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Railway transportation as a source of soil pollution

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ABSTRACT

Surface soil (0–10 cm) samples from 60 sampling sites along the length of railway tracks on the territory of Srem (the western part of the Autonomous Province of Vojvodina, itself part of Serbia) were collected and analyzed for seven polychlorinated biphenyls (PCBs) and ten heavy metals in order to see how the distance from the railroad affects the concentration of some organic and inorganic pollutants in the soil. Samples were taken at a distance of 0.03–4.19 km from the railway. For the soil extraction was used USEPA 3540S method. The extracts were purified on a silica-gel column (USEPA 3630C). The analysis of the extracts was performed by gas chromatography with tandem mass spectrometry. PCBs were not detected only at two locations. Mean total concentration of PCBs for all other sampling locations was 0.0043 ppm dry weight (dw) with a range of 0.0005–0.0227 ppm dw. According to values of Nemerow pollution index Cu, Co, Zn and Ni were the most ubiquitous heavy metals in the area near railroad. Based on these results, it can be said that railway transport is a potential source of PCBs and some heavy metals.

1. Introduction

Soil is one of the most important natural resources. It is the reason we are able to sustain ourselves. But, unfortunately, the pollution of soil is a common thing these days. In recent years scientific workers draw attention to a series of restrictive factors that threaten the quality of soil such as degradation of chemical, physical and biological properties of soil (De Haan, 1987; Baumhardt et al., 2015). If the degradation of soil does not get adequate attention, especially when we talk about contamination with heavy metals, pesticides and other organic pollutants, might come to the occurrence of so-called “chemical time bomb”.

Polychlorinated biphenyls (PCBs) belong to the group of chemicals of concern because they persist in soil and sediment for decades, perhaps centuries, and are locked away in the fatty tissues of animals (Webster et al., 2013), building up in food webs. There are a variety of potential PCB sources in addition to more commonly recognized sources such as electrical transformer and capacitor oils and fluorescent light ballasts (Martínez et al., 2005). PCBs were released (both accidentally and intentionally) into the atmosphere, water, and land through sewers, smokestacks, stormwater runoff, spills, and direct application to the environment. Large volumes of PCBs have been introduced to the environment through the burning of PCB-containing products, vaporization from PCB-containing coatings and materials, releases into sewers and streams, improper disposal of PCB-containing equipment in non-secure landfill sites and municipal disposal facilities, and by other routes (such as ocean dumping) (ATSDR, 2001). The current primary sources of PCB contamination are limited to outdated or illegal landfills and scrap yards and leaks or explosions of electrical equipment and other equipment (such as locomotive transformers) that may still contain PCBs (ATSDR, 2001). According to NIP (national implementation plan) (NIP, 2015), public company Railways of Serbia in 2015th year possessed 110 capacitors and 491

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transformers based on PCB fluid, whereby the 3.6% of the transformers have been identified as contaminated (> 50 ppm of PCBs).

Therefore it is assumed that railroad can be a source of polychlorinated biphenyls, which were used in transformers, capacitors and electric locomotives. The question is are there PCBs accumulated in the soils in the vicinity of railway lines? Are the soils beyond 1000 m away from the railroad also polluted by PCBs? Are there other pollutants, for example, heavy metals (Jian-Hua et al., 2009), accumulated in the soils on railroad?

In this article, railroad sections in Srem district of Vojvodina, part of Serbian Railroad, were chosen as the study section. The length of the sampling section was extended to 4 km from the railroad. The aims of the study were to investigate the combined pollution of PCBs and heavy metals in the railroad-side soils.

2. Materials and methods

2.1. Study area

The study area is in the northwest of Serbia with temperate continental climate with clear alternation of the seasons. The average temperature is about 10.9 °C and the mean relative humidity is about 75.5%. The study sections, located between Stara Pazova–Novi Sad and Stara Pazova-Ruma-Sremska Mitrovica, were constructed about 130 years ago. Sections were used for passenger and cargo traffic. The area around the sampling section was used mainly for the cultivation of corn but there were also present farmlands with cabbage, soybean, sunflower, wheat, sugar beet, vegetables and alfalfa. There were no industrial objects near sampling area.

Some physical and chemical properties of the sampled soils were: pH about 7.1; percent of humus about 2.9%; average percentage of carbonates 2.93%; average of total nitrogen was 0.21% and 32.9% of phosphates. Samples were chernozem and meadow black soil types mainly used as arable land but there are also a couple of neglected lands and one meadow. Average height of the railroad bed compared to the surrounding farmland was about 2 m.

2.2. Soil sampling

To review the content of hazardous and harmful substances in the soils near the railway tracks in the area of Srem, 60 soil samples were collected. Soil samples were taken in disturbed state under the provisions of the System soil fertility control, with agrochemical probe to a depth of 30 cm, on a circular control plots. Various geomorphological types, actually, lower systematic units of the soil, as well as different forms of land use, were covered during sampling.

2.3. Method

The sampled soils were tested for the presence of the following PCB congeners: Bal 28, Bal 52, Bal 101, Bal 118, Bal 138, Bal 153 and Bal 180, and heavy metals: Cu, Zn, Mn, Pb, Co, Cr, Ni, Cd, As and Hg.

2.3.1. Polychlorinated byphenils

Samples were taken from a depth of 0–30 cm. The sample area was created from twenty subsamples taken properly distributed from defined areas. The soil was dry at room temperature, stones and the remains of vegetation were removed and then the soil was ground up and stored until analysis in sealed cardboard boxes. The Soxhlet extraction (United States Environmental Protection Agency - USEPA 3540C) was used, then the extracts were purified on a silica-gel column (USEPA 3630C). The analysis of the extracts was performed by gas chromatography with tandem mass spectrometry, using the device 1300 Thermo Scientific Trace ISQ with automatic injector AI 1310, on a HP-5-MS column (30 m × 0.25 mm × 25 μm). The method of selected ion monitoring (SIM) was used for detection of congeners. The working conditions of the mass spectrometer and temperature mode of the column were described in previous published paper (Stojić et al., 2014).

2.3.2. Heavy metals

Total content of trace elements and heavy metals Cu, Zn, Mn, Pb, Co, Cr, Ni, Cd, As and Hg in soil extract with concentrated HNO_3, was determined using inductively coupled plasma ICP-OES VistaPro Varian, while the content of Fe was determined by AAS.

3. Results and discussion

3.1. Concentrations of PCBs in soil

Fig. 1 shows the concentrations of PCBs in the soil samples. There were only three samples with concentrations od sum of PCBs higher than 0.02 ppm which is limit value defined by the Soil Regulation in Serbia (Official Gazette of RS 88/2010). These are two samples taken near the railway line in the municipality of Ruma and third sampled in the municipality of Šabac. All three samples were sampled at a distance up to 1 km from the railway track. At this distance, there were four more samples with a total PCBs concentration between 0.005 and 0.02 ppm. In the other twelve samples, from this distance group, PCBs concentration was below 0.005 ppm.

Thirty-two soil samples were taken at a distance from 1 to 4 km of railroad. In seven of those samples concentration of PCBs was in the range between 0.005 and 0.02 ppm. In all other samples PCBs concentration was lower. Nearly the same was the situation with