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MIDDLE-TERM FIELD RESEARCH ON AIR AND NOISE POLLUTION IN THE CITY DISTRICT OF BALTIC REGION

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Abstract. Air quality monitoring, as well as physical pollution, in particular noise, is an important component for assessing the quality of life in cities and their regions. Detailed and accurate studies require an analysis of the results obtained with at least an average time interval, which was carried out in this study of the environmental situation in the area of the city of the Baltic region. The results obtained can identify the main areas of greater pollution, enabling new planning of communication systems in small towns, as well as avoiding negative effects on the body of residents, thereby improving overall health. The data was obtained using a mobile laboratory and high-precision equipment, based on international standards for parameter measurement techniques. According to the results of the research, trends were found to reduce particulate matter up to 10 microns, depending on the seasons, by more than 10%. The noise level in most of the area remains unchanged, or gradually increases due to large traffic flows. In contrast to the recreational area, the greatest increase in pollution in the residential area found PM_{10}, NO_2 and benzene, by 30%, 39% and 72% respectively. In the area adjacent to the road infrastructure, concentrations of benzene, ethylbenzene and toluene were 37–54% higher than in the recreational area. The average concentrations of other pollutants were lower.

Keywords: air quality, noise pollution, monitoring, city district, middle-term.

Introduction

The quality of the environment especially affects all human activities, determines the quality of life and comfort, and also reduces the possibility of health problems, improves the quality of natural products and is a good habitat for wildlife.

Air pollution has a huge impact to people life, including up to 6 million deaths over the world due to health problems caused by poor air quality. Chemical and physical pollution of air and anthropogenic sound as noise pollution are two major preoccupations of central world including Europe and Asia. They both could increase the negative impact and provoke health issues for human, wildlife and worsen the general state of the environment. Deafness and partial hearing impairment are a consequence of an increased noise level, and often this is not limited, since the processes also carry emissions into the atmosphere. Such processes occur during the movement of transport, industrial lines, as well as various local events (Ai et al., 2023; Castellani et al., 2022; Zhao et al., 2023).

Cities in the European Union are intensively developing new plans to improve air quality and conducting various types of research, e.g. Valencia's (Spain) city – Air Quality Improvement Plan including implementation of new research sites in future (Acosta-Ramírez & Higham, 2022).

One of the most actual problems in the EU are transportation system and non-effective and polluted logistics. Therefore, the biggest part of Eastern Europe remake and improve an urban transportation system, using renewable technology, city design according to the low emission plan and minimization of carbon sage and energy loss. The Population Mobility Plan includes a network of tools for smarter and more sustainable development, including the expansion of the cycling network and the modernization of public transport, which especially helps to reduce air pollution as well as noise levels. Each country and separately the city should have an individual

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solution plan and the application of these tools (Bronte-Moreno et al., 2023; Feng et al., 2022; Galimova et al., 2022; Vieceli et al., 2023).

The transport system is one of the parts of pollution together with industry. Emissions of hazardous substances from internal combustion engines, as well as general environmental pollution, both natural and anthropogenic, lead to a synergistic effect. For areas with district heating, the heat sector has a big impact on air quality, especially if low quality fuels are used. On the issues of noise pollution, in particular in the European Union, national programs are actively applied, and noise sources are eliminated in every possible way, or engineering solutions are applied to reduce the effect to the norms (Gelb & Apparicio, 2022; Ruiz-Páez et al., 2023; Zock et al., 2018).

There are planned other initiatives to minimize emissions to atmosphere. These procedures apply in the public and private sectors. Switching to a more environmentally friendly fuel, or replacing it with a system that uses renewable energy, renovation of equipment and buildings, the use of various types of purification not only of air, but also of other components of the natural environment (Khaiwal et al., 2016; Le Boennec & Salladarré, 2017; Mohamed et al., 2021; Smith et al., 2020). A special position is occupied by the use of secondary use and the ring economy. Recycled materials are used to avoid increased consumption, or the object is used in an environment with a lower quality level. This allows not only to significantly reduce the need for non-renewable or difficult to extract raw materials, but also to get rid of waste volumes.

Environmental monitoring makes it possible to identify possible problems, as well as the dynamics of their spread. On the other hand, by applying tools to reduce the environmental impact, data can be obtained on the effectiveness of these solutions. Certain types of study can be used as standard methods, to study several parameters at the same time, or selectively determine the most important ones. Of great importance is the choice of a network of zones for study, their environment, including sources of pollution, the meteorological situation, and the object of influence of this pollution. It is important to understand that such a study does not exclude natural impacts, which should be taken into account in the analysis. The applicable directives (2000/69/EC, 96/62/EC and 2008/50/EC) within the European Union limit the levels of pollution, or indicate the targets to which the municipalities of the territories should strive for monitoring. The Green City Accord indicates the means that cities should use for sustainable development to reduce pollution. Given the fact that the population in cities is increasingly increasing, these decisions should be implemented not only as soon as possible, but with a partial expansion. The pace of development and improvement of technologies should also be taken into account. All of the above points can transform even newer forms of tasks to perform (United Nations, 2014).

Noise levels, as well as the impact of particulate matter on the human body, are considered to be the most important problems that arise in an urbanized environment. Ultrafine particles up to 2.5 μm and smaller are dangerous due to their deep penetration, which contributes to serious problems with the respiratory and cardiovascular systems. Particles containing various substances in their composition further enhance the negative effect of exposure. In some cases, the mortality from such particles reaches 5% (Cohen et al., 2005; Nawrot et al., 2011; Pilla & Broderick, 2015; Vardoulakis et al., 2005).

Usually, studies of the effects of noise and air pollution are taken separately. However, there are already works that present an analysis of these parameters as a whole. Such a study is more rational, since the problem is often united by a common source object, and also the influence cannot be only one of the factors, thus the weight coefficients of each of the pollution are taken, and the overall indicator is calculated (Vlachokostas et al., 2014). According to the authors of the work, the state of the environment has a positive effect on human health, and also reduces the impact on climate change. The social component also matters. Most often, low-status areas are more affected due to their proximity to sources of pollution, as well as fewer opportunities to equip housing, move around and purchase the necessary protective equipment (The Lancet Regional Health – Europe, 2023). Papers have been found on air quality studies using modern methods, namely using neural networks, cloud computing and smart drones. However, according to the authors, these methods require additional validation and improvement (Arroyo et al., 2022; Kabir et al., 2022; Palomeque-Mangut et al., 2022; Qu et al., 2023; Rani Hemamalini et al., 2022).

The purpose of this work is the analysis of the results of medium-term environmental air and noise monitoring and the correlation of both types of pollution in a small transit city of up to 35,000 citizens population with agriculture activity.

Methodology

The study was conducted in Raseiniai district, Eastern Europe, Lithuania, and counted eight permanent air quality monitoring sites established in the city (six sites were established near the busy road). Noise pollution was monitored in the city (twelve monitoring points were established, including near the busy road, near the hospital and educational institution, in the quiet zones. Four monitoring sites were established in the city and eight in the district.

In 2021, there were 31,192 inhabitants living in Raseiniai district. The area of Raseiniai district covers 1573 km^2. The average temperature is –4.8 °C in January, a temperature of +17.0 °C in July and an approximate precipitation of 664 mm (annually). South-westerly and

westerly winds prevail in Lithuania. During the studied period, northwest and west winds prevailed, bringing air masses from the mentioned European countries. The aim was to conduct studies in different areas, as close as possible to each other, in order to compare the results of air pollution and to identify the source of pollution. The air quality surveys in Raseiniai district were conducted at 8 urban sites for air quality and 12 sites for noise pollution. The map of the selected sites in Raseiniai district is shown in Figure 1.

Investigations of air pollution in the territory of Raseiniai district municipality were carried out in 2017–2021 at 8 research sites during the winter season and at 6 research sites during the spring, summer, and fall seasons. All measurement locations in the municipality of Raseiniai district were chosen closest to the main streets of the city, located in the vicinity of kindergartens, schools and residential houses. Noise measurements in the territory of Raseiniai district municipality were carried out at the same time as air pollution research in 12 locations: near hospitals, educational institutions, in quiet areas, four sites of them are planned in the city of Raseiniai and eight sites in the territory of the Raseiniai district.

The monitoring sites were selected to represent the areas of recreational, residential and traffic pollution in Raseiniai district. The sites for air quality (A2) and for noise pollution (N1, N12) were selected to analyse zero-level impacts.

In accordance with the Air Quality Directive 2008/50/EC, the results of indicative measurements shall be taken into account for the assessment of ambient air quality in relation to limit values. For indicative measurements, the minimum temporal coverage is 14%, which results in 8 weeks evenly distributed over the year. Therefore, the results obtained can be compared with the established limits for the pollutants measured. The samplers in the enclosures were placed at a height of 3–4 m above the ground. The area where the samples were taken was open, free from buildings, trees and other objects, and

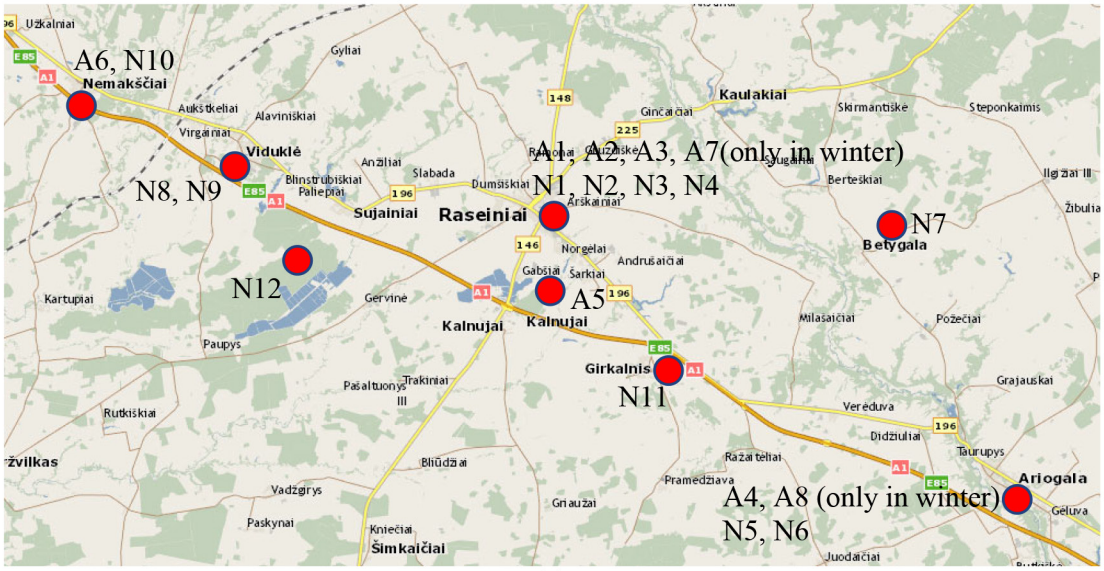

Figure 1. Locations of air quality (A_*) and noise pollution (N_*) monitoring in Raseiniai city (a) and city district (b) zones

at least 1 m away from structures that could disturb the air flow. PM10 was measured by the beta radiation absorption method (International Organization for Standardization [ISO] 10473:2000, 2000) using the Environment S.A. Model MP101M PM10 Beta Gauge Monitor (France) over an 8-hour period at an average flow rate of 1.0 m^3/hour. An average value for PM10 was calculated at each monitoring point. Concentrations of gaseous pollutants (CO, NO_2, SO_2, O_3) were determined in a mobile laboratory using analysers. Detailed information on the devices can be found in the document (Chlebnikovas et al., 2022).

Table 1. Measurement sites

[No of the sites], coordinates (WGS)		
Residential territory	Recreation territory	Areas close to intense transport streets and/ agriculture activity
A3, 55.374631, 23.123699	A2, 55.384472, 23.120308	A1, 55.381015, 23.10907
A4, 55.261801, 23.487671	A5, 55.350623, 23.115664	N2, 55.380759, 23.109009
A6, 55.429847, 22.773176	N1, 55.385325, 23.119136 (zero-level zone)	N3, 55.372496, 23.126893
A7, 55.376808, 23.133174	N4, 55.38478, 23.116058	N10, 55.429148, 22.776449
A8, 55.266555, 23.46418	N5, 55.263033, 23.471429	
N8, 55.408575, 22.893962	N6, 55.258314, 23.479525	
N9, 55.401402, 22.906598	N7, 55.362527, 23.364149	
N11, 55.308749, 23.202755	N12, 55.356628, 22.934913 (zero-level zone)	

Research sites is presented in Table 1. The analysis zones are selected in accordance with the location of settlements, towns and the city of Raseiniai, and the number of zones is proportional to the number of residents. The location of pollution sources, infrastructure, as well as meteorological conditions and the requirements of standard procedures are taken into account.

To study the comparative assessment of the correlation of various parameters of air pollution and noise, an analysis was performed using the Pearson index. Correlation level is accepted according to the corresponding typology: 0 – no correlation; –0.2–0 or 0–0.2 – very weak; –0.4–(–0.2) or 0.2–0.4 – weak; –0.7–(–0.4) or 0.4–0.7 – medium; –0.9–(–0.7) or 0.7–0.9 – strong; –1–(–0.9) or 0.9–1.0 – very strong; –1 or 1 – direct connection.

Results and discussion

Full environmental air monitoring was carried out in the territory of the city district, i.e., over a period of six years, characteristic pollutant surveys were carried out each year in each season. A summary of the results obtained from eight research points is presented in Figure 2.

According to the results, it was established that the concentrations of SO_2, PM_{10} and m, p-xylene varied the most between the different research sites, in some cases very low concentrations of NO_2 were obtained. Concentrations of nitrogen dioxide and solid particles are separated into a separate axis of the scale, because compared to other pollutants, their values are 3–5 times higher. These pollutants are released during all combustion processes – burning fuel in internal combustion engines, boiler houses, and other companies. The main source of nitrogen dioxide in the air of the underground environment is the gas emitted by cars, while the influence of power plants on underground concentrations of nitrogen dioxide is smaller, because the NO_2 entering the environment from tall stacks is dispersed higher. Emissions of solid particles are usually of natural origin, high concentrations are formed in dry, windy weather, and depending on the season, the particles may contain sand, pollen, and various organic traces. Another origin of solid particles is

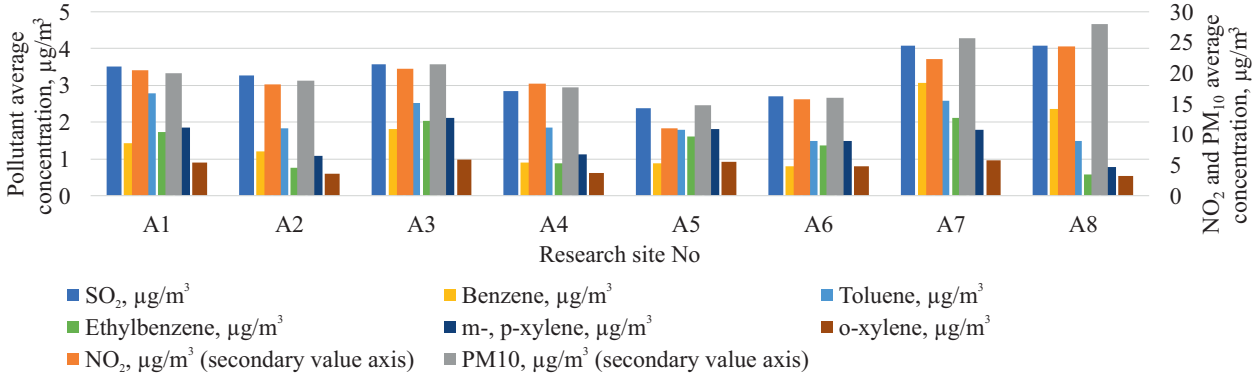

Figure 2. Average concentrations of air pollutants over a six-year period at individual research sites

anthropogenic, which enters the atmosphere from industrial areas, raised pollution from construction sites, transport road surfaces, mobile and stationary pollution sources of various purposes. At all study points except A1 and A4, PM_{10} values were higher than NO_2, and the difference between the values ranged from 1.8% to 25%, but the difference was greater in cases where the values were low. The results obtained at the A1 study site were mostly influenced by the nearby road of regional importance, and assuming that the area of this city has developed agriculture, heavy machinery also moves on the roads, which increases both PM_{10} and NO_2 concentrations. Points A2 and A5 were located in the recreational zone, the concentrations were slightly lower, but the average annual average remains relatively high compared to other more polluted areas. Other survey points were located in accommodation areas, i.e., mostly one-two-story private households. In comparison, during the winter and summer seasons, PM_{10} concentrations reached 20–30 μg/m^3 at these points, and over 45 μg/m^3 in some periods, while NO_2 reached 15–30 μg/m^3, occasionally 35 μg/m^3. Concentrations were significantly lower during other seasons. The pollution generated by households is significant, and accepting the fact that such pollution is generated in a large area, it is obvious that it changes the condition of the ambient air quality in the nearby area, and also causes the pollution transferred to the adjacent areas of the city district or even other districts.

The results of the noise level show a strongly different situation between the maximum and equivalent noise levels, which is 28.6–43.5%, or if we accept the absolute difference – 22.3–36.4 dB. It is clear that in the research points N2 and N3, and in parts N4 and N5, the main sources of noise are motor vehicles passing through road junctions close to research points, where the flow of vehicles reaches 450–500 units per year, and at the most intensive points up to 1300 units.

At other research points, although a small number of passing motor vehicles were detected, the noise levels remained at high levels, for example, the equivalent noise level was in the range of 45–53.4 dB, and the maximum noise level was 69.5–85 dB. This means that even the noise level is not necessarily influenced only by road transport, but some of the highest noise levels were obtained in areas with a mixed layout – residential environment-economic activities and near transport road connections. For comparison, the results in quiet areas indicate that the background equivalent noise level values are mostly close to 40–45 dB, and the maximum noise level does not exceed 74 dB, when the influence of traffic is avoided.

Noise surveys were obtained in spring, summer and autumn seasons, at each survey point the equivalent and maximum noise level was determined at three times of the day – day, evening and night. The obtained results together with the number of identified motor vehicles at the corresponding research point are presented in Figure 3.

Correlation analysis was performed according to the Pearson test for the relationship between the obtained results of ambient air pollution and prevailing noise levels in the respective zones, and the results are presented in Table 2.

Table 2. Correlation air pollutant and average noise level at the similar research sites

Pollutant	Pearson criteria value (Preliminary assessment of correlation)
Sulphur dioxide (SO_2)	0.70 (high)
Nitrogen dioxide (NO_2)	0.72 (high)
Particulate matter (PM_{10})	0.55 (average)
Benzene	0.43 (average)
Toluene	0.86 (high)
Ethylbenzene	0.36 (low)
m-, p-xylene	0.40 (average)
o-xylene	0.34 (low)

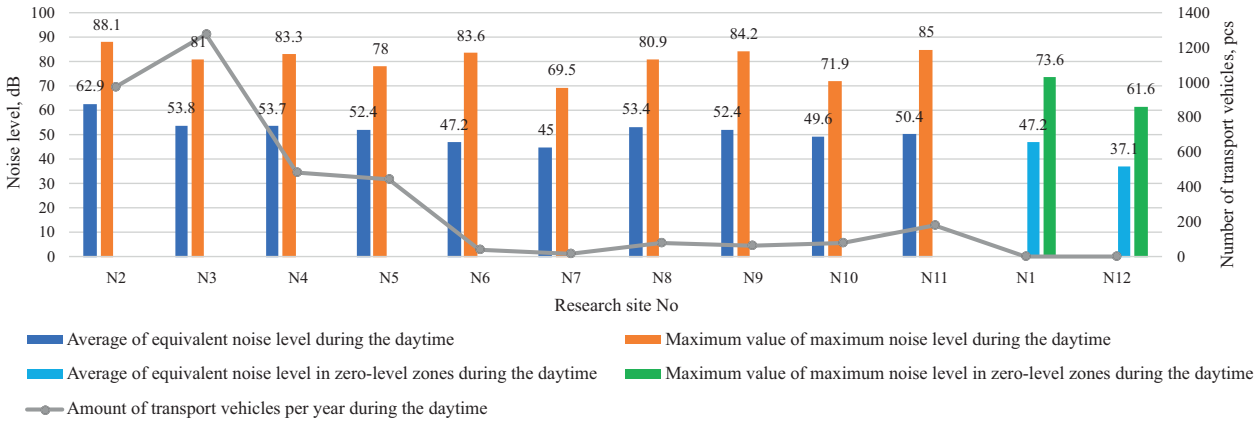

Figure 3. Average annual value of equivalent and maximum noise levels during the day at research points and quiet zone research points and annual number of passing motor vehicles

The values of the correlation criterion indicate the strength of the relationship between a specific air pollution indicator, in this case, the relevant studied pollutant, and the values of the concentration and equivalent noise level of this pollutant determined at the relevant research point. For comparison, the concentrations of all pollutants were analyzed, and the average annual equivalent noise level of the whole day was taken as representative for the impact of noise. The obtained values of Pearson's criterion showed that the strongest of the relationships is established between SO_2, NO_2 and toluene, when the criterion values were above 0.7. Criterion values are in the range of 0.4–0.55 when evaluating the relationship between PM_{10}, benzene and m-, p-xylene concentrations with noise pollution. The lowest correlation was found between ethylbenzene and o-xylene – less than 0.36.

Conclusions

The assessment of environmental monitoring studies is important in order to predict the future dynamics of pollution in the region, so the thought of such studies must be as detailed as possible. The duration of monitoring has a significant influence on the representativeness of the results. Medium-term monitoring allows obtaining more accurate and detailed results than short-term or one-time studies. By operating with at least several indicators and evaluating the dynamics of several years, it is possible to analyze mutual correlations and strive to reduce pollution according to the cause of their occurrence. Evaluating each season over a period of several years reduces the possibility of random errors, averaging evens out possible climatic irregularities. On the other hand, an annual comparison of the seasons allows us to appreciate the different regions of the world's climate zones, where the period of the year clearly changes through the constant four seasons. The results of the research carried out in this scientific paper showed the spread of air pollution of local importance in different areas of the city district, where relevant activities prevail and infrastructure is installed. The results of noise monitoring clearly identified the most affected areas, and also indicated the nature of existing background or, in other words, spontaneous noise in the city area. The obtained statistical relationships make it easier to predict the influence of air pollution and noise phenomena, which are different in nature, on each other and the degree of this correlation. Medium-term studies can be continued further, which would provide additional data from a scientific point of view, and with observations of at least 30 years and more, it would be possible to decide on climate changes and individual environmental components and the general ecological condition.

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