GEOCHEMICAL CHARACTERIZATION OF ROAD DUST IN URBAN ENVIRONMENTS

Ewa Adamiec

AGH University of Science and Technology; Faculty of Faculty of Geology, Geophysics and Environment Protection, Department of Environmental Protection, Krakow, Poland;

eadamiec@agh.edu.pl

Keywords: road dust, brake dust, toxic metals, roads, traffic

Introduction

The purpose of this research is to extend the current knowledge on transformation of traffic-related pollution bounded in solid samples in roads environments. There is still a number of uncertainties relating to the emission rates, physical properties, chemical characteristics of particles derived from road vehicles. Road dust is composed of elements of both geological and anthropogenic origin. Detailed morphology and chemical composition of road sediment based on mineralogical and geochemical studies is necessary to evaluate their harmfulness. Road-specific metals are key tracers of non-exhaust emissions (such as brake, clutch and tire wear). Information on the total concentration of metals in road dust is not sufficient to assess their potential bioavailability and mobility. Fractionation and sequential extraction procedures are widely used to determine various forms of metals and to indicate its environmental impact, however very limited studies are found regarding metal speciation in road dust.

Methods

In order to assess and recognize road-specific pollution sites near roads characterized by a very high traffic and congestions in Cracow and Warsaw as well as in Wroclaw and Opole were selected as research points. In each of the eight research areas, samples of road deposited sediment, roadside topsoil, pavement dust as well as mixed sludge and sediment from gullies were collected during summer and autumn sampling campaigns. Brake lining and road dust samples were sieved into six size-fractions (<20, 20–63, 63–200, 200–1000, 1000-2000, and >2000 µm). Metals were extracted from solid samples by microwave oven digestion (EPA 3050B method). Next, concentration of metals were determined in samples with the use of ICP-MS, ICP-EOS and AAS. Analysis of heavy metals' binding forms (fractionation) was conducted. These tests included road dust bulk samples and were made based on VI steps extraction according to Calmano (1989). Chemical composition analysis of brake dust was performed with the use of ICP-MS as well as XRF. Furthermore, SEM-EDS research was focused on identifying four main components: binders, fibres, fillers and friction modifiers.

Results

Phase analysis (XRD) showed that the most dominant mineral in road deposited sediment, pavement dust and sludge from gullies is quartz, while concomitant minerals are potassium feldspars (microcline), plagioclases (albite) and calcite. The analysis has shown a significant part of amorphous phase, especially in samples of sludge from gullies. Relatively sizeable amount of amorphous phase may suggest its anthropogenic origin: partially eroded minerals, clay minerals (unidentifiable regarding to detection limits), amorphous silicates and organic matter as well as traffic generated particles (break dust and tyre dust). Granulometric analysis of brake dust has shown that particles <20µm from brake linings should be considered as an indicator of heavy metal pollution. Results revealed that road dust and sludge from gullies are especially contaminated with Zn, Cr, Cu, Pb, Fe, Ba and Ti. These metals are key tracers of non-exhaust brake wear emissions and their high concentrations confirm that brake wear highly contributes to road dust contamination. The finest fraction (<20 µm) was heavily contaminated with all of the investigated metals when compared with the remaining fractions. Attention should be also drawn to the fact that significant sources of metals in the finest fractions of road dust could be of geogenic origin. The studies of metal forms in road dust (fine fraction) revealed that Zn is significantly mobile (at exchangeable position and bounded to carbonates). Copper in more than 60% is bound with organic matter and sulfides - comparable amounts with those from the motorway and urban area, whereas Fe in 80-90% in the residue in both cases. Chromium, generally is tightly bound in the residue and about 30% is bound with organic matter and sulphides.Results obtained from SEM-EDS analysis performed on road dust, with the exception of the particles of geogenic origin, have confirmed the presence of brake-lining components as well as other anthropogenical particles such as e.g. fly ashes.

Conclusion

The concentrations of the majority of these elements were significantly elevated when compared with the concentrations found in road dust sampled from relatively traffic-unpolluted areas. Bearing in mind the fact that a large amount of Zn is in ion exchange positions and with carbonates, it constitutes a potential and important source of water and soil contamination. Contamination with Zn can be attributed to the wear and tear of tires because ZnO and ZnS are added to activate vulcanization in the tire tread. No significant differences were found in metal binding fractions in the road dust collected on the urban road and from the motorway.

Acknowledgments

Polish- Norwegian Research Programme operated by the National Centre for Research and Development under the Norwegian Financial Mechanism 2009-2014 in the frame of Project Contract No Pol-Nor / 208849/106/2015

References

Calmano W., (1989); Schwermetallen in kontaminierten Feststoffen. Verlag TÜV, Rheinland, GmbH, Köln, 237.