Ecotoxicology and Environmental Safety 142 (2017) 8–13

Contents lists available at ScienceDirect

Ecotoxicology and Environmental Safety

journal homepage: www.elsevier.com/locate/ecoenv

Cadmium in edible plants from Silesia, Poland, and its implications for health risk in populations

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ARTICLE INFO

Keywords:
Soil
Cadmium
Vegetables
Bioconcentration factor
Health risk assessment
Silesia administration area

ABSTRACT

The health risk associated with cadmium exposure through consumption of edible plants cultivated in different parts of the Silesia administration area inhabitants has been estimated. The impact of the arable soils acidity on the BCF (bioconcentration factor) has been also analyzed. The concentration of cadmium in arable soils and in 118 samples of vegetables - carrots, beets, potato, celery (tuber), parsley (root) were determined. The cadmium content in examined soil samples were in the range from > 0.5–68.5 mg kg^{-1} d.w. The most contaminated samples, above the maximum permissible concentration, originated from the central part of the region. The highest BCF value in case of parsley roots and carrots has been shown (0.941 and 0.828 respectively). Significant correlation between soil pH and BCF in examined edible plants has been demonstrated. In the exposure scenario, which assumes the consumption of the most contaminated vegetables from Silesia administration area, the value of the hazard quotient (HQ) for Cd was 2.56. On the contaminated arable soils from the central part of Silesia administration area the non-edible plants should be cultivated. In case of acidic and slightly acidic pH-range of arable soils, some methods of metals immobilization in soil are recommended e.g. liming.

1. Introduction

Human exposure to heavy metals is one of the most significant environmentally-related risk factors and has been the subject of numerous scientific research (Nouri and Haddioui, 2016; Wang et al., 2016; Zhang et al., 2016). The given problem mainly concerns the population in the areas where non-ferrous metal ores` mining and processing activity has taken or is taking place. Heavy metals such as cadmium, lead or zinc introduced into the environment, last there for many years. Among environmental elements, it is the soil where accumulation of heavy metals takes place. Exposure to heavy metals is mainly due to the consumption of contaminated fruits and vegetables (Eriksen et al., 2014; Liu et al., 2015), and in case of children, the significant role within the exposure is assigned to swallowing of contaminated soil fractions (Pelfrêne et al., 2013).

Heavy metal being assumed as one of the greatest health risks is cadmium, which shows high toxicity and is proven to have carcinogenic potential. Chronic exposure to cadmium may result in kidneys and bones damage (Ke et al., 2015; Wallin et al., 2016). It has been proved that cadmium can reduce men's fertility and increase the risk of pregnancy disorders (Pant et al., 2015; Kippler et al., 2012). Dietary exposure to cadmium constitutes the prostate, breast, ovarian or endometrial cancer risk factor (Adams et al., 2014; Ju-Kun et al., 2016; Lin et al., 2016).

The negative features of cadmium also include its high mobility within the environment and bioavailability in the soil-plant system (Shahid et al., 2017), what represents significantly higher values of the bioconcentration factor (BCF) compared to other heavy metals most commonly found in the environment (Chang et al., 2014). Therefore, in order to decrease of heavy metals bioavailability and uptake in edible plants, cultivated on contaminated soils, effective agricultural practices should be used (Abbas et al., 2017; Shaheen and Rinklebe, 2015).

The problem of significant soil contamination with cadmium is found, besides Silesia administration area, in many places around the globe, which was proved in studies carried out by Hellström et al. (2007); Zhao et al. (2012); Douay et al. (2013); Nawab et al. (2015). In Silesia region residents generally consume locally-grown edible plants, which is a significant health risk (Dziubanek et al., 2015).

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http://dx.doi.org/10.1016/j.ecoenv.2017.03.048
Received 19 January 2017; Received in revised form 28 March 2017; Accepted 29 March 2017
Available online 02 April 2017

This work is an extension of previously conducted studies in the Silesia administration area, located in southern Poland. For many decades the given region has been associated with ~~the~~ mining and processing industry of non-ferrous metal ores such as zinc, lead and cadmium. Despite the elimination of most of the Silesian metallurgical plants in the 90 s contamination of soils with non-ferrous metals still creates a significant problem within this region. The study included both samples: soil and edible crops grown in the cities of the central part of Silesia, as well as on arable areas in locations away from sources of non-ferrous metals emission to the environment. The potential source of soil contamination in this region can be mineral fertilizers that are used on that site (Baldantoni et al., 2016) or sewage sludge (Tai et al., 2016).

The aim of this study was the assessment of Silesia administration area residents` health risk resulting from the intake of edible plants cultivated in various parts of the region and to examine the impact of diverse pH of arable soils in particular locations on bioavailability of cadmium for edible plants.

2. Material and methods

2.1. Study area and sampling

Soil and vegetables sampling points were located in different parts of Silesia administration area. Samples came from 7 cities and 2 country districts. The majority of considered cities: Chorzów (CH), Piekary Śląskie (PS), Ruda Śląska (RS), Siemianowice Śląskie (SI), Sosnowiec (SO) and Zabrze (ZA) is located in central part of the voivodship, mainly associated with metallurgical industry. Another city - Jastrzębie Zdrój (JZ) is located in southern part of the region and is associated with coal mining industry. The other two counties: Kłobuck County (KL) and Myszków County (MY) are located to the north of the Silesia center and are typically agricultural areas (Fig. 1).

The study material consisted of 64 soil samples from arable fields and allotments and 118 samples of most frequently consumed edible plants (carrot, parsley root, celery, potato, beetroot tuber) cultivated on sampling sites. Both types of samples, arable layer of soils and edible plants were collected using the random sampling method.

Soil samples were collected from the stands with the surface of 1 sqm. From 15–20 of individual samples were collected from each stand. The samples were taken from the holes with a depth of 20 cm by using Egner's soil sampler which were then mixed in order to form an aggregate sample representative for the given research stand.

2.2. Sample preparation and chemical analyses

The soil samples have undergo drying with the WG-71 Chemland dryer (Poland) at a temperature of 105 °C degrees. Dried soil was sifted through the sieve with a diameter of < 2 mm. Later that, the excess with a weight of approx. 0.5 g was formulated using AS 60/220/ D /2 Radwag analytical balance (Poland). In case of vegetable samples, some non-edible parts of vegetables were removed. They were then washed, peeled and shredded. Then, the excess matter of 1 g was prepared from each vegetable.

Soil and vegetable samples were subjected to mineralization process with the nitric acid (Merck) in a Teflon vessel using microwave mineralization method in the microwave reactor, model Magnum II, Ertec (Poland) with pressure and temperature computer control. Excess samples of dried soil have undergone mineralization process during which they were digested by 8 ml of nitric acid in 10 min, and the excess samples of fresh vegetables were digested by 6 ml of nitric acid in within 7 min. The pressure range amounted to 42–45 bar.

The content of cadmium in samples of soils and edible plants were determined by inductively coupled plasma optical emission spectrometry (ICP-OES) method, using Integra XL, GBC spectrometer (Australia). For examination of vegetable samples with low cadmium content, the Atomic Absorption Spectrophotometer (AAS), SavantAA Sigma was used with the GF 3000, GBC graphite furnace (Australia). The result was the medium value obtained from 3 repetitions. Cadmium concentration within soil samples calculated by dry weight and in case of edible plants - by fresh matter.

In order to create the calibration curve the Certificate of Reference Material 1000 mg l^{-1} Cadmium Matrix: 2% HNO_3 SPEX CertiPrep. was used. In order to confirm the correctness of performed analytical

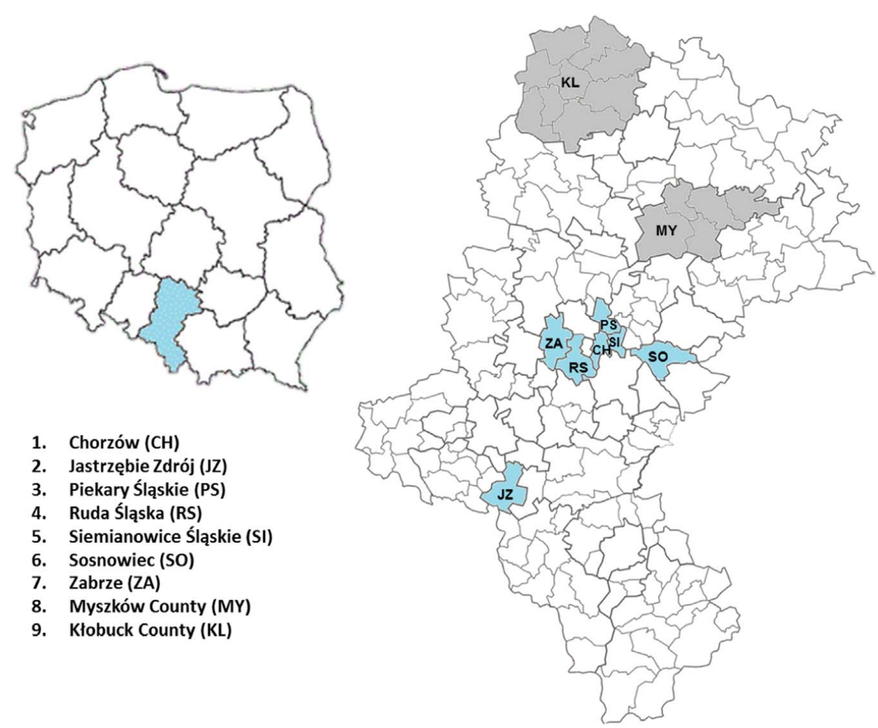

Fig. 1. Study area.