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Environmental assessment of heavy metals around the largest coal fired power plant in Serbia

Mirjana Ćujić [a], Snežana Dragović [b,*], Milan Đorđević [c], Ranko Dragović [c], Boško Gajić [d]

[a] University of Belgrade, Institute for the Application of Nuclear Energy, Banatska 31b, 11080, Belgrade, Serbia
[b] University of Belgrade, Vinča Institute of Nuclear Sciences, PO Box 522, 11001 Belgrade, Serbia
[c] University of Niš, Faculty of Science and Mathematics, Department of Geography, Višegradska 33, 18000 Niš, Serbia
[d] University of Belgrade, Faculty of Agriculture, Institute of Land Management, Nemanjina 6, 11081, Belgrade, Serbia

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ABSTRACT

Anthropogenic activities may lead to increased levels of heavy metals in soil environment and to reduced environmental quality. In this study concentrations of heavy metals (Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, V, Zn) were measured by using an atomic absorption spectrometer and soil samples were collected in the vicinity of the largest coal fired power plant in Serbia. The soil pollution status was assessed and enrichment by heavy metals at some sampling sites was revealed. For investigated metals the enrichment factors were in the range of 0.3 to 15.5, while the mean values indicated deficient to minimal enrichment of heavy metals in the investigated area. The highest contamination factor was determined for Ni, followed by Zn, Co and Cd. Cluster analysis was used to identify associations between heavy metals and soil properties. Significant positive correlations were found between: (1) Cd and Mn, Ni, Pb, Zn; (2) Cr and Cu, Fe, Ni, Pb; (3) Zn and Cu, Ni, Pb; and (4) Fe and V. Spatial distribution maps of heavy metal contents based on geostatistical analysis indicated similar patterns of spatial distribution for Co, Fe and V as well as for Cd, Mn, Ni and Pb. The hot spots for Co, Cr, Cu and Zn were revealed between two blocks of coal fired power plant in the investigated area. The distribution pattern revealed that the highest concentrations matched the predominant wind directions. It may be concluded that operation of the coal fired power plant has no significant negative impact on the surrounding environment with regard to the content of investigated heavy metals.

1. Introduction

The combustion of coal in coal fired power plants (CFPPs) distributes the heavy metals in solid and gaseous products, with most of them accumulated in the ash. Some of these metals become part of the fly ash, part of them is released into the atmosphere by the stack, and finally most of them reach soils and plants by wet or dry deposition. Millions of tons of coal are burnt every year in CFPPs worldwide, producing waste, at each step of the process, starting from mining the ore, through transportation and combustion in a power plant, to deposition of ash in sludge lagoons. The interest of studying the environmental impact of the industrial coal cycle has started during the 1960s (Rosenbaum, 1973). As coal still has a major role in electricity generation worldwide a number of environmental studies in the last decade have been focused on this problem (Dragović et al., 2013; Ito et al., 2006; Karamanis et al., 2009; Li et al., 2014; Mandal and Sengupta, 2006; Rodriguez-Iruretagoiena et al., 2015; Silva et al., 2012). Heavy metals do not undergo microbial or chemical degradation and the total concentration of these metals persists for a long time after they reach the soils (Adriano et al., 2004). They are considered toxic to humans and biota (Ghrefat and Yusuf, 2006). Health authorities in many parts of the world are becoming increasingly concerned about the effects of heavy metals on environmental and human health. Soil quality values are a useful tool in screening the potential for contaminants within soil to induce biological effects and comparing the concentration of soil contaminants to the corresponding soil quality guideline (BMU, 2007; DEPA, 2002; Environmental Agency, 2002; Official Gazette of the Republic of Serbia, 1994). The effectiveness of methods of multivariate analysis applied to environmental data has been widely demonstrated (Charro et al., 2013; Ćujić et al., 2014; Dai et al., 2007; Dragović et al., 2014a, 2014b; Singh et al., 2008; Tsikritzis, 2005).

The main objective of the present work is to evaluate the potential contamination by heavy metals in the soils of the area surrounding the largest CFPP 'Nikola Tesla' in Serbia. To assess the soil pollution due to heavy metals, enrichment factor (*EF*), geo-accumulation index (I_{geo}), contamination factor (*CF*) and pollution load index (*PLI*) were calculated. The associations between the analyzed heavy metals and soil physicochemical characteristics were analyzed by using the hierarchical clustering analysis (*HCA*). The geostatistical mapping tools based on kriging were used to highlight the spatial distribution of heavy metals in soil of the investigated area.

* Corresponding author.
E-mail address: sdragovic@vinca.rs (S. Dragović).

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2. Materials and methods

2.1. Study area and soil sampling

Two blocks (A, B) of the coal fired power plant complex 'Nikola Tesla' are situated in western Serbia (N-44°39′, E-20°11′), 42 km upstream from Belgrade, the capital city of Serbia. They include eight units with total installed capacity of 2892 MW, using lignite from the Kolubara open coal mine. Annual production of coal ash is three to four million tons (EPS, 2009). The ash disposal sites of CFPP 'Nikola Tesla' cover an area of 9 km^2. Coal ash is stored at the dump after being suspended in water taken from the Sava River.

Geologically, the investigated area is composed of Devonian–Carboniferous, Middle and Upper Permian, Lower and Middle Triassic, Jurassic, Lower and Upper Cretaceous, Neogene and Quaternary sediments arranged superpositionally (Federal Geological Survey, 1980). The deep Paleozoic formations are overlapped with Mesozoic and Cenozoic sediments of high potential. Neogene freshwater Pannonian sediments are represented by marl and clay. Quaternary deposits in this part of Kolubara basin are represented by alluvial sediments, proluvial deposits and to a lesser extent by alluvial–proluvial formations.

Soil samples were collected from 95 locations in the vicinity of CFPP 'Nikola Tesla' during the period 2011–2013 (Fig. 1) by applying the 'systematic random sampling' procedure (IAEA, 2004). Samples were taken to depth of 20 cm and the locations were recorded using an eTrex Vista Garmin handheld Global Positioning System (GPS) with a precision of ±10 m. Soil samples were collected with a stainless steel spade and immediately packed in plastic bags. With the aim to

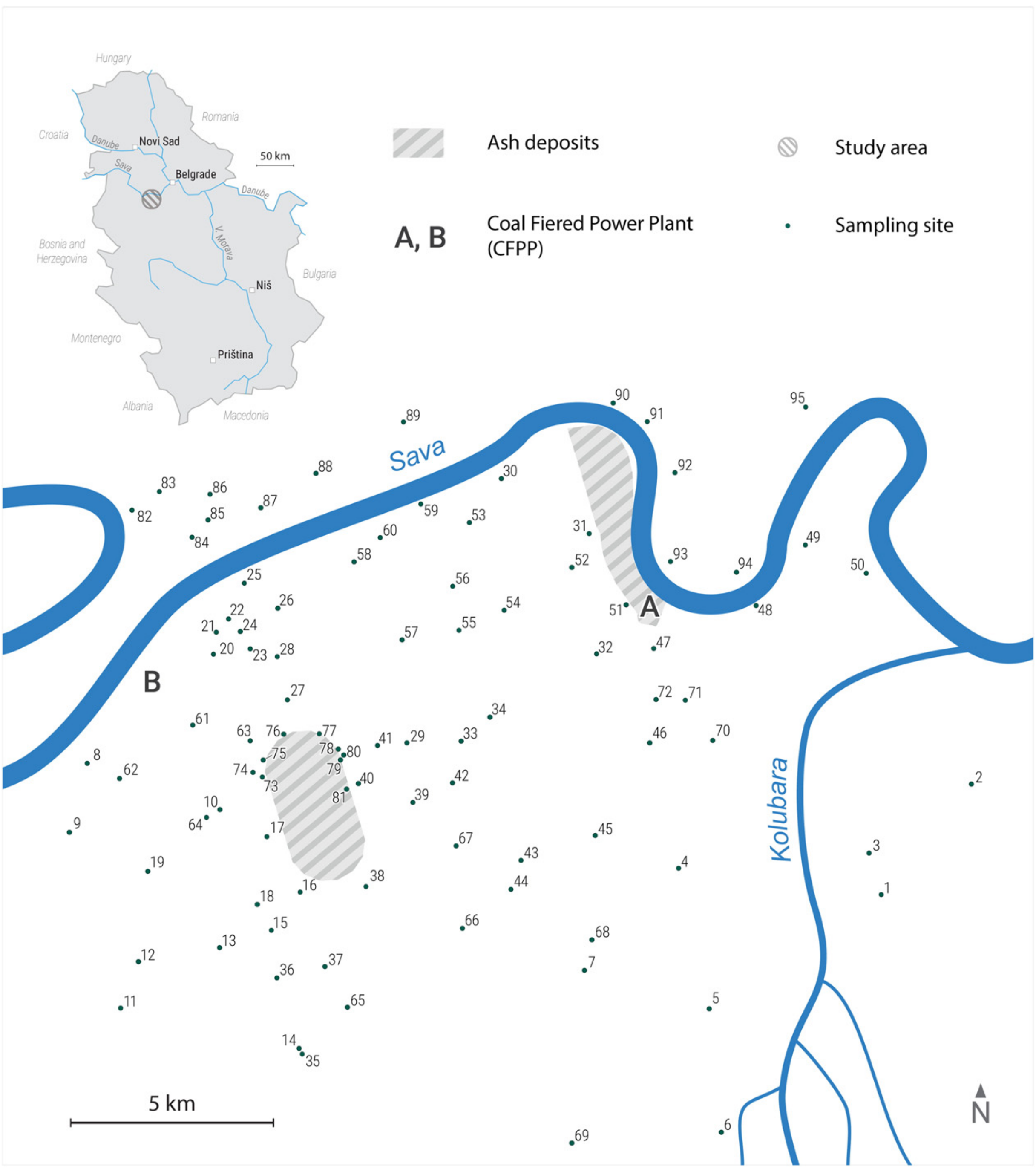

Fig. 1. Simplified map of the study area and distribution of sampling sites.