Study of surface mud sediment in an urban environment

A Seleznev, A Savastianova and I Yarmoshenko

Institute of Industrial Ecology, Ural Branch of Russian Academy of Sciences, S. Kovalevskoy str., 20, 620219, Ekaterinburg, Russia

E-mail: seleznev@echo.uran.ru

Abstract. Surface mud sediment is a media integrating pollution over space and time. Sampling of the mud sediment allows obtaining additional information about environmental state. The results of the study of surface mud sediment in Ekaterinburg city (Russia) are represented in the paper. Particle-size composition of the sediment is primarily represented by dust and fine sand. Study of the sediment allows ranking the territories over pollution degree with heavy metals, identifying technogenic and typomorphic geochemical associations of the elements in environmental compartments.

1. Introduction

The process of forming fine grained particles and dust of various origins occurs in an urban environment permanently. Natural and anthropogenic processes (primarily landscaping and planning) cause the constant redistribution and accumulation of fine grained particles and dust at surfaces and local depressed areas of micro landscape, thus forming the recent anthropogenic sediments. The loose sedimentary material is a product of soil erosion, decomposition and abrasion of various surfaces and materials [1–7]. The sediment may be composed of mineral constituents, natural biogenic materials, anthropogenic inorganic/organic matters. Sediment substance accumulates pollution (pathogens, industrial chemicals and metals) and provides a potential source for a present-day secondary and nonpoint source of pollution in urban environment. Some researchers note that the transported sediment is the main source of particle matters and pollutants of surface water environment [7, 8]. Nature of the transfer of sediments and pollution makes obtaining reliable information on the dominant sources of sediments and the association between the sediment substance and contaminants within urban landscape difficult. Thus the US EPA recommends removing the sedimentary material from the surfaces in an urban area due to its toxicity [9–14].

The sediment characterizes the environment where it is formed. Surfaces participating in the accumulation of the sediment are constructed in various time periods. The sediment accumulates pollution over time from the moment of forming the landscape and over its area. Thus, the sediment is a media integrating pollution over space and time. Sampling of the mud sediment allows obtaining additional information about environmental state and geochemical behavior of pollutants in an urban environment [1, 3–5, 15–17].

The current paper represents the generic and recently obtained results of the study of surface mud sediment in an urban environment (on the example of Ekaterinburg city, Russia).
2. Object and methods of the study

2.1. Object of the research

The object of the research is the mud sediment deposited on the surfaces and in local surface depressed zones of landscape (in other words puddle sediment, PS) in residential districts with multistory buildings in the city. Surface mud sediment can be classified as specific surface facie of the recent anthropogenic sediment in urban environment. Studied sediments participate in migration and accumulation of pollutants in an urban environment [18, 19].

2.2. Methods of the research

Concentrations of metals (typical pollutants and elements of the parent rock), pH level were measured in 210 PS samples collected in 2007–2010. The ‘total’ concentrations of Pb, Zn, Cu, Mn, Fe and Al in PS samples were determined with ICP-MS Perkin Elmer ELAN 9000 (Perkin Elmer Inc., USA). The pH level the aqueous extract solution of the PS samples was determined with ionomeric method.

Particle-size composition was determined in 30 samples of mud sediment collected in 2016. To conduct particle-size composition analysis the sampling of the sediment was conducted at the 6 sampling sites (residential blocks located in different geographical districts of the city) according to the following scheme. The sampling of the sediment was conducted inside and outside the residential block. Samples were collected from asphalt, pavement, green zone and parking (authorized and unauthorized). For particle-size separation the representative subsample with mass approx 200–300 g was taken from the sample of the sediment. The subsample was crushed and homogenized with rubber pounder. Than the particle-size fraction > 1 mm was separated with dry sieving the subsample. The remaining substance was added with distilled water. After that, the particle-size fractions 0.05–0.1 mm, 0.1–0.25 mm and 0.25–1 mm were separated with wet sieving of the remaining material of the sediment subsample. Particle-size fractions 0.002–0.01 mm and 0.01–0.05 mm were obtained from the solution after its decantation and vacuum filtering with membrane filters.

3. Results of the study

3.1. Distribution of heavy metal concentrations in the mud sediment

The analysis of spatial redistribution of concentrations of pollutants in PS samples was conducted by ten enlarged residential districts in Ekaterinburg. The districts can be ranked by pollution degree. The distribution of concentrations of Pb, Zn and Cu in Ekaterinburg is shown in Table 1. City districts where the average concentrations are above the average for the city are highlighted in bold.

| District        | Cu, mg/kg | Geometric mean | Pb, mg/kg |
|-----------------|-----------|----------------|-----------|
| East            | 127       | 473            | 104       |
| West            | 104       | 380            | 90        |
| North           | 93        | 277            | 71        |
| North-West      | 96        | 237            | 75        |
| Center          | 103       | 433            | 91        |
| South           | 104       | 509            | 101       |
| South-East      | 77        | 230            | 57        |
### 3.2. Correlation between the heavy metal concentrations in the sediment

The Spearman’s correlation coefficients were assessed for metals Al, Mn, Fe, Cu, Zn and Pb in PS samples in Ekaterinburg (Table 2).

| District             | Cu, mg/kg | Zn, mg/kg | Pb, mg/kg |
|----------------------|-----------|-----------|-----------|
| South-Eastern suburbs| 82        | 281       | 52        |
| South-West           | 91        | 399       | 82        |
| Southern suburbs     | 79        | 285       | 46        |

* -- correlation is significant under $p < 0.05$

For the studied metals Spearman’s correlation coefficient does not show the strong statistically significant correlation between the elements, though it is significant under $p < 0.05$. Such correlation may correspond to the existence of different sources of the elements.

The analysis of variances showed two geochemical associations of metals in PS: typomorphic (Mn, Fe and Al) and anthropogenic (Cu, Zn and Pb).

### 3.3. Geochemical associations of metals in mud sediment and bottom sediment of water bodies

Comparative analysis of heavy metal content in PS and bottom sediments of anthropogenic water bodies was conducted for Ekaterinburg territory. Studied anthropogenic water bodies are the former open-cut mines flooded with atmospheric precipitations and fire ponds in the suburbs of the city. The composition of sediments of the water bodies is mainly represented by pulp. The characteristic geochemical association for heavy metals Mn-Zn-Cu-Pb is the same for PS and bottom sediments of anthropogenic water bodies in the city.

### 3.4. Association between metals concentration and pH level in mud sediment

The pH level of PS samples ranges from 6.13 to 8.78 with a mean of 7.66 and median value of 7.68. Portion of samples with a weak-acid medium ($pH = 6–7$) is 12 %, with an alkalescent ($pH = 7–9$) – 88 %. The statistically significant correlation between concentrations of Pb, Zn and Cu vs pH was not found. It means that pH level doesn’t determine the significant impact to the variability of content of Pb, Zn and Cu in PS.

### 3.5. Particle-size composition of mud sediment

Each sample of surface mud sediment was divided into six particle-size fractions. The 180 granulometric subsamples were obtained for 30 collected samples. The results of particle-size composition analysis are represented on Figure 1.

The surfaces were divided into two types: ground and asphalt located outside and inside the block. Thus, the sediment is primarily formed with dust and fine sand redistributed within the territory of residential block.
4. Conclusion
The studied surface mud sediment represents the environmental compartment that spatially and temporally integrates surface migration fluxes of pollutants in an urban environment. Study of the sediment as environmental indicator allows assessing the degree of pollution of residential areas, ranking the city territories over pollution degree and identifying genesis of pollutants in urban environment. The results of the current study allowed elaborating the methodology of environmental assessment based on the sampling of the surface mud sediment. The methodology was implemented in Ekaterinburg and (Russia).

Acknowledgement
The reported study was funded by RFBR, according to the research project No. 16-35-60044 mol_a_dk.

References
[1] Wong C S C, Li X and Thornton I 2006 Env. Pollution 142(1) p 1–16
[2] Jartun M, Ottesen R T, Steinnes E and Volden T 2008 Sci. of the Tot. Env. 396(2–3) p 147–63
[3] Selbig W R, Bannerman R and Corsi S R 2013 Sci. of the Tot. Env. 444 p 381–91
[4] Wei B and Yang L 2010 Microchemical J. 94(2) p 99–107
[5] Apeagyei E, Bank M S and Spengler J D 2011 Atmospheric Env. 45(13) p 2310–23
[6] Sabin L D, Lim J H, Stolzenbach K D and Schiff K C 2005 Water Research 39(16) p 3929–37
[7] Hilliges R A, Schriewer A and Helmreich B 2013 J. of Env. Management 128 p 306–12
[8] Shi G, Chen Z, Bi C, Li Y, Teng J, Wang L and Xu S 2010 Env. Pollution 158 p 694–703
[9] US EPA 2005 National Management Measures to Control Nonpoint Source Pollution from Urban Areas (Washington, DC: United States Environmental Protection Agency Office of Water) EPA-841-B-05-004
[10] US EPA 2001 Stormwater to Street Trees. Engineering Urban Forests for Stormwater Management (Washington, DC: United States Environmental Protection Agency) EPA-841-B-13-001

Figure 1. Results of particle-size composition analysis of the mud sediment
[11] US EPA 1991 Construction Site Stormwater Discharge Control. An Inventory of Current Practices (Washington, DC: United States Environmental Protection Agency Office of Water) EPA 833-D-91-100

[12] US EPA 2009 Protecting Water Quality with Smart Growth Strategies and Natural Stormwater Management in Sussex County, Delaware. EPA-NOAA Smart Growth Implementation Assistance for Coastal Communities for Sussex County, Delaware (Washington, DC: United States Environmental Protection Agency)

[13] US EPA 2008 Managing Wet Weather with Green Infrastructure. Municipal Handbook. Green Streets (Washington, DC: United States Environmental Protection Agency) EPA-833-F-08-009

[14] US EPA 2009 Developing Your Stormwater Pollution Prevention Plan: A Guide for Industrial Operators (Washington, DC: United States Environmental Protection Agency) EPA 833-B-09-002

[15] Nolde E 2007 Desalination 215(1-3) 1–11

[16] Kose T, Yamamoto T, Anegawa A, Mohri S and Ono Y 2008 Desalination 226(1–3) 151–159

[17] Duzgoren-Aydin N S 2007 Sci. of the Tot. Env. 385(1–3) 182–195

[18] Seleznev A A, Yarmoshenko I V and Sergeev AP 2015 J. of Env. Radioactivity 142 9–13

[19] Seleznev A A and Yarmoshenko I V 2014 Env. Technology & Innovation 1–2 1–7