Science of the Total Environment 618 (2018) 460–468

Contents lists available at ScienceDirect

Science of the Total Environment

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

Lead in Egyptian soils: Origin, reactivity and bioavailability measured by stable isotope dilution

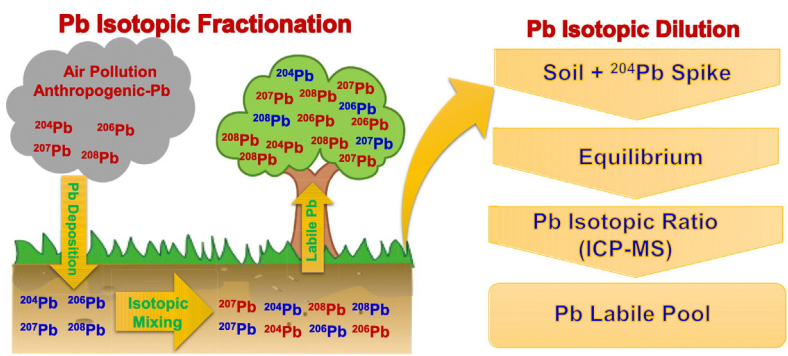
W.H. Shetaya [a,*,1], E.R. Marzouk [b,1], E.F. Mohamed [a], M. Elkassas [b], E.H. Bailey [c], S.D. Young [c]

[a] Air Pollution Department, National Research Centre, 33 El-Bohouth St., Dokki, Giza 12622, Egypt
[b] Division of Soil and Water Sciences, Faculty of Environmental Agricultural Sciences, Arish University, North Sinai 45516, Egypt
[c] Division of Agricultural and Environmental Sciences, School of Biosciences, University of Nottingham, Sutton Bonington, Leicestershire LE12 5RD, UK

HIGHLIGHTS

- Petrol and geogenic-Pb are the main sources of Pb in Egypt.
- Lability of Pb in arid and alkaline soils is low (<25%).
- Petrol/anthropogenic-Pb remains more labile than geogenic-Pb.
- Plants preferentially take up the more labile anthropogenic Pb forms.
- The intake of Pb in urban Egypt is dominated by extraneous foliar Pb dust.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 30 July 2017
Received in revised form 3 November 2017
Accepted 3 November 2017
Available online xxxx

Editor: F.M. Tack

Keywords:
Air pollution
Egypt
Soil Pb
Isotopic dilution
Pb lability
Pb isotopes

ABSTRACT

The current availability of Pb in Egyptian soils and associated plants were studied in 15 locations (n = 159) that had been historically subjected to industrial and automobile Pb emissions. Isotopic dilution with enriched ^{204}Pb was used to estimate the soil Pb labile pool (Pb_E); results showed that $\%Pb_E$ values were mostly <25% which is likely due to the alkaline nature of the soils. Nonetheless, lability of Pb was significantly higher in urban and industrial locations indicating greater reactivity of anthropogenic Pb in comparison to geogenic-Pb. A plot of $^{206}Pb/^{207}Pb$ vs $^{208}Pb/^{207}Pb$ showed that all soils were aligned close to a virtual binary line between two apparent end member signatures (petrol and geogenic-Pb) suggesting that they are the major sources of Pb in the Egyptian environment. Soils with greater Pb concentrations (urban and industrial locations) displayed a significantly greater ratio of labile petrol-Pb to labile geogenic-Pb in comparison to less-contaminated soils. However, this difference was marginal (±5%) suggesting that historically emitted petrol-Pb has substantially mixed with geogenic-Pb into a common pool as a result of prolonged contact with soil. The *proportion* of petrol-Pb in fruits and leaf vegetables was significantly ($P < 0.005$) greater than that of the associated soils suggesting preferential uptake of the more labile petrol-Pb as opposed to the relatively immobile geogenic-Pb. However, it is also possible that the major source of Pb intake by Egyptian consumers is extraneous Pb dust enriched with petrol Pb rather than systematic Pb via roots uptake.

© 2017 Elsevier B.V. All rights reserved.

1. Introduction

Lead (Pb), due to its persistence in the environment (Nriagu, 1996) and its diverse toxic effects on the human body (Needleman and

* Corresponding author.
E-mail address: waleed.shetaya@outlook.com (W.H. Shetaya).
[1] W. H. Shetaya and E. R. Marzouk are co-first authors of this work.

https://doi.org/10.1016/j.scitotenv.2017.11.040
0048-9697/© 2017 Elsevier B.V. All rights reserved.

Bellinger, 1991) is considered one of the major contemporary ecotoxicological threats (WHO, 2010). Anthropogenic activities such as mining and smelting operations, fossil fuel combustion and automobile emissions comprise the major sources of Pb in the environment (Nriagu and Pacyna, 1988). Lead contamination can affect distant environments through attachment to airborne particles and re-deposition (Wang et al., 2010). Once deposited in soil, airborne particles are subject to dissolution, adsorption and saltation processes that affect the extent of incorporation of Pb into crops and transfer to consumers (Salazar et al., 2012).

To accurately estimate the health risks of soil Pb it is useful to determine the lability of Pb which is an indication of its bioavailability and reactivity (Meers et al., 2007). The transformation of deposited anthropogenic Pb in soil has been widely studied since the 1970s (e.g. Teutsch et al., 2001 and references therein). The majority of these studies focus on determining the forms of Pb distributed among different soil-solid phase fractions using sequential extraction procedures (SEP). The objective of an SEP is to audit the various chemical fractions of metal expected to be present in soil, rather than simply discriminate between 'reactive' and 'non-reactive' forms. The inherent limitations of SEPs have been addressed in the past (Martin et al., 1987; Salt et al., 1995; Tack and Verloo, 1995; Young et al., 2005) including the selectivity of the extractants for a given phase and trace metal redistribution during the extraction procedure. By contrast, isotopic dilution (ID) with enriched stable isotopes has been widely used to determine the isotopically exchangeable metal content or '*E*-value' which represents the labile or 'reactive' pool of metal (Young et al., 2000; Gabler et al., 2007). Application of ID techniques involves equilibrating soil-electrolyte suspensions spiked with a small aliquot of an enriched minor isotope. The resulting equilibrium isotopic ratios in the solution phase are then assayed by inductively coupled plasma mass spectrometry (ICP-MS) (Degryse et al., 2009; Huang et al., 2011; Marzouk et al., 2013a). The wider availability of ICP-MS in the last two decades has also enabled source apportionment of Pb based on its isotopic composition (Monna et al., 1997; Chenery et al., 2012; Izquierdo et al., 2012; Mao et al., 2014; Cloquet et al., 2015). Lead is present in the environment as four main stable isotopes, typically: ^{208}Pb (52%), ^{206}Pb (24%), ^{207}Pb (23%) and ^{204}Pb (1%). However, each source of Pb has its own characteristic isotopic ratios (Komárek et al., 2008) and so the isotopic composition of Pb in any environment thus reflects the mixing of these sources and can provide a means of mapping sources and pathways of Pb pollution (Veysseyre et al., 2001).

Egypt is the most populated country in the Middle East and its capital, Cairo, is one of the world's megacities (Safar and Labib, 2010). Greater Cairo (Cairo, Giza and Qalyubia and their urban agglomeration) is home to almost 20 million residents and hosts various industrial complexes that may emit Pb to the surrounding environment (Safar et al., 2014). In the 1980′s and early 1990s the concentrations of Pb in airborne particulate matter in Egypt in general, and Greater Cairo in particular, reached levels well above WHO safety guidelines (Nasralla and Ali, 1984; Ali et al., 1986; Shakour and El-Taieb, 1994; Hassanien and Horvath, 1995; Abdel-Latif, 2001). This was partly due to the numerous Pb-emitting industries scattered around Greater Cairo and the very high levels of Pb used in the commercial petrol used in the city (0.85 g L^{-1}) (Chappell et al., 1997). Environmental protection measures implemented in the mid-1990s, such as phasing out leaded petrol, using liquefied natural gas (LNG) to fuel taxis and buses and relocation of Pb-emitting industries, have resulted in a significant decline in airborne concentration of Pb across Egypt with the exception of areas in the vicinity of Pb-emitting industries (Hassanien et al., 2001; Rizk and Khoder, 2001; Safar and Labib, 2010; Hassan et al., 2013; Safar et al., 2014). Boman et al. (2013), in a study of the correlation of Br and Pb in the fine particulate matter in downtown Cairo, reported that Pb was almost non-existent in Cairo's air.

Surface soils retain Pb strongly, which may pose adverse health effects on the Egyptian population if Pb enters the biogeochemical cycle through plant uptake or leaching to surface and ground waters. Therefore, the main aim of the current work was to determine the source and reactivity of the current soil Pb burden in Egypt and the objectives were to (i) quantify the current lability and bioavailability of anthropogenic Pb (mainly petrol-derived) in Egyptian soils, relative to the native soil geogenic Pb and assess the contribution from the two likely sources to the isotopically exchangeable (labile) soil Pb fraction (ii) determine whether differences in lability were reflected in systemic Pb uptake by vegetables (iii) establish the main source of Pb intake by the urban Egyptian populations i.e. systemic Pb in vegetables or extraneous Pb-dust on leaves and the origin of that Pb in both cases. The findings of this work may also help in understanding the reactivity of Pb in the more arid zones of the world similar to the middle-eastern environment of Egypt (<50 mm rainfall, with calcareous soils) and the soil parameters likely to control Pb lability under these circumstances.

2. Materials and methods

2.1. Soil and plant sampling and characterisation

Soil samples (n = 159) were collected from 15 locations in Egypt that had been subjected to aerial Pb deposition to varying degrees (Fig. 1). Samples were divided into two main groups (A and B) that were collected and processed on two separate occasions (2012 and 2015); plant samples were also collected in 2015 (Table 1). Soil samples were topsoils (0–20 cm depth) and sampled along a transect 0–100 m away from main roads. To obtain a geogenic Pb isotope signature, two additional samples were taken at 80 cm and 120 cm depth from locations RS and SZ, respectively (Fig. 1). These samples were taken by completely excavating the topsoil above the subsoil sample to eliminate any possible contamination with anthropogenic Pb and to ensure an unequivocal assessment of geogenic Pb isotopic signatures.

Soils were collected with a clean stainless steel trowel and sealed in plastic bags for transport. Approximately 250 g of each soil was air dried and sieved (<2 mm) for analysis. Soil pH was measured using a combined glass electrode after equilibrating 5 g of soil in 12.5 mL of Milli-Q water (18.3 MΩ cm) for 30 min. Soil organic carbon content (SOC) was determined (Elementar VarioMax CN analyser) on samples of finely ground soil (agate ball mill, Retsch Model PM400) after acidification with HCl (50% v/v) to remove carbonate. Soil organic matter content (SOM) was estimated by multiplying SOC by the van Bemmelen's factor of 1.72 (Grybos et al., 2007). Available phosphate was extracted and assayed colorimetrically at 880 nm by Olsen's method (Rowell, 1994). The dithionite extraction method of Kostka and Luther (1994) was used to determine reactive iron, aluminium, and manganese hydrous oxides; after reaction samples were centrifuged (20 min at 3000*g*), filtered (<0.22 μm) and supernatant solutions retained for analysis of Fe, Al and Mn by ICP-MS. For determination of total soil Pb (Pb_{soil}), around 0.2 g of finely ground soil (agate ball mill; Retsch, Model PM400) was digested using 2.5 mL hydrofluoric acid (HF; 40% AR), 2 mL HNO_3 (Trace Analysis Grade, TAG), 1.0 mL $HClO_4$ (AR) and 2.5 mL H_2O before analysis by ICP-MS.

For plants, a collection of fruits (strawberry, beans, courgette, hot and sweet pepper, okra, tomatoes and aubergine) and leaf vegetables (parsley, peppermint, arugula, mulukhiyah (Jew's mallow), cabbage, clover and grass) were sampled from some locations (Table 1.). The edible parts for humans and/or farm animals (leaves or fruits) were separated and thoroughly washed with DI water and then dried at 60 °C and finely ground using a Retsch ZM 200 centrifugal mill. Approximately 0.2 g of dried plant samples were digested with 6 mL TAG HNO_3 using microwave assisted digestion for 15 min at 1400 W and total Pb (Pb_{veg}) concentrations were determined by ICP-MS.

2.2. Elemental and isotopic analysis with ICP-MS

Multi-element analysis was undertaken using either a Thermo- Fisher Scientific X-Series^{II} ICP-MS or an iCAP-Q ICP-MS operating in collision

Download English Version:

https://daneshyari.com/en/article/8862085

Download Persian Version:

https://daneshyari.com/article/8862085

Daneshyari.com