Car transport intensity impact on heavy metal distribution in urban environment

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Abstract. Air pollution is one of the main environmental problems and the cause of various diseases around the world. Intensive traffic is one of the main sources of air pollution in an urban environment. In cold and temperate climate regions snow on roads and its surroundings can accumulate significant amounts of pollutants which can affect human health and the environment in both the short and long term. Various urban snow pollution studies were made in many parts of the world, but in Latvia, Jelgava city such an experience is something new. In this article, we studied the relationship between air pollution on different road sections depending on the snow sample sampling distance from the road. In the city of Jelgava near the roads with high traffic there were collected 54 snow samples, in 18 places on 3 road sections in 3 different distances from road 1 m, 50 m and 100 m. Snow samples were collected in January 2018, seven days after snowfall. We analyzed copper (Cu), nickel (Ni), lead (Pb), manganese (Mn), and zinc (Zn) concentrations in snow melting water samples. Mostly Cu concentrations at a distance of 1 m from the road were up to eight times higher than at 50 or 100 m distance. The highest concentrations of Mn, Ni, Pb and Zn are 1 m away from the road. For snow samples at a distance of 50 m and 100 m from road differences are minimal. To better understand pollution spread near road, different intensity roads and streets of Jelgava should be covered. Sample plots should be located all over the city territory, excluding as much as possible other pollutants object impact on performed study.

1 Introduction

Air pollution caused by traffic is an important environmental and health issue worldwide. Every day a person puts himself under the influence of dust particles caused by cars [10]. A versatile mixture of metals from tyres, braking parts wear and exhaust gas comes from cars [5, 7, 9]. Road dust can directly pose a risk to human health by swallowing, inhaling and coming into contact with the skin [6]. Road traffic with particulate matter and gaseous

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emissions is the main cause of air pollution in most urban areas [1]. Zinc (Zn) [5, 10], copper (Cu), nickel (Ni), lead (Pb) [10] and manganese (Mn) are related to traffic dust [9]. Various epidemiological studies worldwide have increasingly shown the impact of traffic on respiratory diseases. This trend is observed in both developed and less developed countries [1, 10].

Snowflakes accumulate more atmospheric pollution than rain drops because their surface areas are larger than rains and fall speeds slow. Thanks to this, in countries in the cold region, collect snow is a good method for determining air quality [2, 3]. Vehicles both cause and transfer pollution by lifting dust in the air during dry weather, contributing to urban pollution levels [10-12].

Street dust and air quality studies are very important. They are needed to determine the origin, distribution and level of heavy metals in urban environment, near streets and roads. The focus should be on concentrations of trace elements that accumulate in the long term and may accumulate in the urban environment [10, 12].

In this article, we studied the relationship between air pollution on different road sections depending on the snow sample sampling distance from the road.

2 Materials and Methods

Jelgava is the fourth largest city in Latvia, both by population and territory. City area is 60.3 km². Around 56000 inhabitants live in the city [4]. Due to Jelgava's geographical location, intensive freight transport is taking place in the city. The services are well developed and easily accessible to both local and international companies. Jelgava is located 42 km from the capital of Latvia – Riga.

In the city of Jelgava near the roads with high traffic there were collected 54 snow samples, in 18 places (Fig.1, Fig.2, Fig.3) on 3 road sections in 3 different distances from road 1 m, 50 m and 100 m as well as 60 samples in Jelgava city (code in data analysis C) according to methodology distances from road 5 m [16]. Snow samples were collected in January 2018, seven days after snowfall. The average thickness of the snow layer during sampling was 9 cm. January average air temperature was -4 °C [4].

We analyzed copper (Cu), nickel (Ni), lead (Pb), manganese (Mn), and zinc (Zn) concentrations melted in snow samples. The ICP-OES spectroscopy device “ICap 7000” is used to identify various metals [7-8].

3 Results

The results show a high concentration range of copper (Cu) 826.7 mkg/l, nickel (Ni) 40.4 mkg/l, lead (Pb) 50.5 mkg/l, manganese (Mn) 1351.1 mkg/l, and zinc (Zn) 992.8
The descriptive statistics of copper (Cu), nickel (Ni), lead (Pb), manganese (Mn), and zinc (Zn) concentrations melted in snow samples are presented in Table 1.

**Table 1.** Simple statistics of copper (Cu), nickel (Ni), lead (Pb), manganese (Mn), and zinc (Zn) concentrations.

| Metal | Statistics | Cu, mkg/l | Ni, mkg/l | Pb, mkg/l | Mn, mkg/l | Zn, mkg/l |
|-------|------------|-----------|-----------|-----------|-----------|-----------|
|       | Nbr. of observations | 114 | 114 | 114 | 114 | 114 |
|       | Nbr. of missing values | 0 | 0 | 0 | 0 | 0 |
|       | Minimum | 2.8 | 0.4 | 0.7 | 5.9 | 9.2 |
|       | Maximum | 829.5 | 40.8 | 51.2 | 1357.0 | 1002.1 |
|       | Range | 826.7 | 40.4 | 50.5 | 1351.1 | 992.8 |
|       | Median | 11.2 | 2.0 | 3.6 | 46.9 | 34.7 |
|       | Mean | 24.5 | 3.4 | 6.2 | 151.6 | 86.6 |
|       | Variance (n) | 5957.7 | 20.1 | 50.7 | 52613.0 | 16154.6 |
|       | Standard deviation (n) | 77.2 | 4.5 | 7.1 | 229.4 | 127.1 |

The copper (Cu), nickel (Ni), lead (Pb), manganese (Mn), and zinc (Zn) concentrations melted in snow samples were analysed by location groups. The road directions east (E), north (N) west (W) and city (C). The Kruskal-Wallis test were used to identify differences between groups. Copper (Cu) and nickel (Ni) concentrations showed statistically significant differences in location Cu p-value was 0.028 and Ni p-values were 0.001, but Pb, Mn and Zn did not show statistically significant differences by location.

Multiple pairwise comparisons using the Steel-Dwass-Critchlow-Fligner [13] procedure was used to identify differences between Cu and Ni concentrations by location groups (West (W); Nord (N); East (E); City center (C). The Wij and group of Steel-Dwass-Critchlow-Fligner procedure by location groups is presented in tables 2 and 3.

**Table 2.** The Cu concentration Wij statistics and group of Steel-Dwass-Critchlow-Fligner procedure by location groups.

| Cu, mkg/l | W | Cu, mkg/l | N | Cu, mkg/l | E | Cu, mkg/l | C | Groups |
|-----------|---|-----------|---|-----------|---|-----------|---|--------|
| Cu, mkg/l | W | 2.462 | 1.477 | **3.874*** | A |
| Cu, mkg/l | N | -2.462 | -0.268 | 1.845 | A | B |
| Cu, mkg/l | E | -1.477 | 0.268 | 2.113 | A | B |
| Cu, mkg/l | C | **-3.874*** | -1.845 | -2.113 | B |

*p-value <0.05

**Table 3.** The Ni concentration Wij statistics and group of Steel-Dwass-Critchlow-Fligner procedure by location groups.

| Ni, mkg/l | W | Ni, mkg/l | N | Ni, mkg/l | E | Ni, mkg/l | C | Groups |
|-----------|---|-----------|---|-----------|---|-----------|---|--------|
| Ni, mkg/l | W | 2.371 | 1.521 | **5.166*** | A |
| Ni, mkg/l | N | -2.371 | -0.515 | 2.499 | A | B |
| Ni, mkg/l | E | -1.521 | 0.515 | 2.885 | A | B |
| Ni, mkg/l | C | **-5.166*** | -2.499 | -2.885 | B |

*p-value <0.001

The copper (Cu), nickel (Ni), lead (Pb), manganese (Mn), and zinc (Zn) concentrations melted in snow samples were analyzed by distance from road. The distance from road 1 meter (1), 5 meter (5), 50 meter (50) and 100 meter (100). The Kruskal-Wallis test were
used to identify differences between groups. Copper (Cu), nickel (Ni), lead (Pb), manganese (Mn), and zinc (Zn) showed significant differences between distance groups with p-value < 0.0001.

The copper (Cu), nickel (Ni) lead (Pb) zinc (Zn) concentrations by distance from road by Steel-Dwass-Critchlow-Fligner procedure are classified in two groups where 1m; 50m and 100m distance is in one group and 5m in second group see Table 4, 5, 6, 8.

Table 4. The Cu concentration Wij statistics and group of Steel-Dwass-Critchlow-Fligner procedure by distance groups.

| Cu, mkg/l | 1     | Cu, mkg/l | 50    | Cu, mkg/l | 100   | Cu, mkg/l | 5    | Groups |
|-----------|-------|-----------|-------|-----------|-------|-----------|------|--------|
| 7.248*    |       | 6.398*    | 6.440*| A         |
| -7.248*   |       | -0.627    | 0.352 | A         |
| -6.398*   | 0.627 |           | 1.040 | A         |
| -6.440*   | -0.352| -1.040    |       | B         |
| *p-value  | <0.0001|           |       |           |

Table 5. The Ni concentration Wij statistics and group of Steel-Dwass-Critchlow-Fligner procedure by distance groups.

| Ni, mkg/l | 1     | Ni, mkg/l | 50    | Ni, mkg/l | 100   | Ni, mkg/l | 5    | Groups |
|-----------|-------|-----------|-------|-----------|-------|-----------|------|--------|
| 7.248*    |       | 6.756*    | 7.849*| A         |
| -7.248*   |       | -0.112    | 1.057 | A         |
| -6.756*   | 0.112 |           | 1.644 | A         |
| -7.849*   | -1.057| -1.644    |       | B         |
| *p-value  | <0.0001|           |       |           |

Table 6. The Pb concentration Wij statistics and group of Steel-Dwass-Critchlow-Fligner procedure by distance groups.

| Pb, mkg/l | 1     | Pb, mkg/l | 50    | Pb, mkg/l | 100   | Pb, mkg/l | 5    | Groups |
|-----------|-------|-----------|-------|-----------|-------|-----------|------|--------|
| 6.354*    |       | 7.227*    | 5.786*| A         |
| -6.354*   |       | 0.291     | -1.308| A         |
| -7.227*   | -0.291|           | -1.979| A         |
| -5.786*   | 1.308 | 1.979     |       | B         |
| *p-value  | <0.0001|           |       |           |

The manganese (Mn) concentrations by distance from road by Steel-Dwass-Critchlow-Fligner procedure are classified in three groups where 1m; and 50m distance is in one group 50m and 100m in second group and 5m in third group see Table 7.

Table 7. The Mn concentration Wij statistics and group of Steel-Dwass-Critchlow-Fligner procedure by distance groups.

| Mn, mkg/l | 1     | Mn, mkg/l | 50    | Mn, mkg/l | 100   | Mn, mkg/l | 5    | Groups |
|-----------|-------|-----------|-------|-----------|-------|-----------|------|--------|
| 6.801*    |       | 7.114*    | 6.004*| A         |
| -6.801*   |       | 0.671     | -2.717| B         |
| -7.114*   | -0.671|           | -3.841**| B       |
| -6.004*   | 2.717 | 3.841**   |       | C        |
| *p-value  | <0.0001| **p-value | <0.034|           |
Table 8. The Zn concentration Wij statistics and group of Steel-Dwass-Critchlow-Fligner procedure by distance groups.

| Zn, mg/l | 1 | Zn, mg/l | 50 | Zn, mg/l | 100 | Zn, mg/l | 5 | Groups |
|----------|---|----------|----|----------|-----|----------|---|--------|
| Zn, mg/l | 1 | 7.114    |   | 7.248    |   | 6.843    |   | A      |
| Zn, mg/l | 50| -7.114   |   | -0.984   |   | -2.029   |   | A      |
| Zn, mg/l | 100| -7.248  |   | 0.984    |   | -2.130   |   | A      |
| Zn, mg/l | 5 | -6.843  |   | 2.029    |   | 2.130    |   | B      |

4 Discussion

Heavy metal concentration data show absolute concentration values as in similar studies looking for correlations between transport intensity and heavy metal pollution in snowmelt waters [2]. The concentrations of copper (Cu), nickel (Ni), lead (Pb), manganese (Mn), and zinc (Zn) in the study show a large amplitude, with very low values and extremely high values. Air quality studies have been carried out in Jelgava City for several years [7, 8, 14-17]. In all these studies, heavy metal concentrations show a high amplitude, which is not always due to the presence of transport corridors. It should be noted that groups showed mixed differences after the sampling site. The central part of the City center (C), North (N) and East (E), showed differences in concentrations of only Cu and Ni, while Mn, Pb and Zn did not show any significant differences between locations. This phenomenon can be explained by potential climate impacts on pollution concentrations, where it would be necessary to analyse climate records during the snow decomposition period. The groups distributed in this study demonstrate the importance of sampling distance from the road. Further studies would need to find out what the trend in heavy metals pollution intensity is.

5 Conclusions

Most concentrations of heavy metals had similar trends. Higher concentrations of pollution were observed within 1 m of the road compared to samples taken from additional sampling points of 5 m, 50 m and 100 m. Spatial analysis of heavy metal distribution shows the difference between the western part and the central part, which could be explained by the prevailing wind direction and point sources of pollution in the central part of the city.

The study would need to be continued in several directions, where it would be necessary to reduce the sampling step from 50m to 5m or even 1m in order to identify trends in pollution deposition intensity. It is necessary to carry out repeated studies analysing the impact of climate on the volume of heavy metals precipitated by the deposit period. Studies should be initiated identifying and quantifying the impact of contamination accumulated in snow melting waters on surface and underground waters where spatial analysis and runoff modelling tools would be used.

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