Environmental Technology & Innovation 1–2 (2014) 1–7

Contents lists available at ScienceDirect

Environmental Technology & Innovation

journal homepage: www.elsevier.com/locate/eti

Study of urban puddle sediments for understanding heavy metal pollution in an urban environment

Andrian A. Seleznev *, Ilia V. Yarmoshenko

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

HIGHLIGHTS

- Puddle sediments are attractive urban objects to use in an environmental study.
- Urban puddle sediments accumulate pollution over space and time.
- Puddle sediments are collected in the residential blocks directly.
- Concentrations of Pb and Zn in puddle sediments reveal urban pollution.

ARTICLE INFO

Article history:
Received 10 April 2014
Received in revised form
30 July 2014
Accepted 8 August 2014
Available online 31 October 2014

Keywords:
Puddle sediments
Heavy metals
Pollution
Urban environment
Environmental assessment

ABSTRACT

Natural processes cause sedimentation in local surface depressed zones of the urban landscape with the formation of micro water bodies (puddles). The urban puddle sediments can be defined as a separate peculiar subtype of geochemical traps of the recent technogenic and anthropogenic sediments. Accumulation of pollutants over space and time is a remarkable advantage of urban sediments in comparison with urban soils. The relevance of urban puddle sediments as an object for the assessment of heavy metals pollution (Pb, Zn, Cu, Ni, Co, Mn, Fe) of an urban ecosystem was studied on the example of Ekaterinburg city, Russia. Samples of urban puddle sediments were collected from 213 locations in residential areas. The study of heavy metals pollution in Ekaterinburg city showed that the puddle sediments provide further opportunities for the analysis of the urban environment.

1. Introduction

Studies of the environmental problems of urban areas are commonly based on the investigations of the soil, air, and deposition media (snow, bottom sediments, dust etc.). However, while the permanent migration of pollutants and sedimentation caused by natural forces is a significant process which takes place under anthropogenic pressure in urban ecosystems, the separate data on the pollution of the environmental compartments do not allow for a comprehensive pattern of pollution in a large metropolis. The main disadvantage of a soil investigation, as a common environmental diagnostic tool in the urban environment, is low representativeness of a single urban soil core due to the spatial and temporal heterogeneity of urban soil material caused by numerous natural and anthropogenic factors (Hillel, 2004; Luo et al., 2012; Rossiter, 2007; Pouyat et al., 2010; Boudreault et al., 2012).

In recent decades, specialists have given much attention to the investigation of the recent anthropogenic sediments in an urban ecosystem (Murakami et al., 2008; Wong et al., 2006; Duzgoren-Aydin et al., 2004; Wei and Yang, 2010; Shi et al., 2010). In particular, the sediments of large water bodies, road dust, atmospheric depositions, street deposited sediments, soakaway and sewage sediments are extensively involved in urban environmental studies (Gunawardana et al., 2012; Nolde, 2007; Selbig et al., 2013; Hilliges et al., 2013; Adachi and Tainosho, 2004).

The origin of various types of the urban sediments is associated with such natural and technogenic processes as soil erosion, atmospheric deposition, and the transfer of traffic related materials (tyre and brake abrasion products, combustion exhaust, and pavement wear) (Murakami et al., 2008, 2009; Wei et al., 2009; Apeagyei et al., 2011; Pey et al., 2010). In comparison with the other types of the recent anthropogenic sediments of the urban environment, the puddle sediments and their role in the redistribution of pollutants is the least studied.

* Corresponding author. Tel.: +7 343 3623421; fax: +7 343 3743771.
E-mail addresses: seleznev@ecko.uran.ru (A.A. Seleznev), ivy@ecko.uran.ru (I.V. Yarmoshenko).

http://dx.doi.org/10.1016/j.eti.2014.08.001
2352-1864/

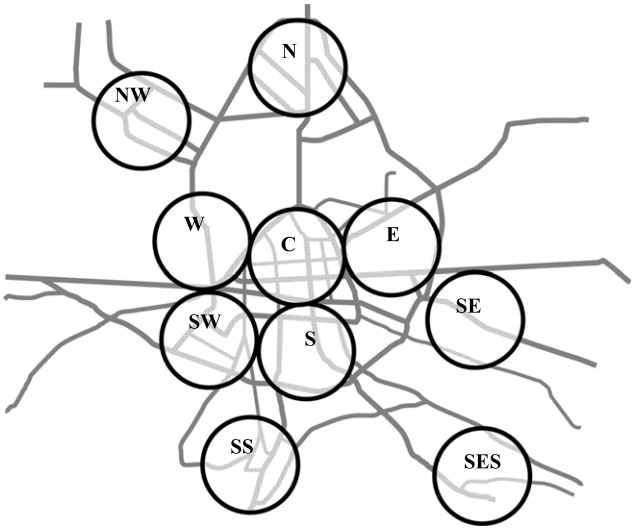

Fig. 1. Location of the residential districts in Ekaterinburg city: North (N), Northwestern (NW), West (W), Centre (C), East (E), Southwestern (SW), South (S), Southeastern (SE), Southern Suburb (SS), Southeastern Suburb (SES). The main road network in the city is also shown.

The precipitated rain and surface water runoff form micro water bodies (puddles) in the local surface depressed areas, filling them with the sedimentary material represented by the solid and suspended particles of soil, erosion material, and other particles (Seleznev et al., 2010) washed out and transported from the water catchment area. The puddle catchment area contains roofs of buildings, grounds, pavements, local roads within the district or neighbourhood and green zones with grass, trees, and bushes and other harvesting surfaces. The process of sedimentation and migration provides an intermixing of soluble and insoluble pollutants over the puddle catchment in the puddle sediments. Summarising all of the above, we can suppose that the puddle sediments of local surface depressed zones of the urban landscape are an ultimate accumulation depot of pollutants in an urban environment.

The objective of the research was to show the relevance of the puddle sediments as an object for the assessment of heavy metals pollution of the urban ecosystem (on the example of Ekaterinburg, Russia). To demonstrate the suggested approach, the set of metals (typical pollutants and elements of the parent rock) for the city was chosen for the analysis. The assessment of the heavy metal concentrations in urban puddle sediments and the comparison with the results of the soil investigation was conducted.

2. Materials and methods

2.1. Description of the sampling area

Ekaterinburg is a major city of the Ural region of Russia, the administrative centre of Sverdlovsk oblast. The linear dimensions of the city are approx. 25 km from north to south and 20 km from west to east. The population of Ekaterinburg is approx. 1.4 million people; the number of cars is approx. 0.3 per person. The city is situated on the eastern side of the Ural Mountains on the Iset River. Ekaterinburg and the Middle Ural region belong to the temperate continental climatic zone with well-marked cold and warm seasons. The average temperature is −14 °C in January and +19 °C in July. The winter lasts approx. 5 months—from November until April. Summer in the Urals is short, with warm weather for only 65–70 days.

Metallurgy, electric power, chemical and petrochemical industries, manufacturers of building materials, roads and rail transport, as well as machine building and metal working plants are located in the northern part of Ekaterinburg, metallurgical—in the south and west. Several major highways pass through the city. Three heat and power stations are also located in the city (in the west, north, and east). The low scattering power of the atmosphere determines the high degree of air pollution in the city. In recent years, the emissions from vehicles have increased due to increasing number of cars. In addition, the emissions of industrial enterprises, located in Ekaterinburg and in the suburbs, are superposed to each other under certain weather conditions.

The environmental monitoring in Ekaterinburg is carried out by the authorised body SRD FSHEM (The Sverdlovsk Regional Department of The Federal Service for Hydrometeorology and Environmental Monitoring). Air pollution monitoring in Ekaterinburg city is conducted by a network of eight stationary monitoring posts (one stationary post per 10–15 km^2 on average). The soil investigations are carried out every five years on an irregular grid at 90 sites in the most polluted parts of the city located mainly in the vicinity of 10 km from the large enterprises in the parks, forest park areas, and places where undisturbed soils are present. The soil sampling is not conducted directly in residential districts. Background soil samples for the city are collected at the sites located at a distance of 50–60 km to the southwest just outside the city.

2.2. Sampling collection and preparation

Puddle sediments sampling sites were chosen on an irregular grid in 10 enlarged residential districts (Fig. 1) consisting of microrayons (primary structural element of the residential area development separated by the forest park zones, major highways, railways, and industrial sites of enterprises). The majority of the contemporary microrayons in Ekaterinburg were formed under the planned construction of the city during the 20th century.