# PATTERNS OF HEAVY METALS CONTENTS IN URBAN SOILS OF VASILEOSTROVSKY AND ELAGIN OSTROV OF SAINT PETERSBURG, RUSSIA.

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## ABSTRACT

The study examined the total contents of heavy metals (TCHM) in urban soils of St. Petersburg. Russia. Soils along areas of heavy traffic density, neighbourhoods of light industrial zones, residential areas, and recreational zones were sampled. The concentrations of cupper (Cu), lead (Pb), zinc (Zn) and manganese (Mn) in soils were significantly high - 5-10 times above regional background levels. The concentration of Pb in soil samples varied from 0.6-110 mg/kg within the limits of Vasilesostrovvsky, and 0.3 – 80 mg/kg in recreational zone of Elagin Ostrov, which is approximately 4 km away from Vaisileostrovsky. The presence of Cu was ubiquitous in all sampled soils and exhibited high contents ranging between 4.0- 30 mg/kg. The contents of cadmium (Cd) in all tested soils were below regional background values indicating low emissions of that element from anthropogenic sources. Furthermore, the concentration of heavy metals in soils was related positively to areas of high traffic density, particularly to the central, eastern and south industrial areas of Vasileostrovsky.

Elagin Ostrov, generally, registered lower contents of total heavy metals and this might be attributed to its location and nature of land use. Appropriate land use and strategic management options that will help in reducing emissions and impacts of heavy metals in urban soils is recommended.

## Introduction

Heavy metals (HM) are among the most dangerous substances causing environment pollution. Pollution in recent years has increased considerably as a result of complex and increasing human activities such as industrialization, burning of fossil fuels, automobile and industrial emissions. Any attempt to reduce emissions is always confronted with the issue of adopting appropriate technology, which is not so easy to achieve, especially within a short period. Exhaust emissions and combustion of fossil fuels were identified as the critical and primary sources of atmospheric metallic pollutants and there has been significant proof that most urban environments are polluted from a higher volume of such emissions (Andreeva and Baeva, 1998). An in-depth assessment of heavy metallic substances in the environment helps to determine their levels of concentration as a basis for regulating and monitoring their levels and for protecting the environment.

Research has revealed that in most urban environments, the presence of heavy metals in soils far exceeded permissible levels, especially Pb which changes within the limits of 30-150 mg / kg of soil and has an average value of 100 mg/kg (Gregoriev and Saet, 1990). Particularly affected are urban soils because of intensive anthropogenic emissions and the ability of soils to absorb atmospheric pollutants (Dobravolsky, 1979). Consequently, urban soils have become a secondary source of environmental pollution. The main documentary on the state of the urban environment of St. Petersburg, Environmental Protection (2003) registered a high release of Pb., Cu., Mg. and Zn into the environment, with high concentrations of these elements in soils. In St. Petersburg, atmospheric concentrations of Zn., Cu., Mg. and Pb were regarded to be a function noted for areas of very high traffic volume. The presence of a metal doesn't necessarily indicate an environmental problem. However, it is a matter of concern when the amounts detected approach or exceed the concentrations that can harm organisms, including humans.

Many research findings indicate that any increase in the concentration of HM in soil above permissible levels frequently act as an inhibitor to the normal functioning of the soil's ecosystem (Dobrovolsky. 1997) and poses environmental risks and health hazards. Several studies have shown that metals such as Pb., Cd. and Zn., among others, are responsible for certain carcinogenic diseases and have lethal effects on biological species

(Muravey, 2000, Ecological Atlas of St. Petersburg, 1970). For this reason, various accredited institutions are much concerned about the effects of urban soil pollution on the environment, especially on the relationship between HM and diseases.

Most studies conducted on heavy metals have been chiefly limited to the main city of St. Petersburg rather than extended to its periphery where land use patterns vary considerably and information on heavy metal contents in soils is limited, making it impracticable for any comparative assessment on heavy metals to be carried out. An attempt to bridge this gap forms the basis of this study. The main objective of this study therefore is to investigate the total contents of heavy metals in soils within Vasileostrovsky (situated relatively at the center of St. Petersburg) and Elagin Ostrove (located on the outskirts of the main city center) and to make a comparative assessment of the degree of heavy metal concentration between the two study areas in order to inform appropriate policy decisions. The information generated from this study is required to put in place appropriate land use and management mechanisms that would enhance sustainable development through appropriate decisions and coordinated planning.

## Materials and Methods

### Study site

The study is located in Russia (fig. 1). The two areas selected for the study comprised Vasileosrtrovsky (fig. 2) – an administrative unit within St Petersburg city –a busy commercial center with a mixture of settlement and industries (an electronic, metallurgical complex and a dockyard for ships) found on the southwestern part, and Elagin Ostrov (fig.3), located about 3.5 km away from Vasileostrovsky which serves as a recreation zone.

These two areas were selected because of the differences that exist between them in terms of land use pattern which reflects the nature and degree of human impact. Secondly, the available data on the environmental status of Vasileostrovsky, particularly on heavy metals, serve as baseline information for making a comparative measure between the two areas so far as pollution of urban environment by heavy metals is concerned. The study was conducted in 2000-2002.

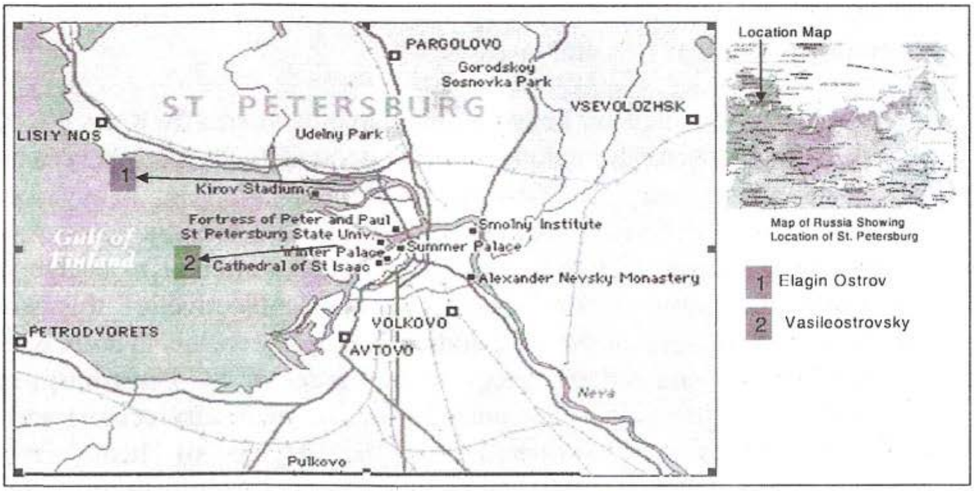


Fig 1 Map of St. Petersburg Showing the two study areas of Elagin Ostrov and Vasileostrovsky

## Soil sampling

Soil samples were obtained from roadsides, neighbourhoods of industrial areas, day nursery centres, parks and gardens, and the vicinity of temporary waste disposal sites of communities. Such sampling was to help determine the pattern of heavy metal contents at different points of land use. Sampling was systematic, avoiding the traditional sampling area of 200 x 200 meter square for determination of territorial differences in heavy metal concentration in urban soils (Ecological state of St. Petersburg, 2002); the adoption of systematic sampling was to help determine the extent of influence of land use pattern on metal concentration in soils (Kasivoв, 1995). The sampling points for Vasileostrovsky and Elagin are shown in figs. 2 and 3 below, respectively

Within the Elagin area, soil samples were taken from different environments- roadsides, areas burdened with recreational activities, slopes, foothills and flat plains. 30 samples were taken from each area with the aid of stainless sheath Dutch anger and bulked. Sampling depth was 0-20 cm. Sampled soils were kept in labeled polythene bags and stored under recommended laboratory conditions.

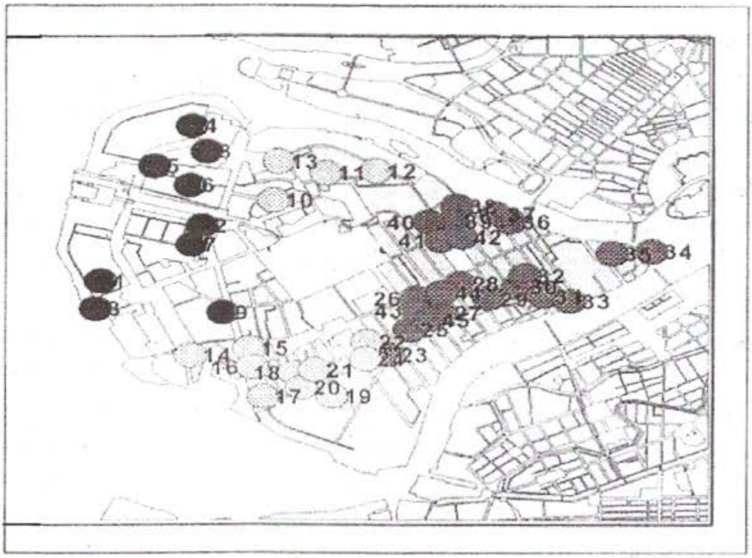


Fig.2. Map of Vasileostrovsky showing sampling points
Location of sample points: 1-9 western, 10-21 central, 22-45 eastern.

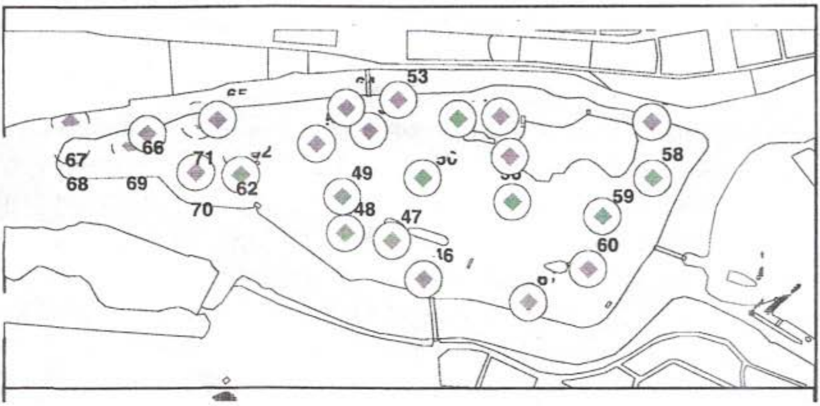


Fig.3. Map of Elagin Ostrov showing sampling points.

## Chemical Analysis

Soil samples were air-dried, crushed and then passed first through a 6mm sieve then through a 4mm sieve, and finally through a 2 mm sieve. For the determination of total contents of heavy metals in soils, 2 grams of the soil sampled was dissolved in 10 ml of 3 % Nitric acid, with $HNO_3$ concentration. The mixture was kept for 12 hours and finally filtered. The resultant extracts were analyzed for total contents of heavy metals Pb, Cd, Mg, Mn, Pb and Zn (lead, cadmium, zinc, copper and manganese) using atomic-absorption spectrophotometer ASS-3 (in line with Methodical instruction…1987) at the Ecological Safety Division of the Department of Geography and Natural Resource Use, St. Petersburg State University. The criteria for selecting the above elements for analysis were based on the fact that the selected elements form the priority elements for chemo-toxicological analysis and possess high toxicity and migratory ability within soil environments Besides, they fall under the priority list of polluting substances of the urban environment of Saint Petersburg (Protection of the Environment, 1998) and are components of many metal-fermentors of urban soils (Haziev, 1990, Vorobyeva, 1998, Muravey, 2000). Soil acidity pH test was also carried out using a multi pH 150 meter; this was to help determine possible pH-heavy metal relationship in soils.

## Results and Discussions

Total heavy metals (Pb, Cd, Mg, Mn, Pb and Zn) content of soils decreases with distance away from the road edges towards the inner parts of the city, and then there is a general decrease from Vasileostrovsky to Elagin Ostrov. Concentrations of metals in the soils were in the order of Cu >Zn>Mg>Pb>Cd.

The average total lead (Pb) concentration in urban soils within the limits of Vasileostrovsky ranges between 0.6-110 mg/kg. However, higher concentrations of 110-120 mg/kg were observed in sampled soils taken from closer to road-sides which are characterised by high traffic density, but these decreased from 10.2- mg/kg to 0.6mg/kg in areas of low traffic density and to 2.3 mg/kg in Elagin Ostrove (a recreational site situated about 3.5 km away from Vasileostrovsky). Within the same distance from Vasileostrovsky, as in the case of Pb, average values obtained for Cu were 235.0 mg/kg, 18 mg/kg, and 16 mg/kg, respectively. Zn, Mg, and Cd showed a similar decrease in value. Even though this general pattern whereby metals decrease from heavily impacted areas to less impacted areas was observed, certain obvious anomalies in the distribution were noted. For example, very low contents of Pb <0.8, Cu <18 and Zn < 43.1 (mg/kg) were observed in sampled soils taken from eastern, central and western areas of Vasileostrovsky, which are close to busy traffic areas.

Generally, in Elagin Ostrove, high contents of Pb, Cu, and Zn were noted in areas where human effect on the environment is relatively high.

Studies conducted by Borisenko (1989) and Andreiva et al. (1998) indicated that high concentrations of metals in soils of densely populated and industrialized cities resulted from increased automobile circulation and industrial emissions. As revealed in this study, significant concentration of Pb, Cu, Zn and Mn were observed in soil samples taken close to the roadside in areas with dense traffic. Such high concentrations might be attributed to the fact that oxide of carbon emission constituted nearly 73%, forming the major source of air pollution in the urban city of St Petersburg (reported by Environmental protection Agency, St. Petersburg, 1998, 1999, 2001). The metals were considered to arise from motor vehicular emissions and electrical power generating stations that use combusting fuels.

Results indicated that, despite the low traffic density in Elagin Ostrov, the contents of Mn are significantly high, 2.5-10 times above permissible levels. Similar increases in Zn. and Cu contents were also observed. Such high contents of Zn, Mn and Cu in an area which is isolated from the urban center and which functions as recreational zone might be attributed to atmospheric emission of pollutants and the use of such elements in construction.

From the study the following key findings were noted:

Firstly, the results indicated a decrease in the contents of heavy metals with increasing distance from Vasileostrovsky to Elagin Ostrov; this result confirmed earlier reports by Environmental Protection (1998) that the concentration of heavy metals in soils decreased from the centre of the town to its periphery.

Secondly, the results indicated a direct influence/relationship between land use and level of metal concentration in soils. This phenomenon was noted in both Vasileosstrovky and Elagin Ostrov. Within Vasoleostrovsky high total contents of heavy metal were observed in sampled sites closer to industrial neighborhoods, high traffic density areas, and sites close to temporary waste dumpsites. Low values of metal contents were noted for residential areas and for others with low volumes of traffic, parks and gardens. Similarly, in the recreational zone of Elagin Ostrov, high concentrations of zinc and manganese contents were registered in areas where human related activities are high, such as recreational spots, boat dockyards and roadsides, while sampled sites located some distance away from hot spots have generally low contents of heavy metals.

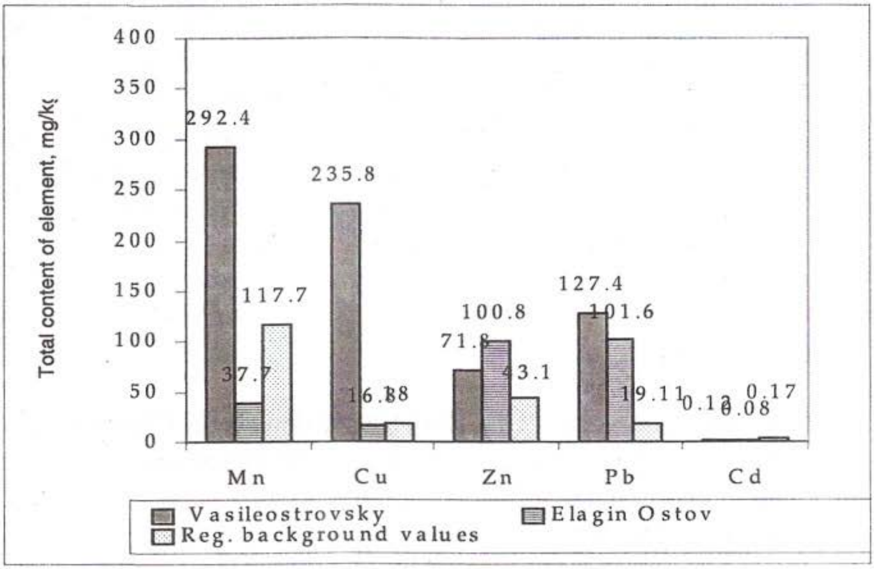


Fig.1.1. The average content of Mn, Cu, Zn, Pb and Cd in urban soils of some selected areas in Saint Petersburg (the average data on St. Petersburg were taken from: Protection of the environment, 2003).

The study also examined the factor of concentration of heavy metals (which is the relation between the average value of a given metal to regional background value, Methodical instructions ….1993). From the analyzed soils of Vasileostrovsky, the factor of concentration for copper was 13.10, Pb - 6.67, Mn - 2.50, Zn - 1.66. For soils in Elagin Ostrov the priority elements were lead, the factor of concentration of which equals – 5.30, Zinc – 2.30. The contents of other metals (copper. cadmium. manganese) were found to be below regional level.

TABLE 1. The contents of heavy metals in urban soils of Vasileostrovsky and Elagin Ostrov

| Element | Back ground value (mg / kg) | Minimum value (mg / kg) | Maximum value (mg / kg) | Average value (mg / kg) | Standard deviation | Coefficient of pollution- average value/ background (# of times) | Average range of excess value of metal content (value/back ground value) |
|---|---|---|---|---|---|---|---|
| Elements of 1st class danger | | | | | | | |
| Vasileo-strovsky | | | | | | | |
| Pb | 19.1 | 0.6 | 635.4 | 127.4 | 227.4 | 6.67 | 1.1-33.3 |
| Cd | 0.17 | 0.04 | 9.36 | 0.12 | 0.08 | <background level - 1.66 | |
| Zn | 43.1 | 13.4 | 508.6 | 71.8 | 60.4 | | 1.1 – 2.96 |
| Elagin | | | | | | | |
| Pb | 19.1 | 0.9 | 258.6 | 101.6 | 119.6 | 5.30 | 9.84 - 13.53 |
| Cd | 0.17 | 0.04 | 0.155 | 0.08 | 0.03 | <background level - | |
| Zn | 43.1 | 80.1 | 38.2 | 100.8 | 45 | 2.50 | 0.90 |
| Element of 2-nd class danger | | | | | | | |
| Cu | | | | | | | |
| Vasileo-strovsky | 18 | 7.69 | 60.4 | 235.8 | 172.8 | 1.8-33.0 | |
| Elagin Ostrov | | 3.0 | 30.2 | 16.8 | 8.4 | < background level | 1.1-1.70 |
| Element of 3-rd class danger | | | | | | | |
| Mn | | | | | | | |
| Vasileo-strovsky | 117.7 | 5.4 | 1.127 | 292.4 | 279.2 | 1.0-9.60 | |
| Elagin Ostrov | | 2.93 | 125.6 | 37.7 | 39.0 | < Background level | 1.10. |

## Conclusion

The results of total contents of heavy metals (TCHM) in soils indicated that the highest values of HM in urban soils were noted for territories lying closer to main streets and characterized by intensive vehicular movements and the immediate environs of the southern industrial zone complex.

Approximately, about 80-90% of analysed soils were found to have total contents of heavy metals (Pb, Cu, Zn and Mn) far exceeding regional background values

Within the limits of Elagin Ostrov, the concentration of Cu exceeded the maximum concentration limit, on the average by 2-5 times; however, this is about 50% lower than values from the investigated sites of Vasileostrovsky. The contents of cadmium, Cd in most soils sampled and analyzed were far lower than the maximum concentration limit set for the region.

The relatively high contents of lead, zinc, and manganese from sampled soils taken from Elagin can be attributed to the use of these elements in constructional activities; however a potential source of pollution could be related to air pollution.

The analysis of spatial distribution of heavy metal in urban soil in this study indicated that soils taken from areas under the influence of motor transport and industrial enterprises are characterized by higher contents of heavy metals. The concentration of lead, zinc, manganese and copper within Vasileostrovsky exceeded the regional background level, while in Elagin Ostrov such high concentrations were observed only for lead and zinc (Table 1).

The values obtained for cadmium in all analyzed sampled soils were found to be far below regional background values.

Significant values of heavy metals (Pb, Zn, Cu and Mn) concentrations exceeding average permissible values for the region were established across the study area.

Generally, the concentration of heavy metals decreases with distance from Vasileostrovsky, an area characterized by high population, high traffic density and industrial activities, to Elagin Ostrov- an area reserved for recreation.

The pH value of soils of the study area ranged within limits of pH 4.7 to pH 8.7, indicating the presence of the strong acidic-alkaline condition of urban soils; however, a mean value of 6.9 pH was recorded. Such a wide range in the acid-alkaline nature of urban soils indicates the complex nature of urban soils under different forms of land use and probably explains the variations in metal contents within urban soils.

Regulation of heavy metal concentration in urban soils, even after anthropogenic emissions are cut down, requires strenuous efforts to regulate pH value of urban soils as this is likely to influence the mobility of metals in soils.

To reduce levels of metal concentration in urban soil from industrial, vehicular and domestic emissions, legal instruments on land use policy that seek to regulate and monitor such emissions must be re-examined, applied and enforced effectively.

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