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Distribution of Iron in Dust Near Streets: Case Study Jelgava City

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Abstract. **The world's urban population is projected to grow to 68% by 2050. According to statistics, 68% of the country's population already lives in Latvia in 2022. Much of the air pollution research in the city is focused on researching highways and streets of very intensive traffic. Small and medium-sized cities with their infrastructure remain unexplored. The population of cities of different sizes is growing every year, so it is important to understand the prevalence of pollution along the streets in small and medium-sized cities, as this pollution has a direct impact on the health of the city population. Snow and stored dust are good matrices to assess the extent of air pollution and metals in urban areas. It should also be stressed that the number of cars in cities is increasing, while the age of the car fleet remains increasing. The aim of the study is to find out how iron is distributed at different distances from the street section in Jelgava city research facilities. Snow samples were collected at 3 monitoring points with a distance of 1 m, 50 m, and 100 m to each side of the street. Snow samples were melted, acidified, filtered, and measured with ICP-OES spectrometer. For data analysis, descriptive statistics, the Kruskal-Wallis test, and the Steel-Dwass-Critchlow-Fligner procedure were used. In all monitoring points, iron pollution in air at 1 m is statistically significantly higher than at 50 m and 100 m (p-value 0.018; and 0.011), which directly indicates the impact of cars on air quality close to the streets. At the monitoring point located on Riga Street, the iron concentration at 1 m distance is 10.9 mg/l and at 100 m 0.33 mg/l. The data obtained can be used when designing streets and conducting urban planning.**

Keywords: Snow, iron, pollution, ICP-OES spectrometer, Kruskal-Wallis test.

I. INTRODUCTION

Iron is an essential component of (PM) particles and its presence in PM is associated with various impacts on human health and the environment. Studies have shown that iron oxide particles are the dominant component of PM in various anthropogenic environments. In research were investigated that iron oxide particles were present in most PM particle samples from the subway, suggesting iron distribution in urban environments [1]. PM particles containing iron were found to cause oxidative stress in human lung cells, highlighting the potential health effects of iron-rich PM particles [2].

The fact that PM particles, especially iron particles and their concentrations in the air, can serve as a source of air pollution for markers in the air, is significant. Research in Europe demonstrated that the percentage of iron particles in PM can indicate traffic-related pollution, highlighting iron's role in identifying sources of pollution [3]. Another research paper stressed that iron is a highly ubiquitous element in the environment and is the dominant transition metal in PM particles, its role in uranium air pollution has so far been underestimated [4].

So far, the biological effects of iron-containing PM particles have been studied in several research papers. In researchers linked iron concentrations in PM particles to respiratory compositions, indicating a link between iron levels and inflammatory effects on pulmonary epithelial cells [5]. In addition, group of scientists described how iron can affect inflammation caused by PM particles,

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suggesting that iron content in PM particles affects lung toxicity [6].

Iron plays a critical role in PM particles in the air, which affects human health and environmental quality. Understanding iron sources in the urban environment is essential to assess and mitigate the impact of particle pollution on public health and ecosystems.

The aim of the study is to find out how iron is distributed at different distances from the street section in Jelgava city research facilities.

II. Materials and methods

Jelgava is a city in the middle of Latvia, Zemgale Plain. The city is a transport corridor between various cities of Latvia and the national capital Riga. Jelgava has a total area of 60.3 km^2, a further description of the city can be found in [7].

Five days after snow fell, snow samples were collected at each point at a distance of 1 metre, 50 metres and 100 metres from the road perpendicular to both sides of the carriageway. Snow samples were collected at three areas of intense traffic flow in the city of Jelgava (see Figure 1). First point describes transit flow of cargo transport and residential traffic. Second location describe residential transport. Third location describe transit between Jelgava City and capital city Riga. A total of 108 snow samples were collected and analysed.

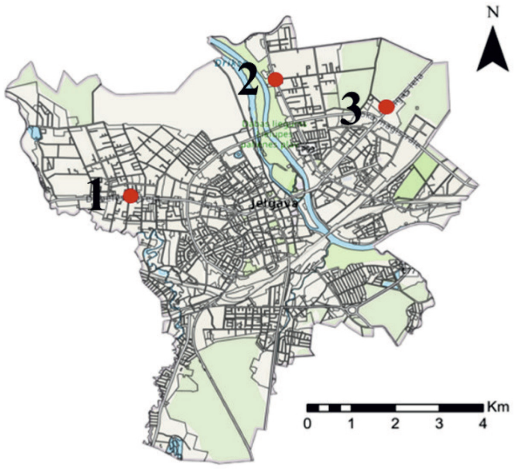

Fig. 1. The location of snow sampling areas in Jelgava City.

Snow samples were melted and analysed in two ways after collection. The first group of samples was filtered to remove PM particles and then acidified. On the other hand, the second group of samples was first acidified with all PM particles in solution and then filtered [8]. The filtered solution was analysed in an ICP-IOP analyser [9].

For data analysis, descriptive statistics, the Mann-Whitney test [10], the Kruskal-Wallis test [11], and the Steel-Dwass-Critchlow-Fligner procedure were used to identify differences between groups [12].

III. Results and Discussions

The analysis of the results was divided into several steps, where samples with PM particles and samples without PM particles were compared in the first step. The next step assessed the effect of distance on the iron content of samples with PM particles and samples without PM particles. In conclusion, the impact of the particular transport corridor on the iron content of the solution was analysed.

Snow samples with PM particles showed much higher iron concentrations than those in the samples without PM particles. The mean iron concentration in samples without PM particles was 0.013 mg/l, while in samples with PM particles 2.26 mg/l. The descriptive statistics of the two groups of samples is presented in Table 1. A Mann-Whitney test was used to find out whether differences between two sample sets were statistically significant. This showed that there are significant differences *(p-value <0.0001)* in iron concentrations between samples with PM particles and samples without PM particles.

Table 1 The Iron concentrations in snow by sample preparation

Variable	With PM particles (mg/l)	Without PM particles (mg/l)
Minimum	0.171	0.006
Maximum	10.963	0.035
Mean	2.260	0.013
Std. deviation	3.517	0.011

In the next step were analysed a sample set with PM particles. According to a distance from the road, three groups of snow samples are formed, characterizing iron concentrations in snow samples at different distances -1m; 50m; 100m from the road. The maximum value for all samples is 10.963 mg l^{-1} and the minimum value is 0.171 mg l^{-1}(see Table 2).

Table 2 The Iron concentrations in snow samples with PM particles by distance from road

Statistics	mg l^{-1} | 1m	mg l^{-1} | 50m	mg l^{-1} | 100m
Minimum	1.211	0.183	0.171
Maximum	10.963	1.221	0.962
Range	9.752	1.038	0.792
1st Quartile	2.360	0.321	0.207
Median	5.984	0.332	0.236
3rd Quartile	9.258	0.465	0.311
Mean	5.940	0.482	0.356

The concentration of iron in snow is highly variable (see Fig.1.).

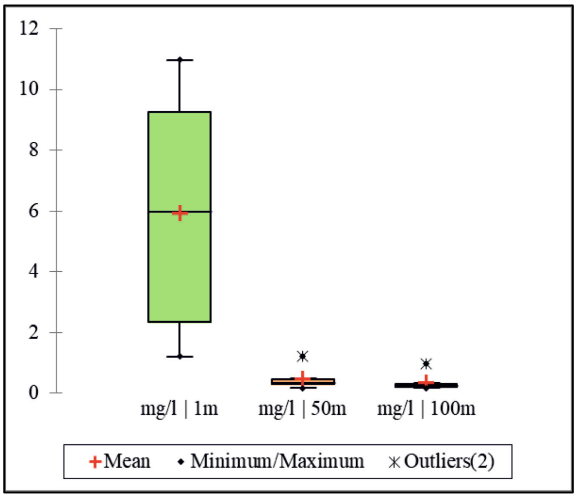

Fig. 2. The variation of iron concentrations by distance from road.

All values of descriptive statistics decrease as the distance from the street increases. The sharpest reduction is between 1 m distance and 50 m distance, while the reduction between 50 m distance and 100 m distance is but less pronounced.

Kruskal-Wallis test show significant differences between groups *(p-value<0.003)*. To understand the differences in between groups the Steel-Dwass-Critchlow-Fligner procedure were used to identify significance of differences between the groups of distances from street. The test results show significant differences between 1m and 50m groups *(p-value<0.018)* and 1m and 100m group *(p-value<0.011)*. There is no significant differences between group 50m and 100m (see Table 3).

TABLE 3 THE P-VALUES AND GROUPS OF IRON CONCENTRATIONS IN SNOW BY DISTANCE FROM ROAD

Distance	1m	50m	100m	Groups	
1m	1	**0.018**	**0.011**	A	
50m	**0.018**	1	0.501	A	
100m	**0.011**	0.501	1		B

The iron concentration in the snow, which characterises transport pollution, is variable not only by distance from the road but also by location in the urban system. Therefore, snow samples were analysed after localisation according to numbering (see Figure 1). All locations are with similar iron concentration variations (see Figure 3). All locations are shown to have extreme iron concentrations found in snow samples collected 1 m from the road (see Table 4).

The first location describes a transit flow that combines the light transport flow through the city of Jelgava and the cargo transport flow that uses this street because the Jelgava bypass flow connects. This location has the highest median value of 1.087 mg l^{-1} due to the presence of cargo transport transit.

The second location describes the average transport flow, which is mainly related to the daily resident transport flows.

The third location is linked to intensive daily traffic linking Jelgava to the capital Riga and the nearest settlements. At the sampling point, the road passes through the forest area, which is reflected in the lower median value of 0.325 mg l^{-1}, as in other locations.

TABLE 4 THE IRON CONCENTRATIONS IN SNOW SAMPLES WITH PM PARTICLES BY LOCATION IN JELGAVA CITY

Statistics	mg l^{-1} | 1	mg l^{-1} | 2	mg l^{-1} | 3
Minimum	0.202	0.171	0.183
Maximum	9.621	8.168	10.963
Range	9.419	7.997	10.780
1st Quartile	0.498	0.270	0.245
Median	1.087	0.414	0.325
3rd Quartile	1.218	1.536	2.933
Mean	2.260	1.883	2.636

Kruskal-Wallis test do not show significant differences between locations groups *(p-value 0.755)*.

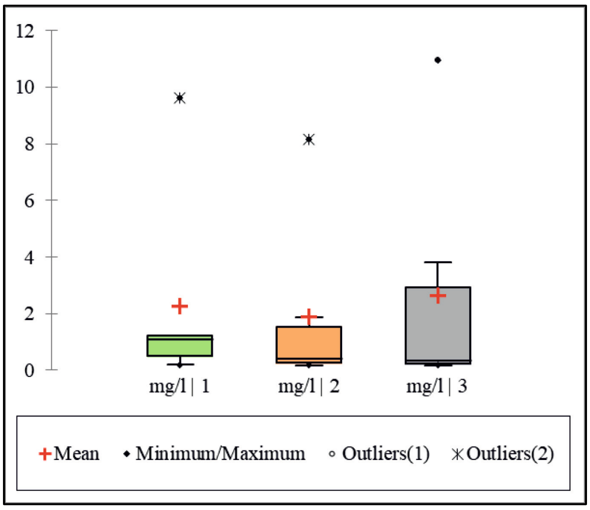

Fig. 3. The variation of iron concentrations by location in Jelgava.

In an research covering 2019 data of the entire city of Jelgava was divided into 4 clusters, with the second cluster describing monitoring points where the composition of chemical elements is typical of traffic-borne pollution, while the third cluster combines monitoring points where the content of chemical elements characteristic of waste and fossil fuel combustion is identified in addition to traffic pollution. [13].

The mean concentration of iron 11.692 mg kg^{-1} from the Suwałki builds dust [14]. In this research the results were quite similar with highest concentrations in snow samples collected 1m from road. Iron was associated with local industrial activities and motor vehicle movement [15].

Studies have shown that concentrations of heavy metals in soils near roads are declining as distance from roads increases. Iron concentrations in soils have been found to decrease away from the road. Negative correlation between iron concentrations in soils and distance from the road has been demonstrated [16]. These studies stifle the findings of this study that road transport is an important source of iron in PM particles that make up urban air pollution [17].

This study analysed the effects of distance and urban location on iron prevalence. However, future research should focus on spatial analysis of multifactors, which would allow more accurate identification of the diffusion of various heavy metals in urban environments.

IV. Conclusions

The transport related iron concentrations in snow samples the highest is at 1 m distance - 10.9 mg/l and the lowest is at 100 m - 0.33 mg/l.

The location in urban area do not play significant role of iron concentrations in snow samples, this show that all transport flows give significant iron particle emissions in atmosphere.

The results obtained can be used when designing streets and conducting urban planning.

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