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Cadmium and lead in vegetable and fruit produce selected from specific regional areas of the UK☆

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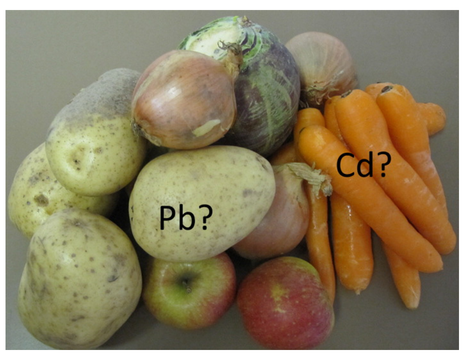
HIGHLIGHTS

- Cadmium and lead concentrations determined in fruit and vegetable produce
- 0.2% of the samples exceeded guideline values for cadmium.
- 0.6% of the samples exceeded guideline values for lead.
- Higher concentrations of cadmium and lead were found in the skins of potatoes.

GRAPHICAL ABSTRACT



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ABSTRACT

Cadmium and lead were determined in fruit and vegetable produce (~1300 samples) collected from a field and market basket study of locally grown produce from the South-West of Britain (Devon and Cornwall). These were compared with similarly locally grown produce from the North-East of Britain (Aberdeenshire). The concentrations of cadmium and lead in the market basket produce were compared to the maximum levels (ML) set by the European Union (EU). For cadmium 0.2% of the samples exceeded the ML, and 0.6% of the samples exceeded the ML for lead. The location of cadmium and lead in potatoes was performed using laser ablation ICP-MS. All tested samples exhibited higher lead concentrations, and most exhibited increased concentrations of cadmium in the potato skin compared to the flesh. The concentrations of cadmium and lead found in fruits and vegetables sampled during this study do not increase concern about risk to human health.

☆ Capsule: Cd and Pb was determined in fruit and vegetable produce, from the SW and NE of Britain, it was determined that less than 0.6% of the produce exceeded guides values for these 2 elements.
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1. Introduction

Cadmium and lead can both have adverse effects on human health. Cadmium is a chronic potent nephrotoxin as well as a class one carcinogen, and is associated with a range of other severe diseases (EFSA, 2012; Clemens et al., 2013). Acute and chronic lead exposures have been linked to a number of conditions (WHO, 2010; Fewtrell et al., 2003). Inorganic lead has also been classified as a compound which is probably carcinogenic to humans (IRAC, 2006). One of the main routes of cadmium intake for humans is through the consumption of food containing cadmium (Kabata-Pendias and Mukherjee, 2007; Clemens et al., 2013).

Toxic metals, including cadmium and lead, can be introduced to soils from various sources (Nicholson et al., 2003). These include sewage sludge, livestock manures, inorganic fertilisers, natural geogenic anomalies, base and precious mining activity, and industrial "wastes" (Nicholson et al., 2003). The main route of lead and cadmium input to agricultural land in England and Wales is through atmospheric deposition, and for cadmium the second highest route is through the application of phosphate fertilisers (Nicholson et al., 2003).

The European Union (EU) has set maximum levels (MLs) of both cadmium and lead in fruit and vegetables based on produce class, all based on wet weight (European Commission Regulation (EC) No. 1881/2006 (as amended)). For cadmium the standard for leafy vegetables, fresh herbs, celeriac, and all cultivated fungi is 200 ng g^{-1}. For stem vegetables, root vegetables, and potatoes it is 100 ng g^{-1}, while for vegetables and fruits excluding leafy vegetables, and other products (listed before), it is 50 ng g^{-1}. The MLs set by the EU for lead in berries and small fruits are 200 ng g^{-1} and 100 ng g^{-1} for other fruits. The ML for lead in brassicas and leaf vegetables is 300 ng g^{-1} while in other vegetables (including peeled potatoes) it is 100 ng g^{-1}. Previously, Weeks et al. (2007) conducted a survey of 12 metals (including cadmium and lead) from 12 allotment sites in the UK (6 urban and 6 rural), measuring a total of 251 fruit and vegetable samples. The study identified no produce above the ML for either cadmium or lead. The highest concentration of lead was found in a blackcurrant sample (160 ng g^{-1}), and the highest concentration of cadmium was in a spinach sample (40 ng g^{-1}). Yuan et al. (2014) conducted a health risk assessment of cadmium from food in China. They determined that the concentration of cadmium in vegetables ranged from below the limit of detection (LOD) to 150 ng g^{-1}, with a mean concentration of 13.3 ng g^{-1}, while the mean concentration of cadmium in fruit was 0.8 ng g^{-1}, and ranged from below LOD to 9.1 ng g^{-1}. In the study they concluded that mean cadmium concentrations of the food groups were below the Chinese maximum limits, but some individual samples did exceed the maximum limits, and the main dietary sources of cadmium were meat, rice, vegetables, and flour (Yuan et al., 2014). In a study looking at the health risk caused by the ingestion of cadmium and lead from a range of vegetables, where cadmium varied from 20–670 ng g^{-1} and lead ranged from 120–6540 ng g^{-1}, it was determined that the ingestion of the vegetables was unlikely to be a risk to the target population (Garg et al., 2014).

The aim of this current survey was to evaluate the concentrations of cadmium and lead in produce grown in the South-West (SW) of Britain (Devon and Cornwall) and the North-East (NE) of Britain (Aberdeenshire). The SW of Britain was picked as it has an extensive history of mining, while the NE of Britain has very limited, and localised, metal extraction industries. Growing produce on mine impacted soils can have an effect on the accumulation of heavy metals in the edible parts of the plants, leading to a hazardous accumulation of arsenic and lead (Gonzalez-Fernandez et al., 2011). Here, for both the SW and NE of Britain, basket surveys of local produce were performed, and in the SW a field survey was also conducted to link soil concentrations of cadmium and lead with concentrations of these elements in the produce. Form the data the following were tested; are the concentrations of cadmium and lead higher in vegetables and fruits grown in an area with historical mining? Is the concentration of cadmium and lead in the soil a predictor of concentrations of cadmium and lead in vegetables and fruits? Do peeled vegetables and fruits have lower concentrations than unpeeled vegetables and fruits? Additionally, laser ablation (LA)-ICP-MS experiments were done to identify the location of the elements within the produce.

2. Materials and methods

2.1. Sample collection

Locally produced fruit and vegetables in retail outlets from the SW of Britian and NE Britian, as well as field crops and soil from the SW, were sampled as described in Norton et al. (2013). The basket survey selected locally grown produce from a wide range of retailers as described in Norton et al. (2013). Samples were prepared by washing the produce to a level normally used in food preparation, in a kitchen sink using local tap water. Once dry the samples were diced in a food processor then frozen before further processing. For items eaten with and without skin (potatoes, root vegetables, apples, etc.), duplicate samples were collected and one was peeled and the other unpeeled, to reflect different dietary exposures.

The samples were prepared as commonly consumed, i.e. unpeeled for apples and courgettes, and peeled for potatoes, swedes, parsnip, carrots, beetroots, and squashes. A duplicate sample was also prepared with the other preparation method (i.e. peeled apples, unpeeled potatoes, etc.), referred to as the "alternative preparation". The SW Britain basket survey consisted of 630 samples with 207 alternative preparations, while the NE Britain basket survey consisted of 190 samples with 69 alternative preparations.

To establish the link between cadmium and lead in the produce and the concentration of cadmium and lead in the soil, both produce (fruit and vegetables in season) and soil in farmers' fields in the SW Britain geographic areas were sampled, with the farmers' permissions, as described in Norton et al. (2013). A total of 174 soil samples were analysed along with corresponding crops, as well as 56 alternative preparations for produce eaten either peeled or unpeeled.

To determine the total cadmium and lead in the skin and flesh of baked potatoes 20 potato samples were collected. For each potato sample three individual potatoes were baked and samples prepared as described in Norton et al. (2013). To compare the concentrations of cadmium and lead in the flesh and the skin a paired t-test was performed on the matching skin and flesh.

2.2. Cadmium and lead analysis

Samples were pureed in a blender, which was thoroughly washed between each sample. Pureed produce samples were accurately weighed into 50 mL polyethylene centrifuge tubes and oven dried at 70 °C, and the moisture content determined. The weight of wet material was to give an estimated dry weight (accurately weighed) of between 0.2–0.3 g. For digestion 2.5 mL of concentrated nitric acid was added to each sample and then incubated overnight. Trace reagent analysis grade reagents were used throughout. Prior to microwave digestion 2.5 mL of hydrogen peroxide was added to each tube and then the samples were digested using a Microwave Accelerated Reaction System (MARS, CEM); digestions were performed as described in Norton et al. (2013). Four certified reference materials (CRM) were used: 1× IC-INCT-MPH-2 mixed Polish herbs, 1× NIST-1568a rice flour, 1× CTA-OTL-1 Oriental tobacco leaves, and 1× NCS ZC73012 cabbage.

Sieved soil samples were weighed (0.1 g) into glass digest tubes and 2.5 mL of concentrated nitric acid was added to each tube. The samples were left overnight with the acid. Hydrogen peroxide (2.5 mL) was added to each tube and the digest tubes were then transferred to a digest-heating block set at 100 °C; after 1 h the temperature was