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Concentration of heavy metals and trace elements in soils, waters and vegetables and assessment of health risk in the vicinity of a lignite-fired power plant

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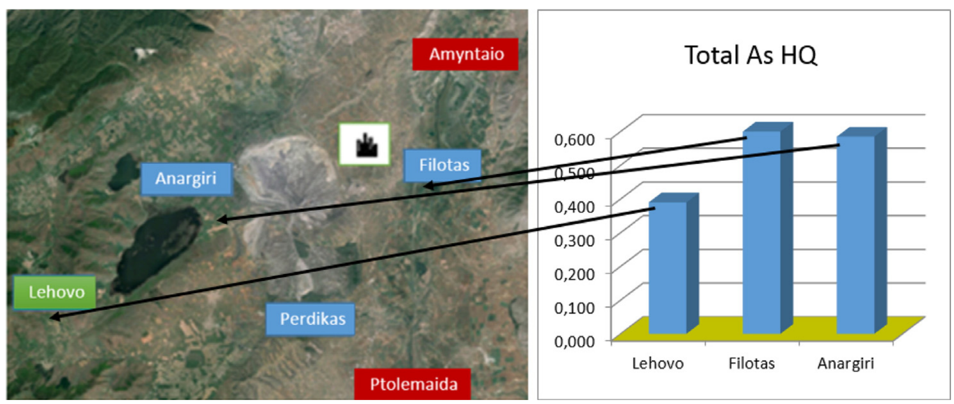
HIGHLIGHTS

- Seasonal variation of heavy metals concentrations in soils and waters in a lignite mining area.
- The elevated concentrations detected by NAA indicating minor contamination of the studied area.
- Determination of minor and trace elements in vegetables.
- The transfer factors and health risk quotients indicating a possible slight contamination in the area.

GRAPHICAL ABSTRACT



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ABSTRACT

The pollution of agricultural soils, waters and products in the regions of lignite mines and fired power plants is of great importance. The concentration of As, Ba, Co, Cr, Sr, Sc, Th, U, Zn in soils and waters in the vicinity of a lignite-fired power plant in Northern Greece was determined using Instrumental Neutron Activation Analysis. The determination frequency was every three months during a period of one year in order to evaluate the seasonal impact of the pollution to the environment. Measurements were performed in three locations around the lignite mine as well as in one reference location at a certain distance from the mine. The results, which exhibited a slight seasonal variation, were compared, where possible, with literature values from other countries. The obtained data in most of the cases did not exceed the normal levels and indicated that the investigated area was only slightly contaminated. The concentration of heavy and trace metals was also measured in three common garden crops (tomato, cucumber and parsley) grown in this area. The calculated transfer factors (TF) from soil to vegetables and health risk quotients (HQ) do not denote a health risk.

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1. Introduction

Lignite is plentiful and inexpensive for energy production but lignite power plants have been considered as the major source of environmental pollution all over the world, affecting the land use and endangering the human health (Asokan et al., 2005). As it is well known the usage of lignite as fuel produce huge amounts of wastes (i.e., flue gasses, bottom ash, fly ash, water contaminated with potentially toxic elements, radionuclides etc.) that are disposed in the area surrounding the power station (Pentari et al., 2006; Mijac and Krizman, 1996; Adamidou et al., 2007). Especially, fly ash particles are regarded as highly contaminating, containing heavy metals (As, Ba, Cr, Zn, Sr, Co, Sc, Cd, Pb, Rb, V, Mo) and radionuclides (U, Th and K-40) (Georgakopoulos et al., 2002; Karangelos et al., 2004; Krylov and Sidorova, 2013).

A significant number of countries in Europe utilize fossil fuels (i.e., lignite) as an energy source so information of the origin and behavior of potential contaminants constitutes priority objectives in the EU. Greece is referred as second (after Germany) among EU countries for lignite coal production. The indicated reserves are 6.7 billion tones with a value of 268 billion € (Georgakopoulos et al., 2002; Karangelos et al., 2004; Papaefthymiou et al., 2007). The number of the environmental problems, often associated with many human health ailments, is increasing in the regions of lignite usage (Chen et al., 2014). The contamination of the soils with low levels of heavy metals and the discharged waters frequently used for irrigating and growing crops leading to the accumulation of toxic contaminants in agricultural plants and thereby enter the human food chain (Pendias-Kabata, 2011; Karamanis et al., 2009; Pentari et al., 2006). Therefore a detailed investigation of the environmental impact of heavy metals and other hazardous materials in the vicinity around lignite thermal power plants is of great concern.

This study was carried out in the region of Ptolemaida-Amynteon (Northern Greece) which is the biggest lignite production basin in Greece. Many research papers have been appeared in the literature dealing with the coal, lignite and their products. For example Pentari et al. and Adamidou et al. have reported data concerning concentrations of trace elements and elements of environmental concern in the same basin and Georgakopoulos et al. have studied the contamination of the soils due to the leaching of the heavy elements from the fly ash (Pentari et al., 2006; Adamidou et al., 2007; Georgakopoulos et al., 2002).

However the drawbacks from the lignite usage (dust, toxic air emissions, fly ash, waste storage and transport) should be further explored. To our knowledge data concerning the potential contamination of water and soil from heavy metals in the surrounding area of a lignite mine or thermal power station as well as their impact to the agricultural crops are limited.

The aim of the present work was to estimate the environmental impact of major and trace elements of environmental concern (As, Ba, Cr, Zn, Sr, Co, Sc) in samples of waters and soils in the vicinity of a lignite-fired power plant. Their distribution and seasonal variation were studied in details as well as comparison being made with samples collected at a reference site. Measurements have been also performed in three common garden crops because the consumption of vegetables grown in (peri-) mine areas might pose a risk to human health due to elevated levels of trace elements. Emphasis was given to the transfer of heavy metals from soil and water to vegetables since this category of food is an essential part of the human diet and the most exposed to environmental pollution due to aerial burden (Li et al., 2015; Warming et al., 2015). Furthermore hazards quotients were calculated taking into account the contribution of soil, water and vegetable consumption. These data are very important, serving as basic information for the particular affected sites and the evaluation of the potential effects of lignite burning on the environment and human health.

2. Materials and methods

2.1. Study area

The studied area, as it is shown, in Fig. 1 is part of the Kozani-Ptolemaida-Amyntaion basin, northwestern Greece. The investigation was focused in the area surrounding the Amyntaion Power Station close to the corresponding mine. In the area the towns Amyntaion (8500 residents) and Ptolemaida (45,000 residents) are located 6 and 12 km from the Power Station respectively. Additionally there are other 14 villages with an average population of 10,000 residents in a surface of 400 km^2. The area is half a mountain region and land region and the principal industrial activity is coal mining. Cultivations such as corn, wheat, potatoes, tobacco and especially home gardening of various vegetables and herbs (tomatoes, cucumbers, carrots, parsley, mint) are common. The climate is humid continental with hot summers and very cold winters. The temperature is ranging between −15 and 30 °C and the median rainfall is about 500 mm. The basement of the basin consists mainly of Palaeozoic and Mesozoic metamorphic and plutonic rocks, underlying Cretaceous limestone and flysch. The Neogene–Quaternary sediments of the basin are characterized as limnic marls and clays and host the lignite seams (Pavlides and Mountrakis, 1987; Georgakopoulos et al., 2002; Megalovasilis et al., 2013).

2.2. Sampling and sample preparation

As sampling points were selected three villages (Filotas, Anargiri and Perdikas) around the lignite mine as well as one village (Lehovo) at the other side of the mountain, 23 km from the mine, for comparison reasons. In Fig. 1 the locations and the sampling points with their distance from the Power Station are shown. The sampling was performed in different periods in order to estimate the seasonal variation of the concentration of the investigated elements. The first period was in March 2012, the second in June, the third in September and the fourth in December 2012. Ground water samples supplied by drilling wells (average depth 40 m) were collected in polyethylene bottles in order to determine the trace elements concentration. The pH and the conductivity of the water were measured immediately after collection and then the samples were transported to the laboratory, filtered through 0.45 μm filters and acidified to pH 2 with nitric acid. Part of the samples (one litter) was dried at 65 °C in order to analyze them by NAA (the dry residue varied from 0.3 up to 1.2 g).

Fig. 1. Map of the investigated area with the mine, the power station and the sampling sites; Anargiri 2.0 km, Perdikas 4.0 km, Filotas 0.5 km and Lehovo 23.0 km respectively from the Power Station.