INFLUENCE OF INDUSTRY ON AIR POLLUTION IN JELGAVA CITY

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Abstract. Air pollution is one of the most important environmental issues in the urban environment and causes health risks for citizens. The small particles PM 2.5 and PM10 consist of different trace elements. Industrial activities such as smelting, refining, and combustion processes are releasing significant amounts of metals into the air, leading to extensive air pollution. The aim of this study is to identify in which parts of Jelgava city the risks of air pollution caused by industry are the greatest. The snow samples were collected from 59 monitoring points in Jelgava and one in a rural area as reference. The snow samples were analysed using ICP MS for Al, Si, Cr, Mn, Fe, Ni, Cu, Zn, As, Mo, Cd, Ba, W, and Pb concentration analysis. The hierarchical cluster analysis of normalized chemical element concentrations was used to divide monitoring points into four groups with high, medium-high, medium, and low risks of industrial air pollution. The industrial air pollution risks are unevenly distributed in Jelgava. High and Medium high risks are indicated in residential areas. The trace element concentration distribution shows significant differences between industrial air pollution risk groups. Kruskal-Wallis test shows statistically significant differences between the clusters for all trace elements (p-value < 0.0001; alpha 0.05). The results show strong evidence of industrial air pollution in Jelgava city. Mostly in Jelgava city dominates low and medium risk of industrial air pollution, however, there are three points with high industrial air pollution risks.

Keywords: heavy metals; air quality; environmental risks.

Introduction

Emissions of heavy metals into the air have become a major environmental concern as they may have harmful effects on human health and the environment [1]. It is also necessary to emphasise fine particles such as PM 2.5, PM 10 present in the air which acknowledge various chemical elements [2]. Industrial activities, such as smelting, refining and combustion processes, release significant amounts of metals into the air causing widespread air pollution [1; 3]. Heavy metals can enter the atmosphere from a variety of sources, including natural processes such as volcanic eruptions, dust storms, wildfires, etc., as well as anthropogenic activities such as industrial processes, transport and energy production. When entering the atmosphere, heavy metals can travel long distances and settle on land and water surfaces, posing a risk to both human health and the environment [1; 4; 5]. Exposure to heavy metals can occur by inhaling air emissions, ingesting contaminated food and water, or in direct contact with contaminated soil or dust. Long-term exposure to heavy metals is associated with various health effects, including respiratory diseases, cardiovascular diseases, and neurological disorders [4; 5].

Various measures have been taken in recent years to reduce emissions of heavy metals into the air, including through cleaner technologies, regulations and policies, as well as informing the public about the need to improve the quality of the air environment. Despite these efforts, emissions of heavy metals into the air remain a major environmental challenge requiring continued research and measures to protect human health and environment [6].

Recent studies have been carried out in several cities, however, there are mostly few samples, samples from plots such as Mazeikiai (a region in the north-west of Lithuania) were collected in 11 plots [7]. In the study conducted in Northeast China, snow samples were collected from December 2017 to March 2018 at 16 locations, with a total of 60 snow samples [8]. The aim of this study is to identify in which parts of Jelgava city the risks of air pollution caused by industry are the greatest.

Materials and methods

Jelgava is the fourth largest city in Latvia by population. The city of Jelgava is located in central Latvia. Snow samples were collected in December 2020. The study uses snow samples collected in 59 monitoring points located in the city (see Fig.1) of Jelgava and one plot located outside the city, a control plot [9]. As well as the study takes into account 106 industrial enterprises in Jelgava that have declared emissions to the State Environmental Service (see Fig.2). Three snow samples were taken on each plot, which is about 5 m from the driveway or pavement. The samples collected were analysed in a laboratory where they were melted at room temperature and analysed after the methodology described in the article [9].

The data of Al, Si, Cr, Mn, Fe, Ni, Cu, Zn, As, Mo, Cd, Ba, W, and Pb concentrations were normalised in the scale from 1 to 100 and used for hierarchical cluster analysis using the Ward method [10]. Differences between clusters were analysed using the Kruskal-Wallis test.

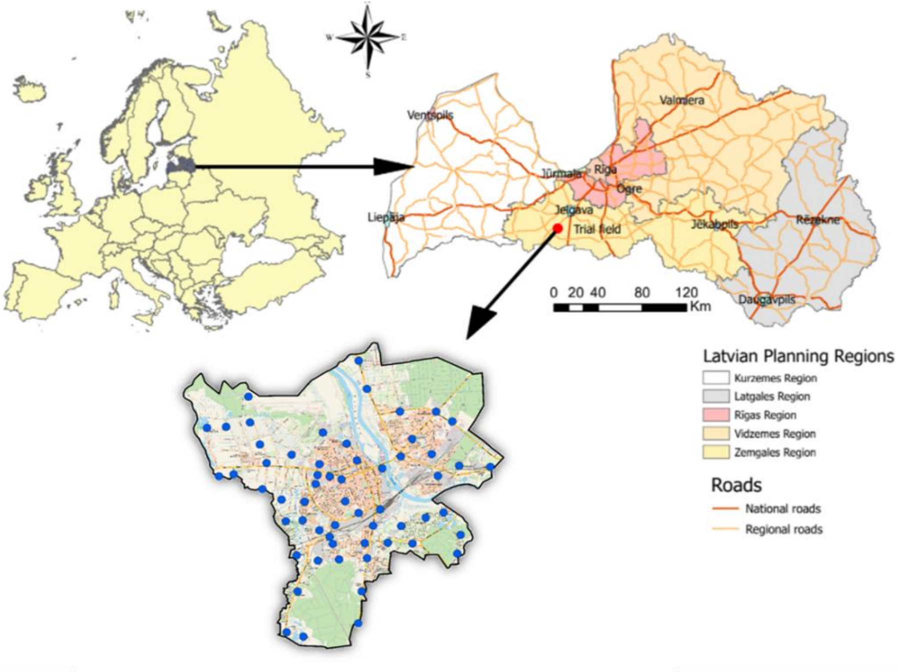

Fig. 1. **Location of air quality monitoring points**

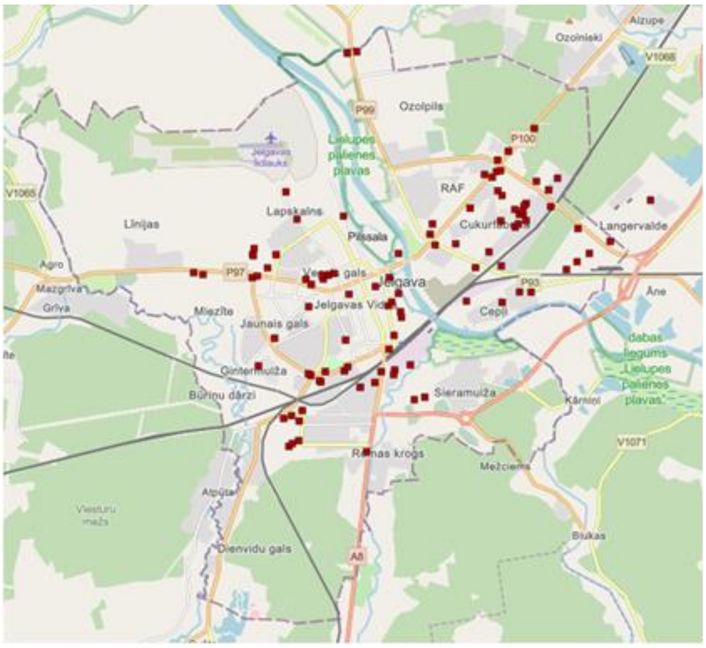

Fig. 2. **Industrial enterprises in Jelgava**

Results and discussion

The results of the hierarchical cluster analysis of the industrial air pollution risk of Jelgava give four well separated clusters (See Fig.3). The dendogram of hierarchical cluster analysis shows that the cluster of low-risk (in red colour) is at low distances and forms a homogenous cluster. This range is a low risk of industrial air pollution risk range. The monitoring points belonging to this cluster are marked green (see Fig.4).

A high-risk range of industrial pollution distinguishes itself with huge distances, unlike other clusters, and is characterized by very high concentrations of analysed substances. This cluster owns three monitoring points marked red on the map (See Fig.4).

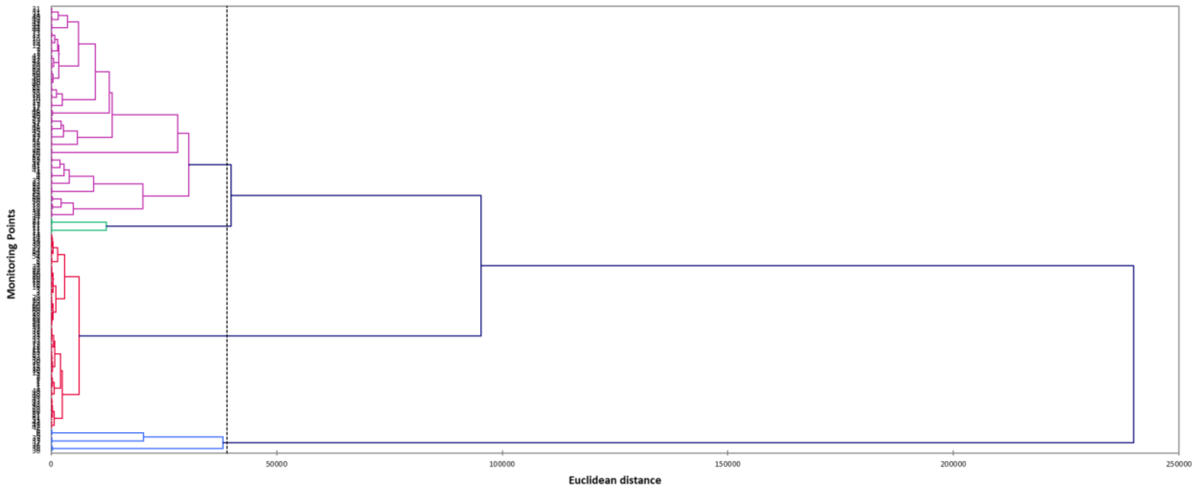

Fig. 3. **Dendogram of industrial air pollution risks**

As it can be seen from the industrial pollution risk spatial distribution map (see Fig.4), the medium risk of industrial pollution prevails throughout the territory of Jelgava city. Chemical pollutants in the cluster group were analysed to understand the main sources of risks of the industrial landscape.

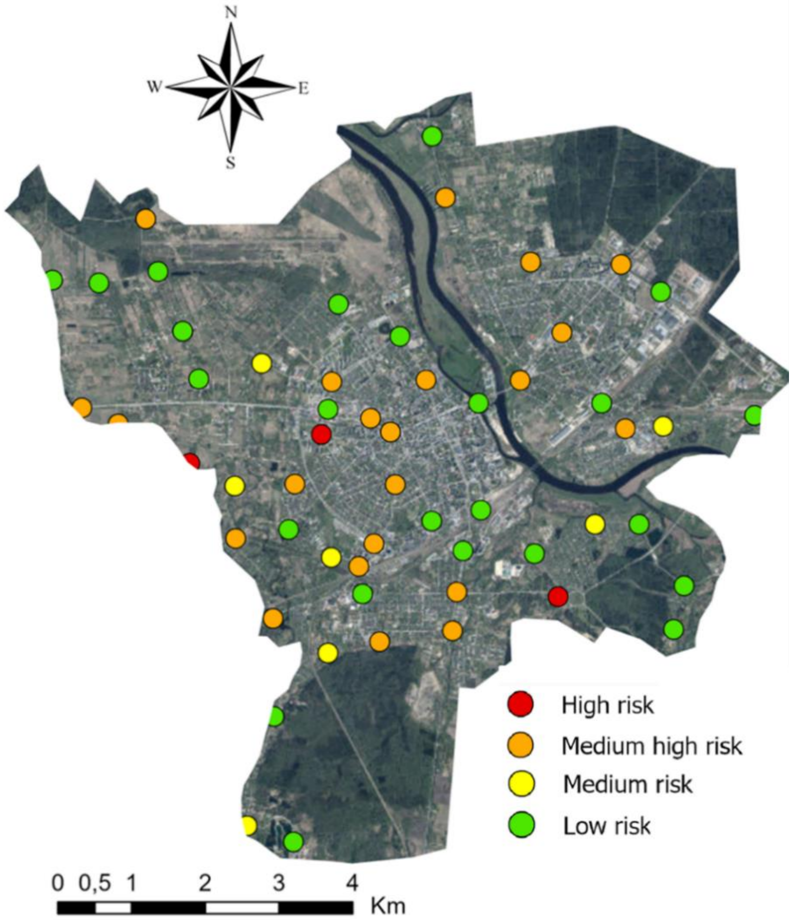

Fig. 4. **Distribution of industrial air pollution risks in Jelgava**

Aluminium pollution in the air comes from industrial activities and is closely linked to pollution from transport [11]. In the city of Jelgava, the concentration of aluminium in snow varies from 0.3 to

1200 μg·l^{-1} and the high - and medium-risk range varies significantly (*p-value* < 0.0001) (see Fig.5). In the study conducted in Southeast Anatolia, Turkey, the regional aluminum concentration ranges from 49.0 to 54.0 μg·l^{-1} [12].

Zinc concentrations in the atmosphere are the result of industrial activities [13], but the impact of transport on the zinc content in the atmosphere should also be mentioned [14]. In the city of Jelgava, the concentration of zinc in snow varies from 0.5 to 47 μg·l^{-1} and the high - and medium-risk range varies significantly (*p-value* < 0.0001) (see Fig.6).

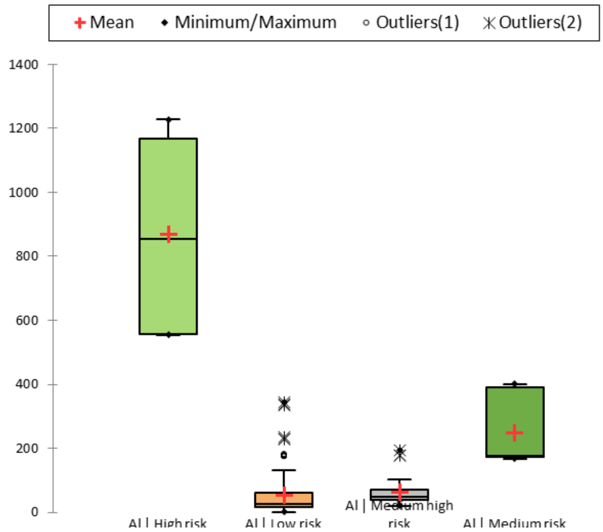

Fig. 5. **Al concentrations μg·l^{-1} by clusters**

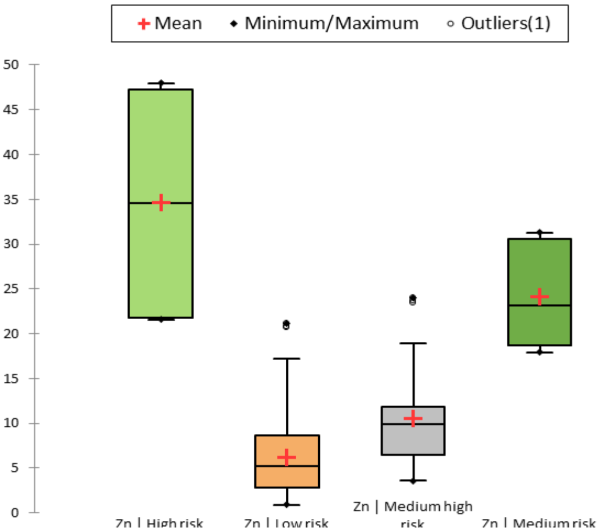

Fig. 6. **Zn concentrations μg·l^{-1} by clusters**

Chromium sources in atmosphere are various, steel production, combustion of fossil energy and others [15]. Chromium in Jelgava city is distributed unevenly [16]. In the city of Jelgava, the concentration of chromium in snow varies from 0.01 to 3.7 μg·l^{-1} and the high and medium-risk range varies significantly from low risk (*p-value* < 0.0001) (see Fig.7). In the study conducted in southeast Anatolia, Turkey, the regional chromium concentration ranges from 58.0 to 60.0 μg·l^{-1} [12], in northwest China, Cr concentration ranges from 0.36-855.24 μg·l^{-1} [8]. The concentration of Cr in snow-dust in the Lithuanian city of Mazeikiai is on average 112.25 mg·kg^{-1}. the sources of Cr can be petroleum refining processes and combustion of petroleum products [7].

The atmospheric deposition of manganese can occur due to various industrial processes [17]. In the city of Jelgava, the concentration of manganese in snow varies from 0.7 to 101 μg·l^{-1} and the high and medium-risk range varies significantly from low risk (*p-value* < 0.0001) (see Fig.8). In southeast Anatolia Mn concentrations range from 119.0-121.0 μg·l^{-1} [12].

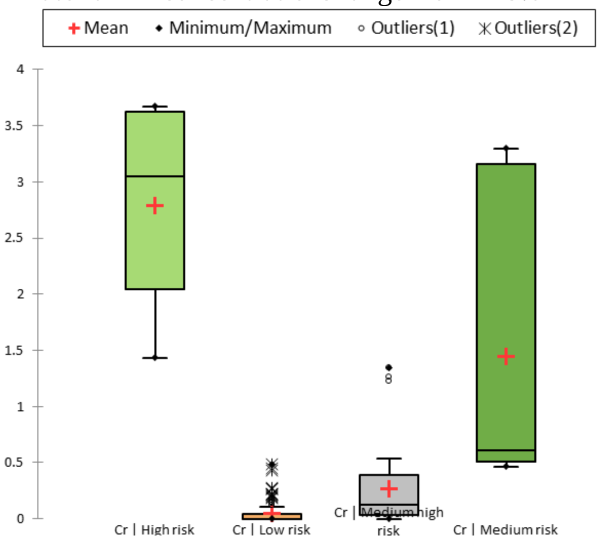

Fig. 7. **Cr concentrations μg·l^{-1} by clusters**

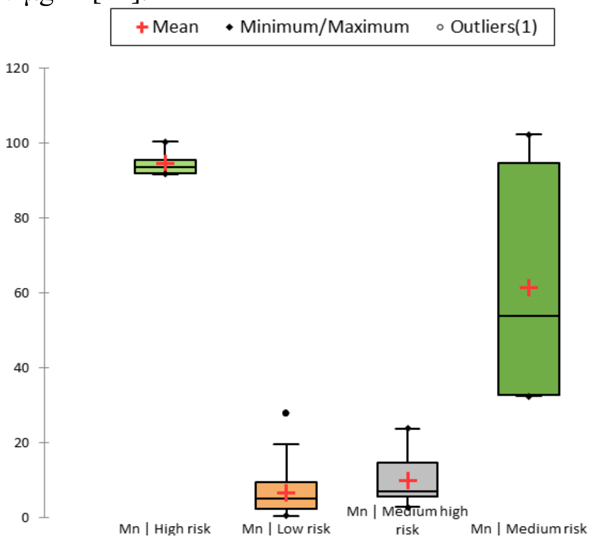

Fig. 8. **Mn concentrations μg·l^{-1} by clusters**

Iron sources in atmosphere are various, steel production, combustion of fossil energy, transport and others [16]. The concentration of iron in Jelgava city differs [9]. In the city of Jelgava, the concentration of iron in snow varies from 11 to 1950 $\mu g \cdot l^{-1}$ and the high and medium-risk range varies significantly from low risk (*p-value* < 0.0001) (see Fig.9). Southeast Anatolia regional Fe concentrations range from 45.0-49.0 $\mu g \cdot l^{-1}$ [12].

The atmospheric deposition of nickel can occur due to various industrial processes [18]. In the city of Jelgava, the concentration of nickel in snow varies from 0.05 to 4.3 $\mu g \cdot l^{-1}$ and the high and medium-risk range varies significantly from low risk (*p-value* < 0.0001) (see Fig.10). In Sivas city study Ni ranges from 10.1-80.4 $\mu g \cdot l^{-1}$ [19], but Southeast Anatolia regional Ni concentrations range from 81.0-185.0 $\mu g \cdot l^{-1}$ [12].

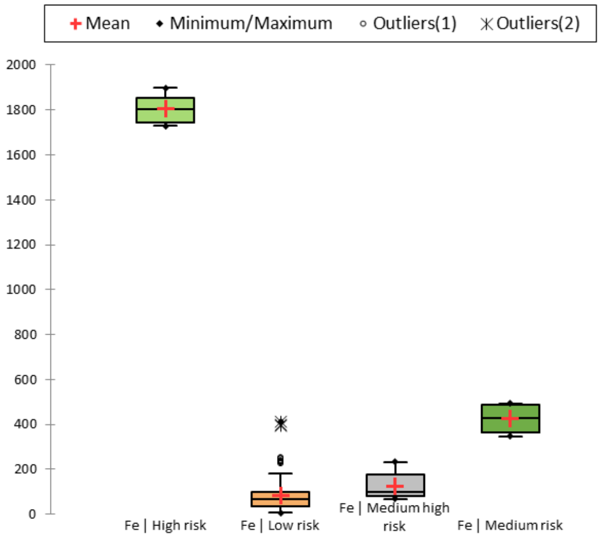

Fig. 9. **Fe concentrations µg·l^{-1} by clusters**

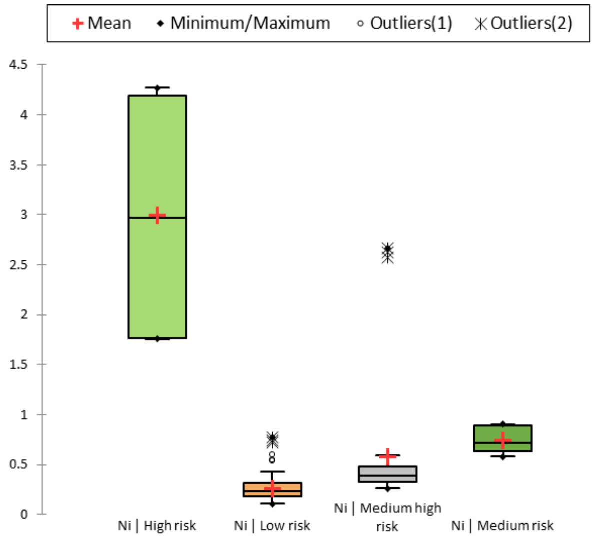

Fig. 10. **Ni concentrations µg·l^{-1} by clusters**

Copper sources in urban air are various, industry, combustion of fossil energy, transport and others [16;8]. The concentration of copper in Jelgava city is uneven by monitoring points [14]. The concentration of copper in snow varies from 0.01 to 14 $\mu g \cdot l^{-1}$ and the high and medium-risk range varies significantly from low risk (*p-value* < 0.001) (see Fig.11). In Sivas city study, Cu ranges from 8.1-90.4 $\mu g \cdot l^{-1}$ [19], but Ni concentrations range from 0.38-2184.06 $\mu g \cdot l^{-1}$ in studies conducted in northwest China [8], southeast Anatolia regional Cu concentrations range from 99.0-104.0 $\mu g \cdot l^{-1}$ [12].

The atmospheric deposition of barium can occur due to various industrial processes [18]. In the city of Jelgava, the concentration of barium in snow varies from 1.5 to 42 $\mu g \cdot l^{-1}$ and the high and medium-risk range varies significantly from low risk (*p-value* < 0.05) (see Fig.12).

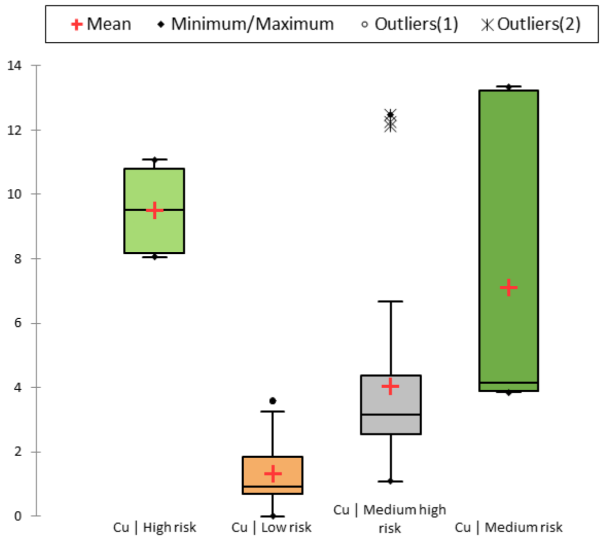

Fig. 11. **Cu concentrations µg·l^{-1} by clusters**

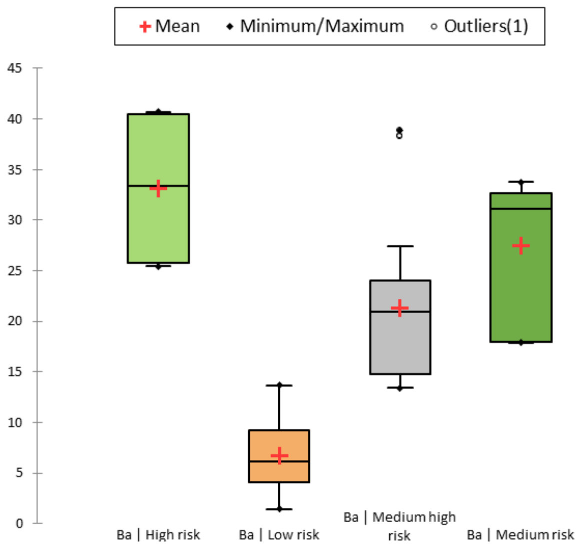

Fig. 12. **Ba concentrations µg·l^{-1} by clusters**

A study conducted close to the Latvian border near Mazeikiai oil plant showed a strong correlation between the analyzed dust and the heavy metals lead (Pb), copper (Cu), chromium (Cr), cadmium (Cd) and the proximity of the plant. It was found that the concentration of heavy metals in snow dust is thousands of times higher than in snowmelt water [7].

Conclusions

1. The results show strong evidence of industrial air pollution in Jelgava city. Mostly in Jelgava city dominates low and medium risk of industrial air pollution, however, there are three points with high industrial air pollution risks.
2. The concentrations of chemical elements in snow differ and show strong evidence of local air pollution in Jelgava city.
3. The chemical elements representing industrial air pollution are related to transport emissions and other sources of air pollution.
4. The future research must use more complicated statistical methods to divide different air pollution sources for specific chemical elements.

Author contributions:

Conceptualization, I.G.; methodology, I.G. and V.G.; software, J.P.U.; validation, J.P.U. and M.B; formal analysis, M.B and J.P.U.; investigation, M.B., K.S., V.G. and J.P.U.; data curation, M.B. and J.P.U.; writing – original draft preparation, I.G.; writing – review and editing, J.P.U. and V.G.; visualization, K.S.; project administration, I.G. All authors have read and agreed to the published version of the manuscript.

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