

Chemical Characteristics of Urban Soils of Vasileostrovsky Ostrov and Elagin Ostrov, St Petersburg, Russia

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Abstract

Chemical characteristics of urban soils of Vasileostrovsky Ostrov and Elagin Ostrov of St Petersburg, Russia were investigated to evaluate the level of chemical contents. Soil samples were collected from the two study areas and analysed for their chemical properties by complexometric titration using a very large molecule of EDTA. Soil organic carbon, pH, total exchangeable bases, total calcium and magnesium, sulfate and ammonium contents of soils were investigated. Correlation analysis was used to study the relationship between the selected chemical soil properties. The result indicated that soil pH ranged from 4.7 to 8.1. The values of Eh were within the range of 335–489 mv. Total amount of calcium (Ca^{+2}) and magnesium (Mg^{+2}) varied within the range of 2.4–28.1 meq/ 100 g soil, whilst the content of soil carbon matter ranged from 0.8% to 8.2%. Total exchangeable bases (TEB) varied within 3.3–49.8 meq/100 g soil. The concentration of sulfate ions, SO_4^{2-} , was substantially low. Generally, the result showed marked variations of chemical parameters of soils analysed, which indicated the heterogeneous nature of urban soils. The study suggests the use of chemical method of soils analysis as a monitoring tool for urban soils management.

Introduction

Urban soils are soils in urban and suburban areas consisting of anthropogenic deposits with natural (mineral, organic) and technogenic materials, formed and modified by cutting, filling, mixing, intrusion of liquid and gases, sealing and contamination (Stroganova *et al.*, 1997).

Soils in urban landscapes are generally thought of as highly disturbed and heterogeneous, with little systematic pattern in their characteristics. As such, most studies have focused on human-constructed soils along streets and in highly impacted areas (Craul & Klein, 1980; Patterson *et al.*, 1980; Short *et al.*, 1997).

“Urban soils” have been viewed as drastically modified and of low fertility (Craul, 1992). However, studies have shown that the chemical, physical and biological

response of soils to urban land use is complex and variable, such that soils that are largely undisturbed or of high fertility have also been identified in urban areas (Schleuss *et al.*, 1998; Pouyat *et al.*, 2007a). The ever pressing issues of urbanization, land use, but, above all, of contamination pushed urban environment into the focus of soil science, especially soils in various urban agglomeration, which dealt intensively with the urban locations, whose urban characteristics deviated so strongly from soils of rural environments (Helmut, 2010).

Changes to the urban environment are related to its overall historical and economical development of urbanization (Bullock, 1991; Vorobieva, 1998). The causes of contaminated urban soils are not limited to factors such as the influence of dust deposition, through industry and traffic, use

of fertilizers and sludge but also the influence of formal industrial locations and depositions of contaminated materials (Burghardt, 2000; Helmut, 2010). Research has assessed the unique chemical properties of urban soils. Specifically, soil pH, basic mineral composition, calcium, magnesium, aluminium, potassium (Andreiva, *et al.*, 1990, Dobrovolsky, 1997), and soil organic matter quantity and quality (Pouyat *et al.*, 2002) have been studied and found to be affected by urban conditions.

From research perspective, changes in soil structure due to urbanization have led to changes in soil physical, chemical and biological characteristics which account for the spatial variability of soils in urban environments (Dobrovolsky, 1997; Gorbovskaya *et al.*, 2001).

Soil biological properties in urban environments also vary and differ from those in other managed and natural systems (Stroganova, 1979; White & McDonnell, 1988; Carreiro *et al.*, 2009) whilst biochemical characteristics of soils provide a comprehensive understanding of the potential activeness of soil microorganisms (Gorbovskaya *et al.*, 2001). The quantity and quality of urban soil organic matter are quite variable (Beyer *et al.*, 1997; Carreiro *et al.*, 1999; Pouyat *et al.*, 2002). Craul (1993) and Harris *et al.* (1999) indicated that in preparation for infrastructure topsoil is removed, leading to reductions in soil organic matter.

Thus, many research results indicated a transformation of urban soil properties from natural soils of the region due to urbanization. In many urban towns of Russia, including St Petersburg, urban soils show soaring tendency towards a basic pH, high concentration of heavy metals and

carbonates (Kasimov, 1995). It is estimated that organic matter, Ca^{2+} , Mg^{2+} , P_2O_5 , K_2O , SO_4 , NO_3^- , and heavy metals in urban soils far exceed their maximum concentration limits (Dobrovolsky, 1997).

Urban soils in St Petersburg have received several attentions by many researchers due to diverse forms of land use and the fact that urban soils form a secondary source of environmental pollution pose threat to human life. These findings have prompted the need to address problems related to soil pollution through research. In view of this, many researchers have adopted different methods to assess the character of urban soil properties of St Petersburg, which includes bioindication (Terekhin, 1998) and physico-chemical analysis (Andreiva *et al.*, 1998, 1999, 2002, 2003). The variations in these research findings suggest the need to undertake further research into urban soils as a means of verifying the state of urban soils for effective monitoring decision.

Materials and methods

Study area

The study area comprises Vasileostrovsky Ostrov and Elagin Ostrov, which are fairly close to each other. However, they are quite distinct in terms of land use. Vasileostrovsky Ostrov, administrative unit of St Petersburg, is characterized by settlements and educational, social, commercial and industrial activities. Elagin Ostrov, on the other hand, serves as a recreational model zone made of parks and gardens, with limited physical structures. It is situated about 3 km away from the centre of Vasileostrovsky Ostrov. The two study areas boarder the delta of River Neva, at the eastern end of the Gulf of Finland. Most of the city is built on both

banks of the Neva, and on islands in the river.

Soil sampling sites

The study involved a review of literature on chemical characteristics of urban soils, landscape characteristics and land-use pattern, which serve as the basis to specify sampling sites.

Sampling sites were selected based on accessibility and sites that have been previously investigated. Soil samples from Vasileostrovsky Ostrov were taken from day care nursery grounds, parks and gardens, compound houses and periphery of industrial premises. Such systematic sampling was considered necessary due to the varied scale of human influence on urban land use. To determine the chemical response of soils to urban land use, Vasileostrovsky Ostrov was divided into three sampling areas (according to period of urbanization), the eastern (oldest), central (middle age) and western (young age). Urban soil properties are not only distinguishable from other systems, but also vary within types of landscapes in urban environments.

Soils sampled were taken with the aid of stainless sheath Dutch auger from a depth of 0–20 cm recommended for bio-physical and chemical assessment of soil properties (Gorbovskaya, *et al.*, 2001). Samples were bulked and kept in labelled polyethylene bags, and stored under standardised laboratory conditions. The following chemical parameters of the sampled soils were analyzed: redox potential (Eh), soil reaction (pH) and ammonia (NH_4^+) concentration. Measurement were determined by measuring the electric potential arising from special electrodes immersed in the solution by using

pH 150 universal meter. All major ions, total calcium (Ca^{2+}) and magnesium (Mg^{2+}) (TCaMg), total exchangeable bases (TEB) and sulfate ions (SO_4^{2-}) were analysed by complexometric titration (Arinushkina, 1970), while concentration of soil organic matter was measured by oxidizing soil carbon in potassium dichromate ($\text{K}_2\text{Cr}_2\text{O}_7$) (Vorobieva, 1998).

Results and discussions

The chemical characteristics of the study area are presented in Tables 1, 2 and 3, and Fig. 1–3.

Chemical characteristics

Soil reaction is one of the most important physiological characteristics of the soil. The result of all soils sampled indicated variation in any soil reaction (pH, H_2O), ranging from slightly acidic to alkaline. From Vasileostrovsky Ostrov soil pH ranged from 4.7 to 8.1, and Elagin Ostrov, pH from 5.5 to 7.8. The results showed a deviation of soil pH of the natural dernovo-podsol soils, which has a pH range of 4.5–6.5 (Dobrovolsky, 1997). Alkali soils may be due to the comparatively high degree of base saturation. Salts like carbonates of calcium, magnesium and sodium give a preponderance of OH^- ions over H^+ ions in the soil solution. Calcium (Ca^{2+}) and magnesium (Mg^{2+}) were the two most abundant base cations from the results obtained, hence, it presupposes that the concentration of calcium and magnesium may have greater influence on soil pH. The result of soil pH confirms earlier findings by Dimitriv *et al.* (2001), which indicated that urban soils of St Petersburg ranged within slightly acidic to alkaline (4.5–8.7).

TABLE 1
 Characteristics of soils collected from Vasileostrovsky Ostrov (western)

| Parameter | Min | Max | Mean | SD | CV |
|-------------------------------------------------------------|-------|-------|-------|-------|------|
| pH (H ₂ O) | 6.5 | 7.8 | 6.9 | 0.38 | 0.06 |
| Eh (mV) | 356.0 | 455.0 | 412.3 | 29.94 | 0.07 |
| Total exchange bases, cmol(+)/kg | 5.4 | 37.8 | 16.8 | 9.27 | 0.55 |
| Total Ca ²⁺ and Mg ²⁺ ions cmol(+)/kg | 2.5 | 19.1 | 11.0 | 5.51 | 0.50 |
| Soil organic carbon (%) | 0.8 | 6.2 | 3.0 | 1.89 | 0.63 |
| Cmol(+)NH ₄ ⁺ /kg | 0.9 | 4.3 | 2.5 | 1.23 | 0.49 |
| SO ₄ ²⁻ , mg/100 g | 12.5 | 180.0 | 58.6 | 61.99 | 0.6 |

TABLE 2
 Characteristics of soils collected from Vasileostrovsky Ostrov (central)

| Parameter | Min | Max | Mean | SD | CV |
|--------------------------------------------------------|------|-------|-------|-------|------|
| pH (water) | 4.70 | 7.90 | 6.93 | 0.83 | 0.12 |
| Eh (mV) | 336 | 466.0 | 422.8 | 42.31 | 0.10 |
| The sum of exchangeable bases cmol(+)/kg | 3.30 | 49.80 | 24.67 | 13.85 | 0.56 |
| Total Ca ²⁺ and Mg ²⁺ cmol(+)/kg | 2.40 | 14.60 | 9.03 | 3.64 | 0.40 |
| Soil organic carbon (%) | 1.30 | 8.20 | 3.24 | 1.82 | 0.56 |
| NH ₄ ⁺ cmol(+)/kg | 0.85 | 4.32 | 1.96 | 1.26 | 0.64 |
| SO ₄ ²⁻ , mg/100 g | 12.5 | 147.0 | 52.70 | 41.70 | 0.80 |

TABLE 3
 Characteristics of soils collected from Vasileostrovsky Ostrov (east)

| Parameter | Min | Max | Mean | SD | CV |
|--------------------------------------------------------|-------|-------|--------|-------|------|
| pH (H ₂ O) | 6.2 | 8.1 | 7.32 | 0.50 | 0.07 |
| Eh (mV) | 335.0 | 489.0 | 394.75 | 37.15 | 0.09 |
| Total exchangeable bases, cmol(+)/kg | 3.9 | 48.5 | 30.89 | 13.78 | 0.50 |
| Total Ca ²⁺ and Mg ²⁺ cmol(+)/kg | 7.1 | 28.1 | 13.84 | 4.52 | 0.33 |
| Soil organic carbon (%) | 1.7 | 7.8 | 4.1 | 1.89 | 0.42 |
| NH ₄ ⁺ cmol(+)/kg | 0.9 | 5.3 | 2.43 | 1.33 | 0.55 |
| SO ₄ ²⁻ mg/100 g soil | 12.5 | 176.0 | 46.4 | 44.3 | 0.95 |

In Elagin Otrov, (Mets, Svetkova, Melichuck, 1989) indicated that the application of lime fertilizer to improve soil conditions in the 1970's resulted in changing soil pH from 2.8 to 4.0 within a relatively short period of time. Adding limestone replaces acidic hydrogen and aluminium

cations with basic calcium and magnesium cations, which increases the base saturation and raises the pH.

The wide range of soil reaction, from slightly acidic to basic, may have serious implications on the presence of high concentration of heavy metals and availability

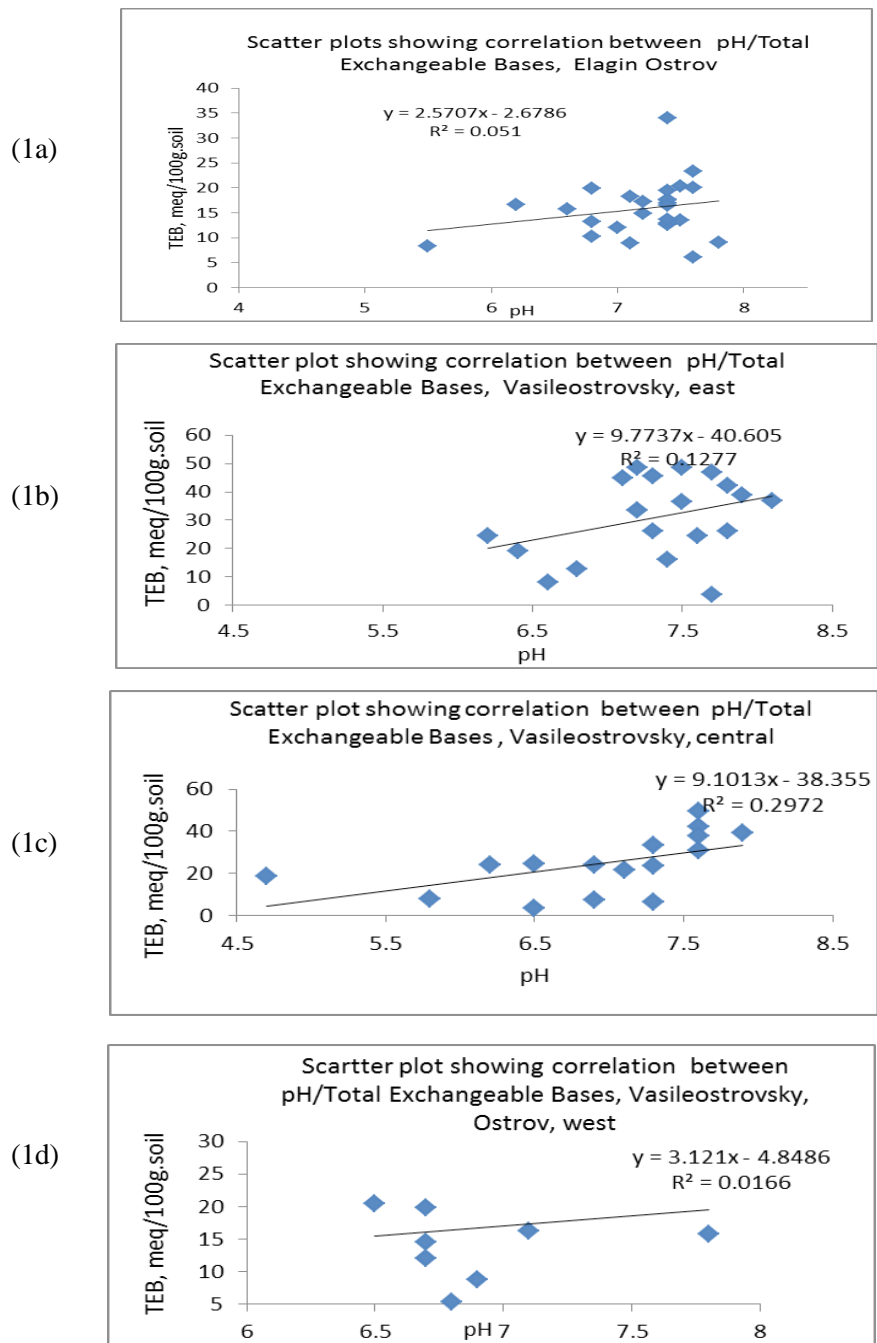


Fig. 1a–d. Scatter plots showing correlation between pH an total exchangeablebases in sampled soils from Elagin Ostrov and Vasileostrovsky Ostrov.

of nutrients in soils for plant growth, since the mobility of these elements are influenced by soil pH.

The value of Eh in Vasileostrovsky Ostrov ranged from 335 to 489 mv, Elagin Ostrov, from 356 to 492 mv. This is quite lower as compared to Eh of dernovo-podsolic soils (550-700 mv). Such factors as high precipitation, low permeability, and stagnant hydrodynamic regime of groundwater and the presence of natural organic matter, which are prevalent in St Petersburg city, can cause a decrease of redox-potential and O₂ content of soils.

There were low levels of sulfate ions (SO₄²⁻) in all soils tested; a situation which is not typical of soils of podzol type (Gorbovskaya, *et al.*, 2001). On the average, the highest value of sulfate ions (58.6 meq/100 g) soil was measured in the western part of Vasileostrovsky, Vasileostrovsky east, 46.4 meq/100 g soil, and 52.4 meq/100 g soil for Elagin Ostrov. According to Dmitrieva *et al.* (2000), the presence of sulfate ions in soils could be attributed to atmospheric pollution with sulphur dioxide (SO₂) through human activities.

The level of organic carbon in soils varied over a wide range. Higher values were observed in parkland areas of Elagin Ostrov (0.7-13.7%), with a mean value of 5.1% which is higher than organic carbon of natural dernovo-podsol soils, 1-2% and podsol soils, 2-4% (Dobrovolsky, 1997). In Vasileostrovsky Ostrov, organic substance was relatively lower as compared to Elagin Ostrov, and ranged within 0.8-8.2% with an average value of 3.%. High values of organic carbon could be attributed to organic waste materials that found their way into urban soils. In Elagin Ostrov, the decomposition of organic

matter could be attributed to high recorded values of organic carbon soil.

The total content of calcium and magnesium varied in both Vasileostrovsky Ostrov and Elagin Ostrov. In Vasileostrovsky Ostrov, total contents of calcium and magnesium ranged from 2.4 to 28.1 mg eqv/100 g, whilst in Elagin Ostrov, total calcium and magnesium ranged from 6.1 to 34.0 mg eqv/100 g. Comparatively, the concentration of total Ca²⁺ ions and Mg²⁺ ions in soils are higher than the background value of 5-10 meq/100 g (Dobrovolsky, 1997).

The exchangeable Ca²⁺ and Mg²⁺ concentrations are affected by several factors, including those related to the origin and nature of soil parent materials, slope position and water movement within the soil (Kabrick *et al.*, 2011). Therefore, it can be inferred that the presence of carbonate rocks and precipitation of St Petersburg could be influential factors in determining the concentration of calcium and magnesium in soils of the study area.

Exchangeable bases varied spatially. The measured range values are as follows: Vasileostrovsky east, 24.8-36.9 meq/100 g soil, central, 17.9-31.5, western, 22.5-38.9, and in Elagin Ostrov, 29.4-38.9 meq/100 g soil. These values are higher as compared to total contents of exchangeable bases of dernovo-podsol soils, 5-10 meq/100 g soil (Dobrovolsky, 1997). It could be inferred that the generally high amount of total exchangeable bases, calcium and magnesium, could be attributed to increasing content of soil organic carbon since organic matter is a major source of cation exchange capacity, and has a high total exchangeable cations. In the park zone of Elagin Ostrov, the high concentration of calcium and magnesium may be influenced by vegetation since,

according to Johnson & Todd (1998) and Trettin *et al.* (1999), the cycling of carbon and magnesium by trees probably plays an important role in retaining these carbons as well.

To determine the relationship between soil pH, calcium-magnesium, soil carbon, total exchangeable bases and NH_4^+ , correlation analyses were carried out for these variables for both Vasileostrovsky Ostrov and Elagin Ostrov. A linear correlation was obtained between the data sets, and the fitted equations on the data were generated with their corresponding correlation coefficients (r). The correlation coefficients of the fitted equations were positive but generally weak for both Vasileostrovsky and Elagin Ostrov.

The correlation results showed a weak positive correlation between pH and TEB, ranging from 0.0166 to 0.2972 as shown in Fig. 1a–1d. Vasileostrovsky western, 0.00166, Vasileostrovsky central, 0.2972, and Vasileostrovsky east, 0.1277 whilst Elagin Ostrov showed 0.2738. Correlation analysis between pH and total Ca^{2+} and Mg^{2+} ions (TCaMg) (Fig. 2a–2d) showed a very weak positive correlation for both Elagin Ostrov and Vasileostrovsky Ostrov. The correlation coefficient for Elagin Ostrov, 0.051, Vasileostrovsky Ostrov east, 0.0541, Vasileostrovsky Ostrov central, 0.0062, and Vasileostrovsky Ostrov western, 0.1526. The results of the above correlation indicated that a linear correlation cannot be assumed for the selected parameters. This might well be a reflection of the type and concentration of minerals present in the different soils in relation to the level of pH.

Correlation analysis between soil organic carbon and TCaMg for Elagin Ostrov and Vasileostrovsky Ostrov (Fig. 2a–d) also showed a weak positive correlation with the

only exception of Vasileostrovsky Ostrov (western) where the fitted equation $y = 2.7817x + 2.6881R^2$ and the correlation coefficient obtained was 0.9148. The high correlation for Vasileostrovsky Ostrov (western) explains the fact that there is a linear relationship between the two variables, and that high concentration of organic matter could form the basis for high TCaMg exchange. It was observed that at any given pH value there was a considerable difference in the degree of base concentration for the soils. This might well be a reflection of the type of minerals present in the different soils.

The correlations between organic carbon and TCaMg for the remaining areas are as follows: Vasileostrovsky Ostrov central, 0.3014, Vasileostrovsky Ostrov east, 0.0208 and Elagin Ostrov, 0.0593 (Fig. 2a–d). Thus, it was observed that correlation between organic substance and TCaMg for Elagin Ostrov and Vasileostrovsky Ostrov showed a weak positive correlation in both Vasileostrovsky Ostrov central and Vasileostrovsky Ostrov east, and Elagin Ostrov.

Correlation analysis between organic carbon showed weak positive correlation with NH_4^+ in both study areas as the following degree of correlation shows: 0.0002, 0.1048, 0.2189, and 0.059 for Elagin Ostrov, Vasileostrovsky Ostrov east, Vasileostrovsky Ostrov central and Vasileostrovsky Ostrov west, respectively. The weak correlations between organic matter and NH_4^+ could be due to the fact that the concentration of ammonium (NH_4^+) ideally occurs under soil pH 5.5–7.5 (Mengel & Kirkby, 1987), which contradicts with the wide range of soil pH in the study area. Such a variation in soil pH conditions could substantially depress microbial NH_4^+ activity.

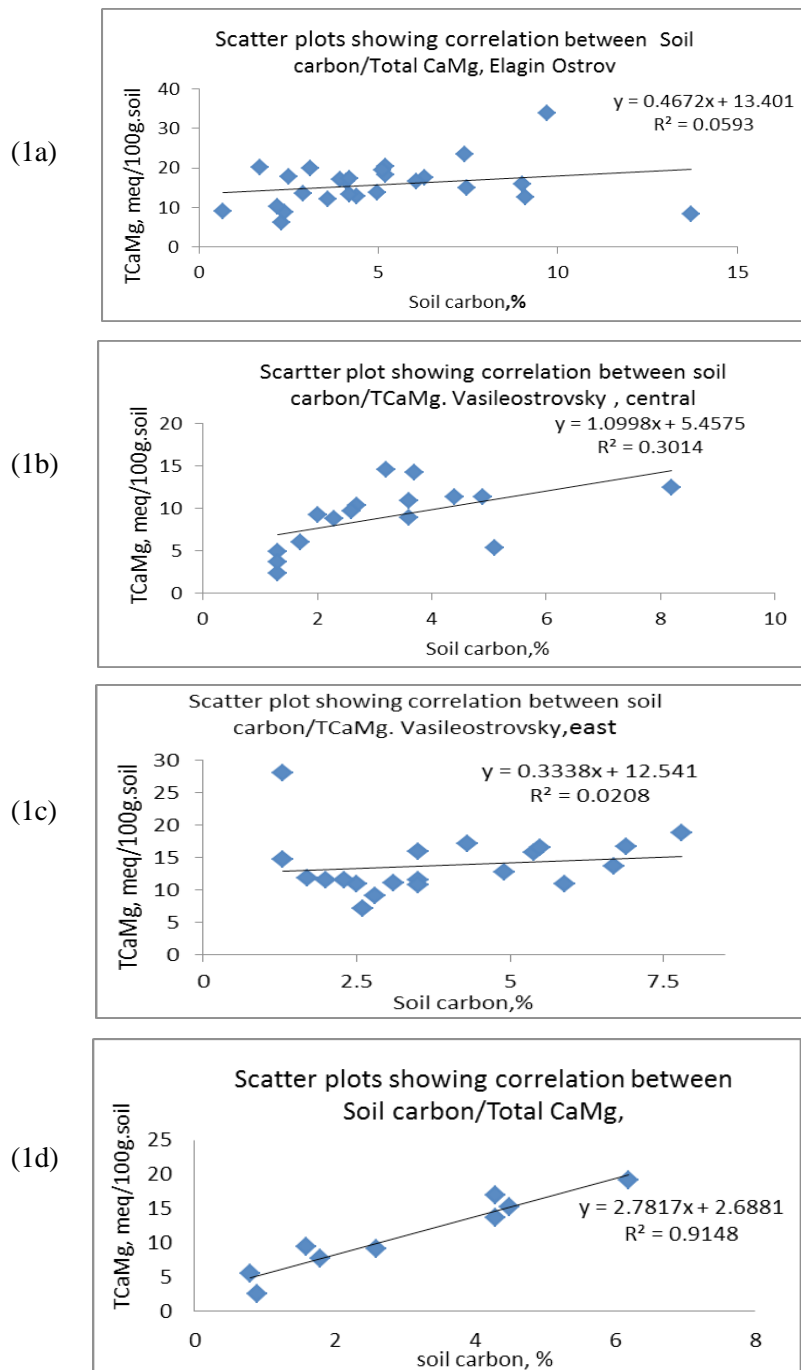


Fig. 2a–d. Scatter plots showing correlation between soil carbon and total calcium and magnesium sampled soils from Elagin Ostrov and Vasileostrovsky Ostrov

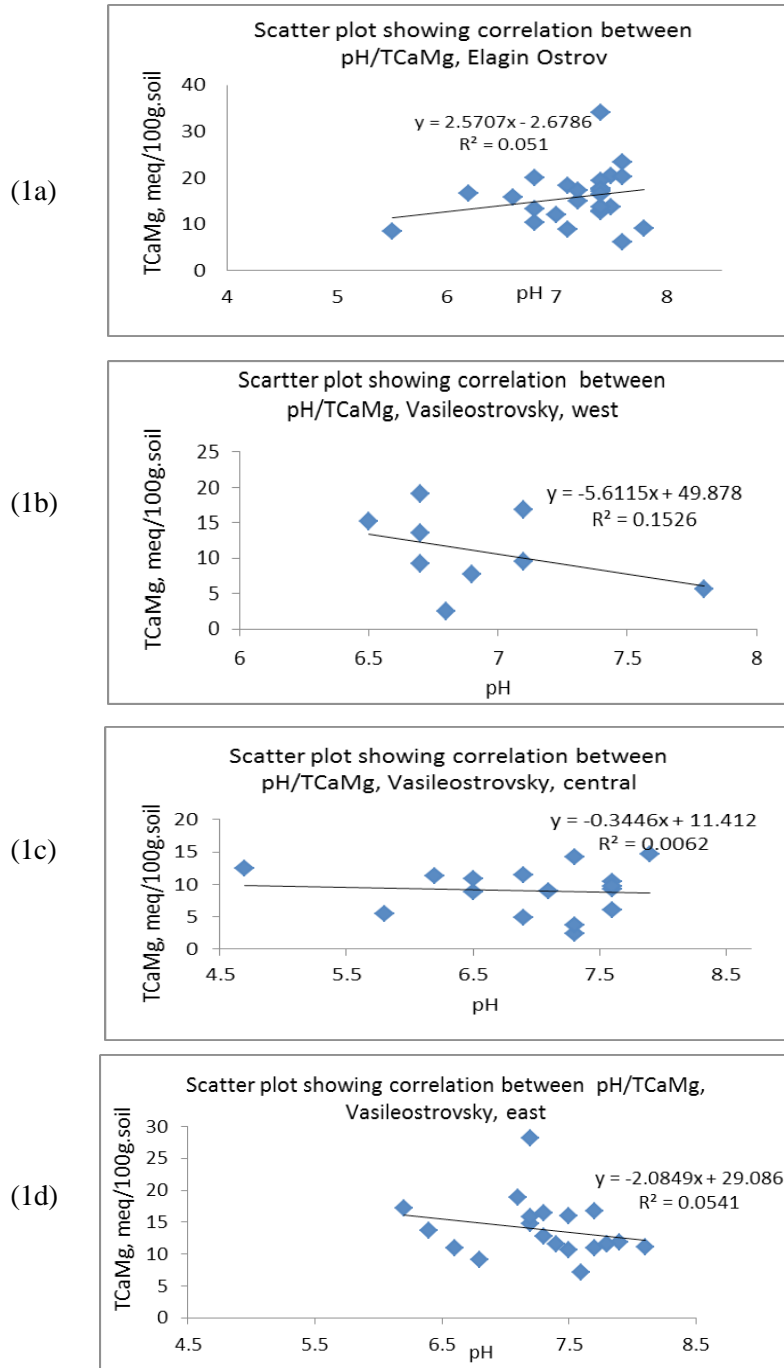


Fig.3a–d. Scatter plots showing correlation between pH and total calcium and magnesium in soils sampled from Elagin Ostrov and Vasileostrovsky Ostrov.

The weak positive correlation of total exchangeable bases, total Ca^{2+} and Mg^{2+} ions with pH could be due to the wide range of soil pH from slightly acidic (4.7) to alkaline (8.7) impacting on major cations in different ways; slightly acidic soils pH may cause leaching of cations whilst alkaline soils may withhold major cations, making it difficult to make them readily available in solution. The weak positive correlations between total Ca^{2+} and Mg^{2+} , pH and organic carbon soil and NH_4^+ for both Vasileostrovsky Ostrov and Elagin Ostrov, revealing a non-linear relationship between the two parameters, could indicate that the origin of calcium in the soils of the two study areas could be the presence of carbonate rocks. It can be inferred from the correlation results that generally, soil chemical properties at Vasileostrovsky Ostrov and Elagin Ostrov varied on spatial scales resulting in relationships with poor predictive power among soil properties.

From the above, it can be said that for correlation coefficient being near zero, it implies that there is no significant relationship between the variables, calcium-magnesium and organic substance, and, thus, a linear correlation cannot be assumed. This situation is said to be a common characteristic feature of the natural environment where processes are variable and dynamic. Studies have identified soil water and land use as important factors that control exchangeable chemical properties, their concentrations and distribution across urban landscapes.

In an attempt to determine the chemical response of soils to urban land use, soil samples were taken from lawns, nursery play grounds and households and were analyzed for their pH , Ca , Mg , NH_4 , TEC , SO_4^{2-} , and soil organic matter content. The average

values of the results indicated that of the parameters analyzed, it was only the result of sulfate ions, SO_4^{2-} , concentration that differ and it was higher in lawns than in household compounds (Fig. 4). Lawns are sited close to road sides and, therefore, could be impacted upon by exhaust fumes from cars which may contain some amount of SO_4^{2-} . From the results, it can be said that land use types did not demonstrate significant impact on soil pH , NH_4^+ , soil carbon matter, moisture and total Ca^{2+} and Mg^{2+} in most areas that were investigated.

Conclusion

Soil pH for most analysed soils was characterized as slightly acidic, near neutral to alkaline. Values for organic content and sulfate ions in soils are above recommended values for dernovo podzol soils, and correspond to values of soils in many urban territories. The statistical analysis of results generally showed rather high variability of chemical values (Tables 2–5), which apparently reflects the variable nature of urban soils.

On the basis of results obtained, it can be said that urban soils differ, considerably, from soils of the podzol type. Soil pH changes over a wide range and, at the same time, exhibit neutral and alkaline character. High acidity of urban soil can be attributed to underground and surface drained waters having high concentration of chlorides of calcium and sodium (Dmitrieva *et al.*, 2000).

Analysis of the chemical results revealed territorial differences in urban soil; however, some observed trend was noted. Firstly, pH values in both territories of Vasileostrovsky Ostrov and Elagin Ostrov are higher compared to soil pH of regional background values (the natural zone soils). However,

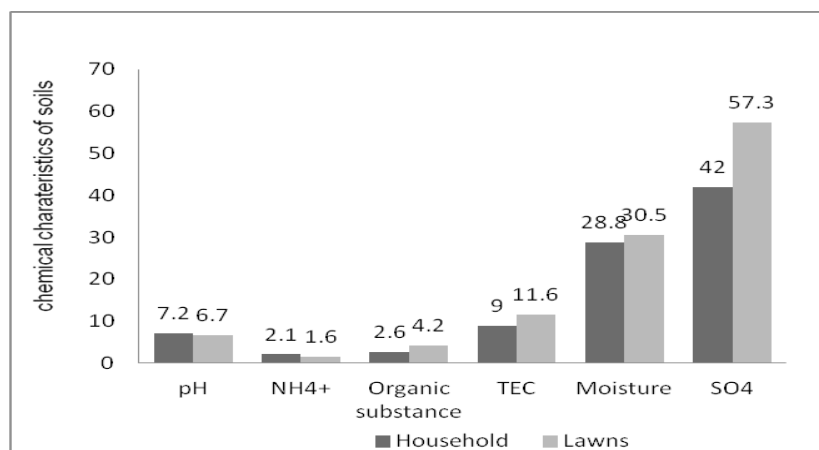


Fig..4. Concentration of chemical elements in Nursery/household compounds and lawns.

TABLE 4
 Characteristics of soils collected from Elagin Ostro

| Parameter | Min | Max | Mean | SD | CV |
|-------------------------------------------------------------|-------|-------|-------|-------|------|
| pH (H ₂ O) | 5.5 | 7.8 | 7.17 | 0.50 | 0.07 |
| Eh (mv) | 256.0 | 492.0 | 366.7 | 44.38 | 0.12 |
| Total Exchangeable Bases, cmol(+)/kg | 12.9 | 48.9 | 34.15 | 12.40 | 0.36 |
| Total Ca ²⁺ and Mg ²⁺ ions cmol(+)/kg | 6.1 | 34.0 | 15.76 | 5.65 | 0.36 |
| Soil organic carbon (%) | 0.67 | 13.7 | 5.1 | 2.97 | 0.58 |
| NH ₄ ⁺ cmol(+)/kg | 0.5 | 2.6 | 1.46 | 0.70 | 0.48 |
| SO ₄ ²⁻ , mg/100 g | 12.5 | 165.0 | 52.4 | 55.86 | 0.6 |

minimum pH values were recorded in the youngest part of the city landscape, western Vasileostrovsky, an area that is least subject to anthropogenic influence.

Secondly, the content of soil organic matter in urban soils was considerably higher (at $P = 0.95$) than organic matter in natural soils of the dernovo-podzol soils as a reference standard; maximum value of soil organic matter were noted at the park zone of Elagin Ostrov, where decomposed vegetative matter forms substantial input of soil formation. Thirdly, urban soils as compared to natural zonal soils of the region are characterized by lower level of oxidation-

reduction potential, as indicated by the Eh values. Fourthly, there is significant increase in values of total exchangeable bases in soils of Elagin Ostrov and in the eastern part of Vasileostrovsky Ostrov whilst lower values of the same parameter were observed in the western and central parts of Vasileostrovsky Ostrov.

Thus, from the analysis of the various chemical parameters, it can be concluded that there was marked deviation in chemical characteristics of urban soils from their background values; this again reflects the high coefficient of variation of the examined parameters (Tables 1–3). However, in some

cases, variation among certain values was found to be insignificant and such is the case for total exchangeable bases, calcium and magnesium, organic matter (in the western part of Vasileostrovsky) showing a variation of 0.55, 0.50 and 0.63, respectively; exception is the high significant variation of 0.95 for SO_4^{2-} in east Vasileostrovsky Ostrov.

References

- Andreiva V. G., Baeva A.S. and Barkova N. V.** (1998). *Protection of the Environment, Natural Resource Utilization and Providing Ecological Safety of Saint Petersburg in 1998*. St Petersburg. 442 pp.
- Anon.** (1992). The Ecological State of St Petersburg City. The state-of-the-art review. St Petersburg.
- Anon.** (1998). *Protection of the Environment, Natural Resource use, and Providing Ecological Safety of St. Petersburg*, (V. G. Andreiva, A. S. Baeva and N. V. Barkova, eds), pp. 442. St. Petersburg.
- Anon.** (1999). *Protection of the Environment, Natural Resource use, and Providing Ecological Safety of Saint Petersburg in 1999*. (A. S. Baeva, and N. D. Golubeva, eds), pp. 543. St Petersburg.
- Anon.** (2003). *Protection of the Environment, Natural Resource use, and the providing Ecological safety of Saint Petersburg*. (D. A. Golubeva and N. D. Sorokina eds), 468 pp. Saint Petersburg.
- Anon** (2002). *Protection of the Environment, Natural Resource use, and the provision Ecological safety of Saint Petersburg in 2002*. (D. A. Golubeva, and N. D. Sorokina, eds), 446 pp. St. Petersburg.
- Arinushkina E. V.** (1970). *Instructions in Chemical Analysis of Soils*, Moscow. Moscow State University, Moscow. 487 pp.
- Borisenko I. L.** (1989). *Technogenic pollution of various hierarchy of landscape under the influence of nonferrous metallurgical activity: Biogeochemical methods of studying the environment*. State Publishers, Moscow. pp. 4–10.
- Bullock P. and P. J. Gregory.** (1991). Soils: A neglected resource in urban areas. In *Soils in the urban environment*. (P. Bullock and P. J. Gregory, eds). Blackwell Scientific Publ. Oxford, UK.
- Burghardt W.** (2000). First International Conference on Soils of Urban, Industrial, Traffic And Mining Areas. Preface. Proceeding Vol. 1. *Paper presented at International Conference on Soils of Urban, Industrial, Traffic And Mining Areas*. Essen, Germany.
- Carreiro M. M., Pouyat R. V., Tripler C. E. and Zhu W. X.** (2009). Carbon and nitrogen cycling in soils of remnant forests along urban–rural gradients: Case studies in the New York metropolitan area and Louisville, Kentucky. In *Ecology of cities and towns: A comparative approach*. (M. J. McDonnell *et al.*, eds), pp. 308–328. Cambridge Univ. Press, Cambridge, UK.
- Craul, P. J.** (1992). *Urban soil in landscape design*. John Wiley and Sons, New York.
- Craul P. J., and Klein C. J.** (1980). Characterization of streetside soils of Syracuse, New York. *Proc. of the Third Conference of the Metropolitan Tree Improvement Alliance*. Rutgers, New Brunswick, NJ 1992. *Urban soil in landscape design*. John Wiley and Sons, New York.
- Dmitrieva V. V. Myakisheva N. V. and Tetreikova V.** (2000). Integral assessment of the Ecological State of the Urban Territory. *Vestnik St. Petersburg. Geology, Geography Serial 7 4(7)*: 43.
- Dobrovolsky G.V. (1997). *Soils, Cities, Ecology*. Science, Moscow. 332 pp.
- Dobrovolsky G .V. and Nikitin E. D.** (1986). *Ecological Function of Soils. Test book for University Students and Specialists in Agrochemistry and Soils*. Moscow State University, Moscow.
- Gorbovsckaya A. D., Movchan V. N. et al** (2001). *Ecological State of Soils in Kostomuksha and its' Adjoining Territory*. Vestnik, St. Petersburg Serial 7. **1(7)**: 135–140.
- Grigorjan S. V. and Saet J. E.** (1980). *Geochemical Methods of assessing some Ecological Problems*. The Soviet Geology. p 11.
- Helmut Meuser** (2010). *Contaminated Urban soils. Environmental Pollution* 18. DOI 10.1007/978-90-481-93-282. Springer Science. Dordrecht Heidelberg, London New York.
- Johnson D.W. and D. E. Todd, Jr.** (1998). Harvesting effects on long-term changes in nutrient pools of mixed oak forests. *Soil Sci. Soc. Am. J.* **62**: 1725–1735.
- Kabrick J. M., Keith W. G., Zhaofei Fan and Dennis Meinert.** (2011). Landscape Determinants of exchangeable Calcium and Magnesium in Ozark

- Highland Forest Soils. *Soil Sci. Soc. Am.* **75** (1):164–180
- Éasimov N. S** and **Perelman A. I.** (1995). *Ecogeochemistry of City Landscapes*. Moscow State University, Moscow. 333 pp.
- Kuprianov V. V.** (19) *Hydrological aspects of urban environment of Leningrad*. Hydro-publication, Moscow. 184 pp.
- Patterson J. C., Murray J. J.** and **Short J. R.** (1980). The impact of urban soils on vegetation. Proceedings of the third conference of the Metropolitan Tree Improvement Alliance (METRIA).
- Pouyat R. V., Yesilisis. I. D., Szslavec K., Goffman P. M.** and **Schwarz K.** (2010). Soil American Society of Agronom, Crop science society of America, Crop Science Society of America. Agronomy. Monograph 55. Urban Ecosystem ecology, 119–147
- Pouyat R., Groffman P., Yesilonis I.** and **L. Hernandez.** (2002). Soil carbon pools and fluxes in urban ecosystems. *Environ. Pollut.* **116**: S107–S118.
- Pouyat R.V., Yesilonis I. D., Russell-Anelli J.** and **Neerchal N. K.** (2007a). Soil chemical and physical properties that differentiate urban land-use and cover types. *Soil Sci. Soc. Am. J.* **71**: 1010–1019.
- Schleuss U., Wu Q. L.** and **Blume H.P.** (1998). Variability of soils in urban and periurban areas in Northern Germany. *Catena* **33**:255–270.
- Short J. R., Fanning D. S., Foss J. E.** and **Patterson J. C.** (1986a). Soils of the Mall in Washington, DC: I. Statistical summary of properties. *Soil Sci. Soc. Am. J.* **50**: 699–705
- Stroganova M. N. Myakova A. D.** and **Prokofieva T. V.** (1997). *The role of soils in urban ecosystem*. Moscow State University. Moscow. pp. 96–101
- Terekhin N. B.** (1998) *Multi-criteria method of phytoindication assessment of ecological state of urban megapolis environment*. (PhD Thesis.). Department of Geographical Sciences. Saint Petersburg State University 1998 pp.20
- Trettin C. C., Johnson D. W.** and **Todd D. E. Jr.** (1999). Forest nutrient and carbon pools at Walker Branch watershed: Changes during a 21-year period. *Soil Sci. Soc. Am. J.* **63**:1436–1448.
- Vorobyeva L. A.** (1998). *Chemical analysis of soils*. Moscow State University, Moscow. 272 pp.
- White C. S.,** and **M. J. McDonnell.** (1988). Nitrogen cycling processes and soil characteristics in an urban versus rural forest. *Biogeochemistry* **5**: 243–262
- Mets A. R, Svetkova S. D.** and **Melichuck I. A.** (1989) *Morphological characteristics and agrochemical characteristics of soils of Central park Kirova and Primorskaya Pabedi. Forest, vegetation culture and soils*. Interschool Collections. Leningrad. pp. 73–78.