefore much more attention should be given to special air pollution mitigation measures.

Key words: *ground level ozone precursors, intensity of ground level ozone precursors, Lithuania.*

1. Introduction

Ground level or tropospheric ozone is one of the most common secondary pollutants. Although the troposphere layer contains only about 10% of the total amount of atmospheric ozone, but each year the high ground level ozone concentration 0-2 km above the earth surface is becoming a more pressing global problem of air pollution.

Ground level ozone can adversely affect all living organisms - plants, animals, and people (Girgždys, Šopauskienė, 1999, Gražulevičienė, Laurinavičienė, 2003, Dėdelienė, Juknys 2008). It also constitutes a major part of photochemical smog and contributes to a greenhouse effect (Chadyšienė et al. 2004).

In the past 50 years ground level ozone concentrations doubled (Girgždys, Šopauskienė 1999). According to the European Environment Agency (2010) the main anthropogenic pollution sources include transport, energy, industry, agriculture and other industries (Fig. 1). Transport sector carries the main responsibility for emissions of ground level ozone precursors (45%).

Baisc ground-level ozone precursors are nitrogen oxides (NO_X), carbon monoxide (CO), volatile organic compounds (VOC) and methane (CH_4) which during complex photochemical processes with ultraviolet radiation form a secondary pollutant – ground-level ozone.

It is globally observed that ground level ozone concentration is increasing yearly. During the past 20 years in Lithuania the ground level ozone concentration was growing at an annual rate of 0.9 mg/m^3 (Girgždys, Šopauskienė 1999).

Hence, some researches show that ground level ozone level is strongly influenced by long range trans-boundary air pollution (Girgždienė, Girgždys 2003, West et al. 2009), local activities, especially transport greatly influence air quality in Lithuania (Chadyšienė et al. 2004, Laurinavičienė 2009, Schipa et al. 2009).

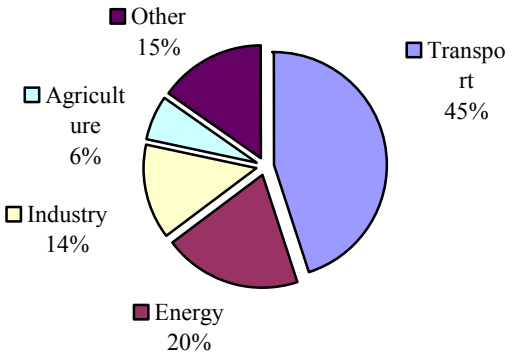

Fig. 1. Input of different sectors to the emissions of ground-level ozone precursors. Based on: EEA 2010

The paper aims to analyse changes in emissions of ground-level ozone precursors and to assess changes in the intensity of these emissions in Lithuania 1990 – 2006. The paper is structured as follows: first, some data and methodology issues are discussed, then results are presented and at the end some conclusions are drawn.

2. Data and methodology issues

The paper is based on descriptive analysis and focuses on the changes in ground-level ozone precursors during the period of 1990-2006. The data on the ozone precursors in air emissions (thousand tonnes) are obtained from the European Commission Eurostat database. To compare ongoing changes in the emission of ozone precursors the reference point of 1990 is chosen (1990 = 100%). Changes in the emission of ground-level ozone precursors according their ozone formation potential equivalent (TOFP - Tropospheric ozone forming potential) are also presented in the paper. The emission of ground ozone precursors according their TOFP equivalent is used to calculate the derived indicators and to compare them to the respective indicators at the EU-15 level. Ground level ozone formation is assessed on the basis of ground level TOFP equivalent, with a combined contribution of these four precursors: (1) nitrogen oxide (TOFP in NMVOC equivalent – 1.22), (2) non-methane volatile organic compounds (TOFP in NMVOC equivalent - 1), (3) carbon monoxide (TOFP in NMVOC equivalent – 0.11), (4) methane (TOFP in NMVOC equivalent – 0.014) (de Leeuw 2002).

The paper also evaluates one of the major eco-efficiency indicators - pollution intensity. In this case it is calculated in terms of emissions per unit of GDP, i.e., total ground-level ozone precursors (in TOFP) divided by GDP (Millions of PPS (Purchasing Power Standard)). Purchasing Power Standard - is an artificial currency unit in the EU to express the volume of economic indicators, to avoid the impact of the difference between price and purchasing power, and to make meaningful comparisons among countries.

3. Results

3. 1. Trends of emissions of ground level ozone precursors

As mentioned above the main ground-level ozone precursors are nitrogen oxides (NO_X) and volatile organic compounds (VOC). One of the most important chemical substances that affect the ground-level ozone formation is methane (CH_4) and carbon monoxide (CO). The changes in these ground-level ozone precursors are presented in Figure 2.

Over the period of 1990 – 1995 the emissions of ground-level ozone precursors were related to the transformational economic depression. Then air pollution decreased significantly. Until 1995 emissions of the main precursors, such as nitrogen oxides declined 60 %, carbon monoxide, methane, and NMVOC – twice. In the second half of the last decade, the country‘s economic situation started to improve and the emissions of ground-level ozone precursors started to increase, mainly due to increased consumption of energy resources in energy and transport sectors. Over the period of 1995-1998 emissions slightly increased: nitrogen oxides and methane by 1-2 %, and carbon monoxide and non-methane volatile organic compounds by 10 %. A short-term Russian economic crisis also had an influence on Lithuanian economy and consequently emissions of ground-level ozone precursors dropped to the level of 1995. Hence, with a pronounced economy growth since 2001 an increase in emissions of ground-level ozone precursors is observed: NMVOC – 18 %, NO_X – 5 %. A quite significant recent increase in NMVOC is mostly related to industrial activities. During the analysis period (1990-2006) in overall terms NMVOC decreased – about 30 %, methane – 45%, nitrogen oxides and carbon monoxide more than twofold compared to the 1990 level (Fig. 2).

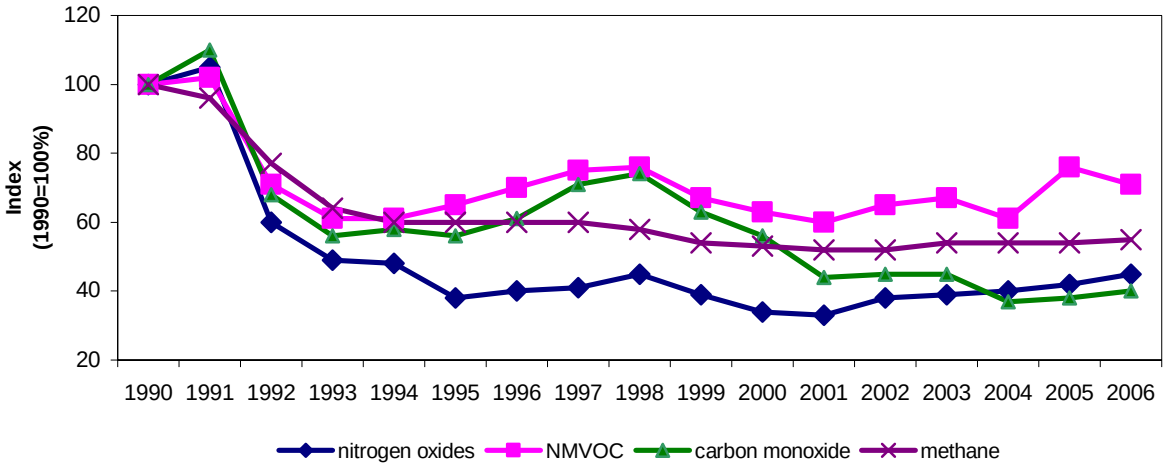

Fig. 2. Changes in emissions of ground-level ozone precursors in Lithuania over 1990-2006 (1990 = 100%). Based on: Eurostat 2010

3.2. Contribution of different pollutants to the emission of ground level precursors

Analysis of structural changes in the emissions of ground-level ozone precursors (Fig. 3) reveals that carbon monoxide emissions were dominating over the whole period under analysis, accounting from 40 to 51% of all emissions of ground-level ozone precursors. Methane accounted to 28 – 32%, non-methane volatile organic compounds to 11 - 16% and nitrogen oxides to 9-13% of emissions of ground-level ozone precursors (Fig. 3). In 2006 the structural composition of precursor emissions was slightly different compared to that in 1990. While the share of carbon monoxide emissions decreased, the share of methane and NMVOC emissions increased by 4-5 %.

It should be noted that despite carbon monoxide emissions accounted for the biggest part, overall influence of CO on the ground-level ozone formation was quite minor compared to NMVOC and NO_x as the ozone forming potential of carbon monoxide was much more lower than that of other ground level ozone precursors: NMVOC and NO_x.

Changes in overall emissions according to TOFP are presented in Figure 4.

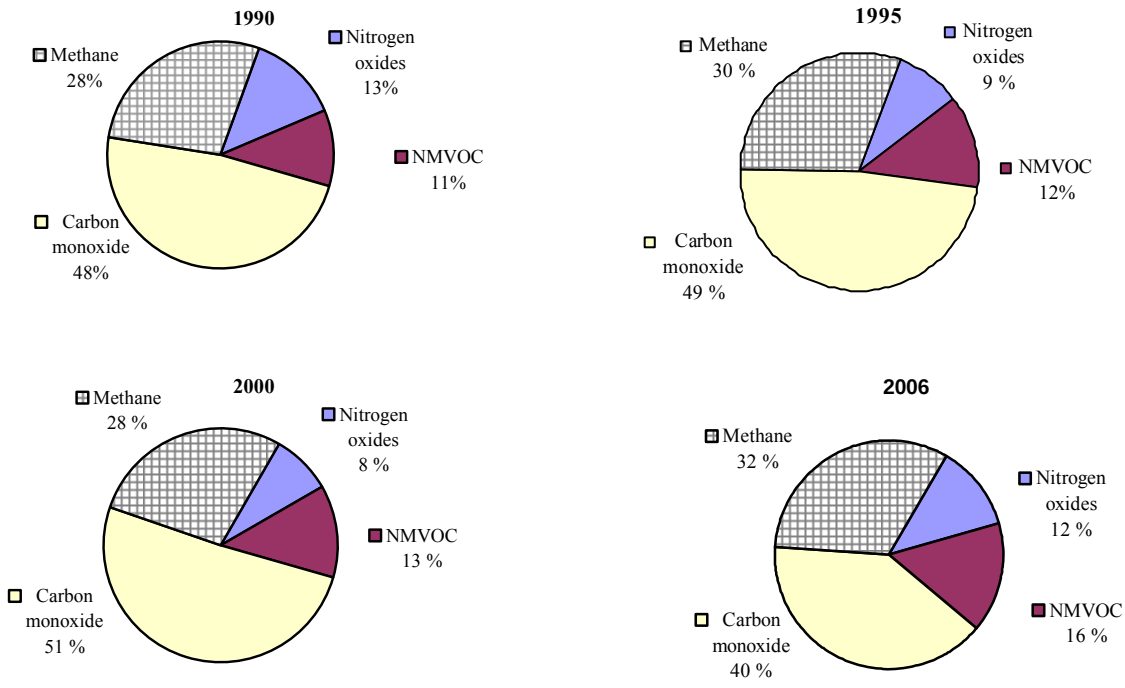

Fig. 3. Emission structures of ground-level ozone precursors over the period of 1990-2006. Based on: Eurostat 2010

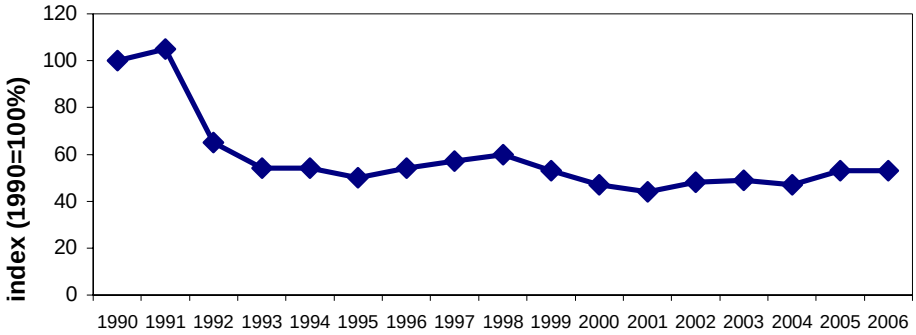

Fig. 4. Emissions of ground-level ozone precursors, 1990-2006 (according to their ozone-forming TOFP equivalent)(1990 = 100 %). Based on: Eurostat 2010

Over the whole period under analysis the emissions of ozone precursors (according their TOFP) were the highest in 1991. Afterwards, air pollution declined almost twofold during the transitional economic depression and fluctuated more or less at the same level. Due to the Russian economic depression the lowest emissions of ground-level ozone precursors over the whole period were achieved in 2001. However, if the emission of ozone precursors in absolute terms increased approximately by 5% after the Russian economic crisis (Fig. 2), the emission of ozone precursors according to their TOFP increased by 9% (Fig.4). This can be explained by the fact that emissions of nitrogen oxides and NMVOC were on a relatively more pronounced increase and their TOFPs are the highest (1.22 and 1, respectively).

Over the analysed period (1990-2006) despite a recent increase the emissions of ground-level ozone precursors according to their TOFP equivalents decreased twofold and amounted to 117.03 tons in 2006. These positive changes could be a result of penetration of advanced technologies, more efficient energy consumption, less polluting cars, and change in fuel mix.

The transport sector has the greatest influence on formation of ground level ozone precursors in Lithuania. Although during the analysis period (1990 – 2006) emissions of these substances have declined by more than twofold in the transport sector, but the latter was responsible for 45% of the total emissions of ozone precursors in Lithuania (Eurostat).

3.3. Intensity of pollution with ground level ozone precursors (according their TOFP)

One of the strategic aims of Lithuania, expressed in the National Sustainable Development Strategy (NSSD 2009) is to achieve that consumption of natural resources and environmental pollution should grow much more slowly than the economy or should not grow at all. The Lithuanian National Sustainable Development Strategy (NSSD 2009) seeks that the resources consumption and environmental pollution must grow at least twice slower than manufacturing and services.

The highest pollution intensity was registered during the period of economic depression. Then this indicator reached the value of 18t/1000PPS in 1995 (Fig. 5). That increase could be associated with old technologies, consumption of lower-quality fuel, reduced environmental control. After the economic depression air pollution intensity began to decrease gradually (Fig. 5). During the period of 1995–2006 pollution intensity declined about threefold from 18 to 5 t/1000 PPS.

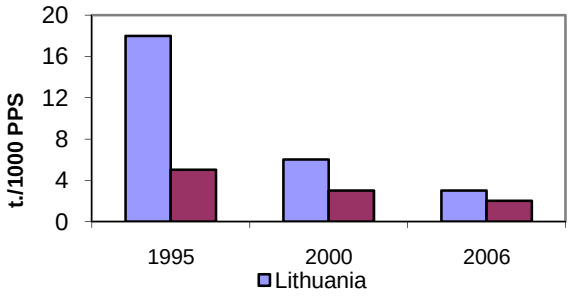

Fig. 5. Intensity of pollution with ground level ozone precursors (according their TOFP) in Lithuania and the EU-15. Based on: Eurostat 2010, and our calculations

Then, comparison of pollution intensity in the EU and Lithuania indicates that in both of them pollution intensity has declined. In the EU-15 the main driver of this reduction should be considered implementation of catalytic converters in vehicles (Colberg et al. 2005). Positive changes in Lithuania could be explained by more efficient energy use in general, advanced technologies and relatively renewed car fleet (Juknys, Dagiliūtė 2004). Despite the fact that both the EU-15 and Lithuania have decreased pollution intensity, it is observed that at the beginning of the period under analysis the pollution intensity index in Lithuania was three times higher compared to the EU-15 countries on average. As it was mentioned above, positive changes took place after transitional decline in Lithuania, along the growing economy the pollution intensity significantly decreased. It can be concluded that Lithuania is catching up with the EU-15 countries on average. At the end of the analysed period the difference between

Lithuania and EU-15 amounted only to 1.5 times. However, introduction of various environmental measures should be given much more attention to achieve the aims of the strategy to reach the level of pollution intensity indicators of EU-15. Pollution mitigation especially in a transport sector should be given the priority implementing a "polluter pays" principle and fostering public and alternative means of transport, as well as more efficient cars. Second the largest source of ground level precursors – energy sector – also should be addressed properly, especially large fuel combustion plants. According to the EU Directive on the limitation of emissions of certain pollutants into the air from large combustion plants (2001/80/EC) these plants have to fulfil certain requirements and pollution limits in order to minimize pollution and to comply with the national limits and pollution reduction plans, e.g. the National Ceiling Directive (2001/81/EC) sets national targets for Lithuania for certain pollutants in 2010: NO_x – 110Kt, VOC – 92Kt. Hence, in 2006 national emissions of NO_x amounted only to 61.37Kt and VOC – to 77Kt in Lithuania. The international commitments are recently fulfilled, namely, closure of Ignalina Nuclear Power Plant, whereas at the same time recovering industry, especially transport will raise additional challenges.

4. Conclusions

During the analysis period (1990-2006) emissions of ground level ozone precursors have decreased twofold in Lithuania. Most significant reductions are in carbon monoxide - about 50%, while volatile organic compounds are reduced much less - about 12%. The largest part in the structure of the ozone precursors falls to CO - even 40-51%. CO having a major share in the structure of ground-level ozone precursors, nevertheless, the influence of this pollutant to ground-level ozone formation is not as great as that of NOx and NMVOC possessing a much higher ozone forming potential. The transport sector has the greatest influence on the formation of ground level ozone precursors. Although during the analysis period (1990 – 2006) in this sector the emissions of these substances have declined by more than twofold, the transport sector leads to 45% of the total emissions of ozone precursors in Lithuania.

In the period of 1995-2000 maximum intensity of ground-level ozone precursors was registered in 1995. Afterwards positive changes took place and after the transformational recession period the intensity of ground-level ozone precursors began to decrease gradually and in overall terms have decreased threefold: from 18 to 5 t/1000PPS. Intensity of ozone precursors having significantly decreased, it is still higher than in the EU old member states. For this reason introduction of various environmental protection measures should be given much greater attention in order to reach the foreseen goals and fulfil international commitments.

References

Chadyšienė R., Girgždienė R., Girgždys A. 2004. Ultraviolet radiation and ground-level ozone variation in Lithuania. *Journal of Environmental Engineering and Landscape Management.* Vilnius: Technika, Nr. 1, 31-36.

Colberg, A. Ch., Tona, B., Catone, G., Sangiorgio Chr., Stahe, W.A., Sturm P., Staehelin, J. 2005. Statistical analysis of the vehicle pollutant emissions derived from several European road tunnel studies. *Atmospheric Environment,* 39 (2005) 2499–2511

de Leeuw, F.A.A.M. 2002. A set of emission indicators for long-range transboundary air pollution. *Environmental Science & Policy,* 5 (2002), 135–145

Dėdelienė, K., Juknys, R. 2008. Skirtingų vasarinių miežių veislių jautrumas ozonui [Ozone Sensitivity Of Different Sring Barley Cultivars] *Žemės ūkio mokslai*. VDU: Lietuvos mokslų akademijos leidykla. Nr. 4., 35–39.

EAA. 2010. Emissions of ozone precursors (CSI 002) - Assessment published Oct 2010 URL. http://www.eea.europa.eu/data-and-maps/indicators/emissions-of-ozone-precursors-version-2/assessment

Eurostat dababase. 2010. URL: http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database

Girgždienė, R., Girgždys, A. 2003. The Troposphere Ozone – an Indicator of the Environment Sustainability. *Environmental research, engineering and management*, 2003. No.4(26), 45-50.

Girgždys, A., Šopauskienė, D. 1999. *Atmosferos oro tarša ir jos sklaida.* [Air pollution and its dispersion] Vilnius. 196 p.

Gražulevičienė, R., Laurinavičienė, D. 2003. Ilgalaikės aplinkos oro taršos azoto dioksidu ryšys su miokardo infarkto rizika [Long-term Ambient Nitrogen Dioxide Relation to Myocardial Infarction Risk]. *Environmental research, engineering and management*, 2003. No. 2 (24), 37-432

Juknys, R., Dagiliūtė, R. 2004. Changes in Lithuanian Transport Sector from the Point of Sustainability *Environmental research, engineering and management,* 2004. No.3(29), 37-43

Laurinavičienė, D. 2009. Ground-level Ozone Air Pollution in Vilnius City. *Environmental Research, Engineering and Management,* 2009. No. 3(49), P. 21-28

Schipa, I.,·Tanzarella, A., Mangia, C. 2009. Differences between weekend and weekday ozone levels over rural and urban sites in Southern Italy. *Environmental Monitoring and Assessment* (2009), 156:509–523

The Lithuanian strategy for sustainable development (NSSD). 2009. Approved by Resolution No.1247 of September 16, 2009 of the Government of the Republic of Lithuania.

West, J.J., Naik, V., Horowitz, L.W., Fiore, A. M. 2009. Effect of regional precursor emission controls on long-range ozone transport –Part 1: short-term changes in ozone air Quality. *Atmospheric Chemistry and Physics Discussions*. 9, 7033–7077

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Priežemio ozono pirmtakų išlakų pokyčių analizė Lietuvoje 1990–2006 metais

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(gauta 2010 m. lapkričio mėn.; atiduota spaudai 2010 m. gruodžio mėn.)

Remiantis Lietuvos nacionaline darnaus vystymosi strategija, reikalinga sumažinti oro taršą, tenkančią BVP vienetui, ir užtikrinti tarptautinių įsipareigojimų įgyvendinimą. Priežemio ozonas (O3) yra vienas iš svarbiausių antrinių oro teršalų, darančių neigiamą poveikį aplinkai ir žmogaus sveikatai. Pastaruoju metu tai yra viena iš pagrindinių miestų oro taršos problemų. Straipsnyje siekiama aptarti priežemio ozono pirmtakų išlakų pokyčius Lietuvoje. Tiriamuoju laikotarpiu (1990–2006 m.) Lietuvoje priežemio ozono pirmtakų emisijos sumažėjo beveik perpus. Priežemio ozono pirmtakų intensyvumas taip pat sumažėjo perpus. Nepaisant to, šis rodiklis Lietuvoje vis dar yra didesnis nei Europos Sąjungos senbuvėse. Todėl ir toliau reikėtų daugiau dėmesio skirti būtent oro taršos mažinimo priemonių diegimui.