Chapter 14
Dispersion of Contaminants in Urban Regions and Beyond

Sebastien Rauch

Abstract Cities are important sources of contaminants at the local, regional, and global scales. In urban areas, automobile traffic, leaching from building materials, urban runoff, and industrial sources are resulting in the occurrence of elevated concentrations of metals, including Ag, Cd, Cu, Pb, Pt, Rh, Sb, Sn, W, and Zn. Here, we show that in addition to local impacts, urban contamination extends beyond the urban boundary. Two examples are provided to show that atmospheric and water-based dispersion result in regional-scale contamination. In Stockholm, contaminants are found in sediments downstream from the urban center. Platinum-group elements (PGEs) are used as tracers of urban contamination and show that a significant fraction of contaminants emitted into the atmosphere can be transported at regional scales. The projected growth of cities will lead to an increase in pollution, especially in developing countries where environmental legislation is still lagging and material use is soaring. There is in general an urgent need to raise awareness and implement programs to reduce the environmental impact of urban activities.

Keywords Trace elements • Platinum group elements • Urban environment • Dispersion

14.1 Introduction

Today, over 50 % of the global population lives in urban areas. Cities concentrate human activities and our impact on the environment, including the release of potentially hazardous contaminants. Air and soil pollution is a well known problem in many urban areas. Transport of contaminants during rain events and discharges also result in the contamination of the aquatic environment. Although the contamination is most severe in cities, i.e., close to the sources, contaminants can be transported at regional and global scales. Elevated heavy metal concentrations

S. Rauch (✉)
Department of Civil and Environmental Engineering, Chalmers University of Technology, 412 96 Gothenburg, Sweden
e-mail: sebastien.rauch@chalmers.se

M. Yokohari et al. (eds.), *Sustainable Landscape Planning in Selected Urban Regions*, Science for Sustainable Societies, DOI 10.1007/978-4-431-56445-4_14

have, for instance, been found in Alpine glaciers (Barbante et al. 2004) and as far away as Greenland (Hong et al. 1996; Barbante et al. 2001), indicating that our cities have a widespread impact.

Trace elements, which are normally found at low concentrations in the environment, are valuable markers of human activities. This chapter presents two studies that have aimed to assess local and global contamination by human activities, respectively. First, the concentrations of trace elements are provided for an urban region to determine the impact of specific human activities on trace element levels and assess water-based dispersion. Second, platinum-group elements (PGEs) are presented as a tracer of automobile traffic in urban and remote environments, to assess atmospheric dispersion at both regional and global levels.

14.2 Materials and Methods

14.2.1 Assessment of Water-Based Dispersion

Sediments are an interesting source of information on trace element contamination because aquatic systems integrate deposition in a watershed and many elements are in a particulate or particulate-reactive form. Sediments were collected at selected locations in Stockholm, Sweden, including background, upstream, urban, and downstream sites. Collection was performed using a piston corer and surface sediments were retained for analysis. Samples were prepared by microwave-assisted acid digestion using *Aqua regia* and analyzed by quadrupole ICP-MS (Elan 6000, PE Sciex) with pneumatic nebulization and using conventional settings (Rauch 2007).

14.2.2 Assessment of Atmospheric Dispersion

The impact of urban emissions on the occurrence and cycling of PGEs has been assessed using data obtained in our laboratory during the past 15 years. These data are complemented by results obtained in collaborative studies, as well as results presented in the literature. A variety of urban samples have been collected, including airborne particles, road dust, roadside soil, water, sediments, and vegetation in European, North American, Asian, and African cities. In addition, samples from non-urban locations have been collected to assess regional and global impacts of cities. Elemental analysis has been performed by inductively coupled plasma-mass spectrometry, using quadrupole or sector field instruments with single or multicollector detection (e.g., Rauch et al. 2001, 2004, 2005b).

14.3 Results and Discussion

14.3.1 Assessment of Water-Based Dispersion

Trace element concentrations (i.e., antimony (Sb), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), platinum (Pt), rhodium (Rh), silver (Ag), tin (Sn), tungsten (W), and zinc (Zn)) in sediments in Stockholm are present at elevated concentrations relative to background sites as a result of urban contamination. Copper is present at high concentrations at most sampling sites according to Swedish EPA sediment concentration guidelines. Zn and Pb are only present at high concentrations at specific sites. In addition, Ag concentrations exceed the apparent threshold concentration for Ag at several sites, whereas it is exceeded at one site for Sb. Urban emissions of Pt, Rh, and W were also found, but no guideline exists for these metals, making the assessment of potential risks difficult. This study indicates that the occurrence of trace elements in Stockholm is a potential risk for humans and the environment.

The spatial distribution of trace elements in sediments demonstrates that the contamination is the result of diffuse sources of many elements and it is therefore difficult to control. Major sources of trace elements include automobile traffic, urban surfaces (road pavements), buildings, and combustion, as well as location-specific sources. The lowest concentrations were found upstream and at background sites for most elements. Spatial trends indicate that these elements have urban sources, characterized by a concentration increase upstream and in most cases a decrease downstream. Elevated Ag downstream from Stockholm indicates that this element is released into the Baltic sea with higher efficiency than that of other analyzed elements (Fig. 14.1). The results suggest that water-based transport results in regional contamination, with urban regions being contaminated downstream from urban sites.

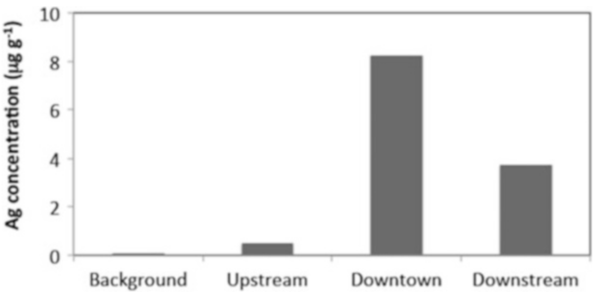

Fig. 14.1 Ag concentrations in Stockholm sediments showing elevated Ag concentration at the downstream site

14.3.2 Assessment of Atmospheric Dispersion

Platinum-group elements (PGEs; i.e., Pd, Pt, Rh, Ru, Ir, Os) are among the least abundant elements in the continental crust. Increasing use has, however, resulted in the occurrence of elevated concentrations of these normally rare metals in urban areas. Automobile exhaust catalysts are generally believed to be the main source of PGEs in the environment. These catalysts use Pd, Pt, and Rh to promote the removal of gaseous pollutants in vehicle exhausts and a fraction of the PGEs in catalysts is emitted during vehicle operation. Emissions are expected to be in the ng km^{-1} range (Moldovan et al. 2002). PGEs are potential candidates for the tracing of urban contamination at regional and global scales owing to their generally low natural concentration and specific emissions from automobile sources, which are typically concentrated in urban areas, as well as the atmospheric character of Pt and Rh emissions. PGEs are among the elements whose global biogeochemical cycles are the most affected by human activities (Rauch 2010).

A global catalyst emission of 1–4 metric tons of Pt $year^{-1}$ can be inferred, assuming that 500 million vehicles are equipped with catalysts with an average yearly mileage of 15,000 km $vehicle^{-1}$ and an average emission rate of 0.1–-0.8 μg km^{-1} (Rauch and Morrison 2008). Other less significant urban sources include discharges from hospitals where Pt-based drugs are used in cancer treatment (Kummerer et al. 1999). In addition, it is possible to infer PGE accumulation based on concentrations measured in environmental samples, known material accumulation rates, and surface areas (Rauch et al. 2005a). Yearly accumulation Pt estimates are presented in Fig. 14.2.

While concentrations are highest in urban environments where the human population is directly exposed to emitted PGEs, a significant fraction of emitted PGEs is dispersed at a regional scale where food is often produced, owing to their

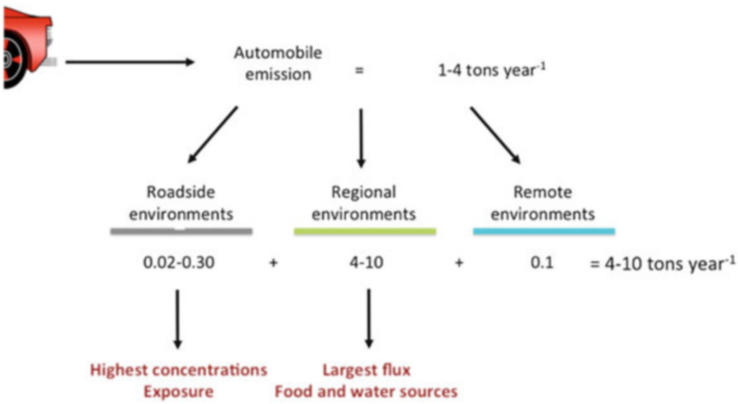

Fig. 14.2 Accumulation of Pt in roadside, regional, and remote environments estimated based on measured concentrations, material accumulation rates, and surface areas. Further details on the definition of roadside, regional, and remote environments are provided in Rauch et al. (2005a)

occurrence in fine particles (Rauch et al. 2005a). Elevated PGE concentrations have also been reported at remote sites (Barbante et al. 2001; Moldovan et al. 2007; Rauch et al. 2010).

Although present concentrations do not support the presence of acute effects on humans and the environment, chronic effects cannot be excluded. As environmental PGE concentrations are increasing, there is a need to provide a reliable assessment of potential risks. Risk assessment should include chronic effects; therefore, toxic effects need to be determined for low exposure concentrations under environmentally relevant conditions.

14.4 Conclusions

Urban areas are an important source of contaminants at local, regional, and global scales. Elements including Ag, Cd, Cu, Cr, Pt, Pd, Rh, Sb, and W have been found to be present at elevated concentrations in urban areas. The regional impact of cities on trace element contamination is demonstrated by the analysis of downstream samples and the use of PGEs as tracers of automobile-derived contaminants. The presence of contaminants raises concern over potential environmental and human health risks. While the occurrence of elevated contaminant concentrations in urban areas can result in direct exposure and subsequent effects, accumulation of contaminants at regional scales can lead to the contamination of agricultural production and food supply. Cities are projected to grow in the coming years and environmental contamination is expected to follow a similar trend, especially in the developing world where environmental legislation is lagging and material consumption is soaring. The use of metals in Asian cities is, for instance, increasing rapidly and emissions are at present poorly controlled. It is important to limit emissions from urban sources to limit potential risks and reduce our impact on the environment.

References

Barbante, C., Veysseyre, A., Ferrari, C., Van de Velde, K., Morel, C., Capodaglio, G., et al. (2001). Greenland snow evidence of large scale atmospheric contamination for platinum, palladium, and rhodium. *Environmental Science and Technology, 35*, 835–839.

Barbante, C., Schwikowski, M., Doring, T., Gaggeler, H. W., Schotterer, U., Tobler, L., et al. (2004). Historical record of European emissions of heavy metals to the atmosphere since the 1650s from Alpine snow/ice cores drilled near Monte Rosa. *Environmental Science and Technology, 38*, 4085–4090.

Hong, S. M., Candelone, J. P., Soutif, M., & Boutron, C. F. (1996). A reconstruction of changes in copper production and copper emissions to the atmosphere during the past 7000 years. *Science of the Total Environment, 188*, 183–193.

Kummerer, K., Helmers, E., Hubner, P., Mascart, G., Milandri, M., Reinthaler, F., et al. (1999). European hospitals as a source for platinum in the environment in comparison with other sources. *Science of the Total Environment, 225*, 155–165.

Moldovan, M., Palacios, M. A., Gomez, M. M., Morrison, G., Rauch, S., McLeod, C., et al. (2002). Environmental risk of particulate and soluble platinum group elements released from gasoline and diesel engine catalytic converters. *Science of the Total Environment, 296*, 199–208.

Moldovan, M., Veschambre, S., Amouroux, D., Benech, B., & Donard, O. F. X. (2007). Platinum, palladium, and rhodium in fresh snow from the Aspe Valley (Pyrenees Mountains, France). *Environmental Science and Technology, 41*, 66–73.

Rauch, S. (2007). *Trace elements in Stockholm sediments*. Stockholm: Stockholms Miljöförvaltningen.

Rauch, J. N. (2010). Global spatial indexing of the human impact on Al, Cu, Fe, and Zn mobilization. *Environmental Science and Technology, 44*, 5728–5734.

Rauch, S., & Morrison, G. M. (2008). The environmental relevance of platinum group elements. *Elements, 4*, 259–263.

Rauch, S., Lu, M., & Morrison, G. M. (2001). Heterogeneity of platinum group metals in airborne particles. *Environmental Science and Technology, 35*, 595–599.

Rauch, S., Hemond, H. F., & Peucker-Ehrenbrink, B. (2004). Recent changes in platinum group element concentrations and osmium isotopic composition in sediments from an urban lake. *Environmental Science and Technology, 38*, 396–402.

Rauch, S., Hemond, H. F., Barbante, C., Owari, M., Morrison, G. M., Peucker-Ehrenbrink, B., et al. (2005a). Importance of automobile exhaust catalyst emissions for the deposition of platinum, palladium, and rhodium in the northern hemisphere. *Environmental Science and Technology, 39*, 8156–8162.

Rauch, S., Hemond, H. F., Peucker-Ehrenbrink, B., Ek, K. H., & Morrison, G. M. (2005b). Platinum group element concentrations and osmium isotopic composition in urban airborne particles from Boston, Massachusetts. *Environmental Science and Technology, 39*, 9464–9470.

Rauch, S., Peucker-Ehrenbrink, B., Kylander, M., Weiss, D. J., Martinez-Cortizas, A., Heslop, D., Olid, C., Mighall, T. M., Hemond, H. F. (2010). Anthropogenic forcings on the surficial osmium cycle. *Environmental Science and Technology, 44*, 881–887.