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CONTRIBUTIONS OF STREET TRANSPORT, RESIDENTIAL HEATING AND LOCAL INDUSTRIAL SOURCES TO AIR POLLUTION IN A SMALL TOWN IN ESTONIA

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Abstract

The ambient air quality is monitored mostly in cities, near big industries and in contrary, at remote rural sites for understanding the background pollution. This paper is focused on a small but compact town in a remote area, far away from big cities, big industries and highways. This is the first air quality model-measurement intercomparison study in a small town in Estonia and to our knowledge, in the Baltic countries as well. This study is based on *in-situ* air quality measurement with diffusive samplers, dispersion modelling, and a questionnaire study of residents. The aim of this study is to analyze, synthesize, compare and generalize NO_2 and SO_2 pollution in urban area. Are there any signs of elevated concentrations of SO_2 and NO_2 in certain places? Does burning of fuels in private houses affect the local air quality? How much contribute the street transport and industrial sources to the concentrations beyond the rural background? The model-measurement intercomparison statistics give rather good fit by means of average and dispersion, when the simultaneously measured concentration from a rural remote station is added to the modelled values, but still underestimates the highest NO_2 at street crossing by 34%. The Gaussian dispersion model AEROPOL performs adequately, reproducing the geographical and seasonal pattern in general.

Key words: *street transport, residential heating, local industrial sources, air pollution, AEROPOL model*

INTRODUCTION

A trend in today's society is steady economic growth and rising of living standards. The focus is on sustainable development, but the rapid growth of industry and urbanization, especially in low- and middle- income countries, has led to a deterioration of the air quality in many locations and a greater risk to the health of the population. Humans need the clean air to breathe, thus it is important to ensure that pollution levels do not exceed the permissible limits. A 2016 WHO report found that 92% of the world's population lives in places that do not meet the safe air quality levels required by the WHO, resulting in nearly 6 million deaths each year as a direct result of air pollution (Geneva, 2016). Air pollution ranks fourth among all global health risks, behind high blood pressure, unhealthy food choices and smoking (Health Effects Insitute, 2018). The joint study of University of Tartu and Estonian Enviromental Research Centre has pointed out that air pollution affects people's health in Estonian cities (Orru et al., 2009).

Pursuant to Directive 2016/2284/EU, Estonia has an obligation to reduce SO_2 emissions by at least 32% between 2020 and 2029 and 68% from 2030 onwards (reduction compared to 2005). To commitment to reduce NOx emissions by 2020-2029 is at least 18% and from 2030 it will be 30%. There is also a need and opportunity to improve air quality in the Otepää town.

The main purpose of this work is to clarify the origin and local sources of pollution in one of the most popular small towns in Estonia, summer and winter resort Otepää. The climate of Otepää is relatively continental (relative scarcity of precipitation and high fluctuations in air temperature). The author's goal is to analyse and synthesize the concentrations of nitrogen dioxide (NO_2) and sulphur dioxide (SO_2) in the ambient air of the town of Otepää and, based on the performance data, to assess the quality of the city's ambient air. The measurement data and other materials were collected during 2017-2018. Air quality studies in small towns have been carried out to a minimal extent in Estonia in past. One of the aims of this work is partly to fill this gap.

MODELS AND METHODS

In this research, both measurement and modelling methods are used to study the concentrations of NO_2 and SO_2 in the air. The questionnaire study of town dwellers, aimed to quantify the emissions from residential heating, is an essential part of this work.

Passive sampling

Measurements with passive (diffusive) samplers were carried out at four sites in the town of Otepää. Measurements were made during the summer (10.07-09.08.17) and winter (27.01-26.02.18) period. Three measuring points were located in the most polluted area of the town of Otepää (sites number 1,2,3) and one measuring point was slightly away from the town (site number 4), at a popular outdoor sports site. The main objective of the spread of measuring sites was to cover the urban area geographically, including the neighbourhood of largest sources of impact. Site number 1 represents the busiest crossing of streets in the town.

Modelling

Model AEROPOL 5.3.2. is a stationary Gaussian plume model developed in University of Tartu, Estonia. The model takes into account the reflection and partial absorption of the pollutant plume on the underlying surface, wet deposition and the initial thermal rise of the plume from the stack. The model is mainly used for environmental impact assessments and urban pollution dispersion calculations. In the past, a number of studies have been carried out for validation of the AEROPOL model (Kaasik & Kimmel, 2003, Geertsema & Kaasik, 2018) and it has been found that AEROPOL is a pretty reliable model for urban air quality assessment (Kaasik et al., 2019,).

The single-point meteorological data for modelling originate from Tartu-Tõravere observation station of Estonian Weather Service (20 km away). The street emission data are based on traffic counting, provided by Transport Administration of Republic of Estonia. The emission coefficients according to EURO vehicle categories were applied as reported by TU Graz (2009). The emission data on boiler houses and small local industrial enterprises are based on governmental environmental licensing statistics. The emissions from 6 boiler houses were considered, where the highest emitting one is UPM-Kymmene boiler house (2,14 tons per year of SO_2 and 21,42 of NO_x). The emissions of NO_x from all boiler houses are many times higher than SO_2 emissions, which certainly affects the concentrations in the air.

Questionnaire study

For residential heating emissions (incl. saunas) a questionnaire on heating habits (35 respondents) was performed. It was found that by energetic value, 92% of used fuel is firewood, rest 8% consisting of peat and liquid fossil fuel. The emission factors from firewood are based on wood burning experiments made by Estonian Environmental Research Centre (Teinemaa, 2013). The estimated emissions were generalized for entire number of locally heated houses in the town, 638 houses in total, which were then treated as point sources in modelling.

RESULTS AND DISCUSSION

In Figure 1 are presented the maps of modelled average concentrations of NOx and SO_2 from all sources in summer and winter episodes of passive sampling. For comparison with measured NO_2, it was assumed that 75% of locally emitted NOx is in form of NO_2 as average during the sampling time. In addition, the regional background values (0.8 μgm^{-3} of NO_2 and 0.2 μgm^{-3} of SO_2 in summer episode, 3.2 and 1.4 respectively in winter) measured in Saarejärve rural air quality monitoring station (70 km to NE), operated by Estonian Environmental Research Centre, were added to the modelled concentrations. Comparison of modelled (incl. added background) and measured concentrations is given in Figure 2. It is evident that the concentrations of both NO_2 and SO_2 are higher in winter due to heating, which is partially visible in regional background as well.

However, the highest NO_2 levels at busy crossing (1) and lowest levels of both NO_2 and SO_2 in the forest site (4) are reproduced by the model, as well as relatively uniform distribution of SO_2, which originates mainly from residential and district heating. In wintertime the concentration of NO_2 in the traffic site (number 1) is underestimated by 34%, which may occur due to underestimated traffic flow, as the generalized governmental statistics may not catch the specific features of a winter resort.

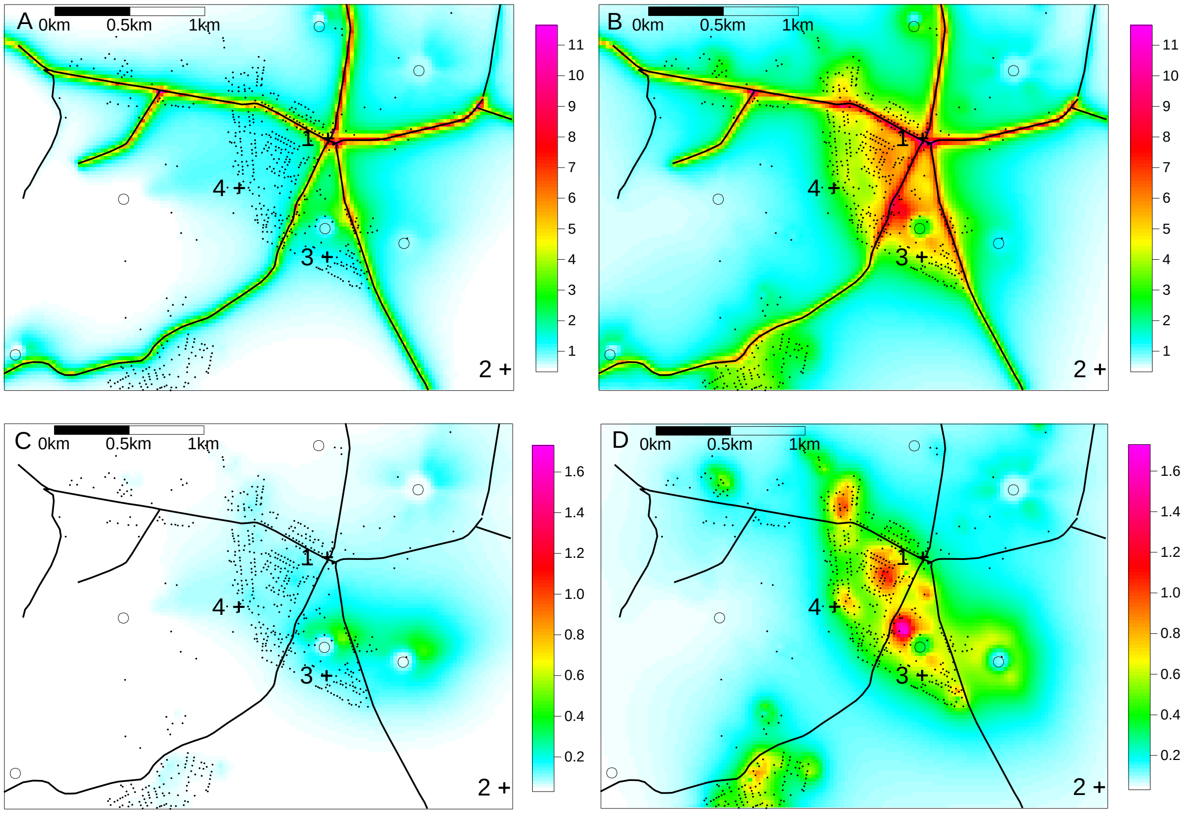

Figure 1. Modelled maps of concentrations of NO_2 in summer (A) and winter (B) and SO_2 in summer (C) and winter (D). Industrial sources are marked with black circles, Dwelling houses with small black dots and main streets with black lines. The crosses with numbers indicate the sampling sites.

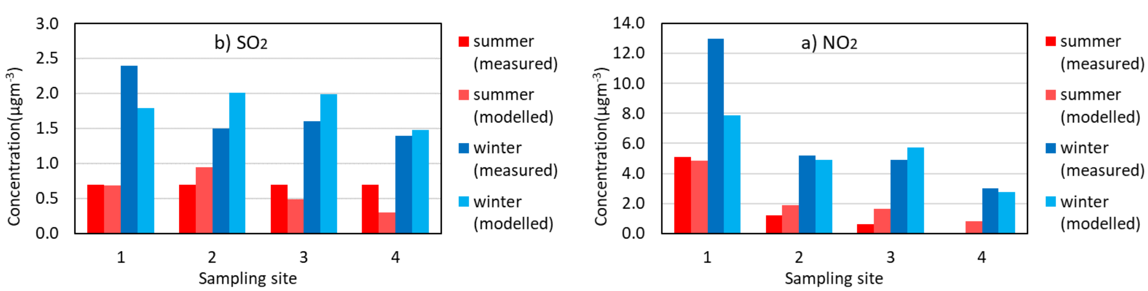

Figure 2. Measured winter- and summertime concentrations of NO_2 and SO_2 in sampling sites compared to model results.

In general, the model performs rather reliably, the measured and modelled concentrations are relatively similar, well below the European annual average limit values for NO_2 (40 μg/m^3) and SO_2 (20 μg/m^3).

Figure 3 shows the modelled winter and summer NOx concentrations from street vehicles. The highest concentration is at sampling site number 1 in both sampling times, 4,55 μgm^{-3} in summer and 4,56 μgm^{-3} in winter. Differences in winter and summer concentrations calculated for sampling sites are very minimal.

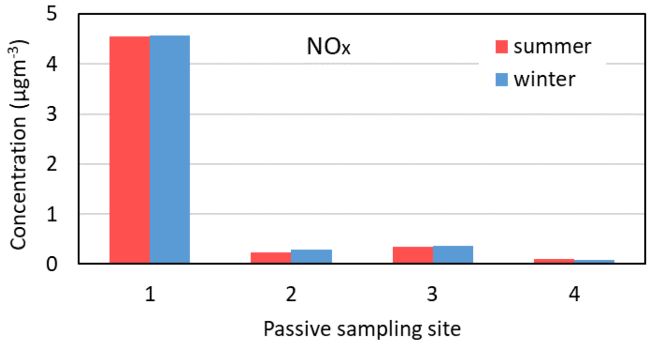

Figure 3. Modelled NOx concentrations from vehicle emissions in passive sampling sites.

The questionnaire study revealed that on very cold winter days (when outdoor temperature reaches nearly -20 ºC), the wood-heated dwelling houses are usually heated twice a day (morning and evening) and in days with more usual temperature, once a day (predominantly in the evening). Based on heating times and ambient temperature (cold, normal), concentrations of NO_x and SO_2 vary (Figure 4).

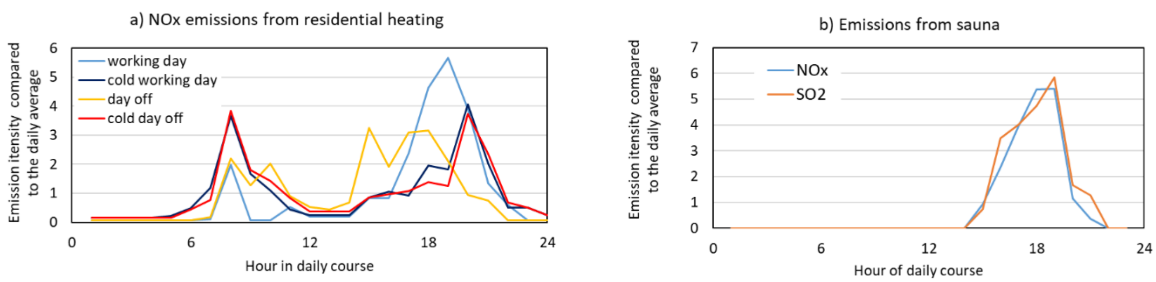

Figure 4. Daily course of emission intensity of NOx from residential heating (a) and daily courses of NOx and SO_2 from saunas (b).

Figure 4 shows that respondents to questionnaire study heat up their houses on normal working days after the work, at around 19:00 in the evening, and some also during the morning hours. Only very few of them heated from 10:00 to 14:00. On weekdays and holidays, duration of heating is fairly similar, 2-4 hours a day (except for dwellings with automated boiler systems). On a holiday, the houses are heated according to the situation, but on a working day usually after the work hours. The daily course of NO_x emissions is similar to the SO_2, but for SO_2 the morning emission peak is slightly higher due to the specificity of peat heating households. In addition, most respondents have a sauna at home (70% of the respondents), which is usually heated twice a week. Some households that have sauna as the only washing facility, heat it every second day. Saunas are mostly heated with wood, but about 11% saunas are heated electrically.

Most of respondents were very satisfied or satisfied with local air quality. Only one person did not have certain opinion on the air quality of the Otepää town. The main concern for them was making of fires in the neighbour garden, dust and smoke spreading by the wind. Another specific concern was increased humidity in neighbourhood of the ski centre, when making artificial snow. The smell from car exhaust from major roads through the town, and smoke from the boiler house were mentioned as well.

CONCLUSIONS

This study is one of a few ones on concentrations and sources of NO_2 and SO_2 pollution in small towns in the region. The results of this paper reveal that the source resulting in highest air pollution levels in a small Estonian town of Otepää is the car transport. There is only one traffic light junction in the town, but at least 2 000 motor vehicles pass through it every day, constituting a hotspot of nitrogen dioxide concentration. Predominantly wood-burning residential heating is the second contributor to the higher wintertime pollution levels. It is mentioned that the Gaussian plume model AEROPOL, considering also the regional background, reproduces reasonably the spread of air pollution in Otepää town.

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