ARTICLE IN PRESS

STOTEN-21749; No of Pages 8

Science of the Total Environment xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Science of the Total Environment

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

Refining health risk assessment by incorporating site-specific background concentration and bioaccessibility data of Nickel in soil

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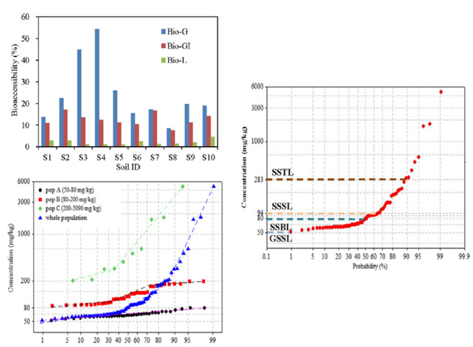
HIGHLIGHTS

- Site-specific background level of Ni was derived using multiple lines of evidence technology
- Site-specific target level of Ni was derived by incorporating site-specific oral and inhalation bioaccessibility data
- Tiered risk assessment incorporating site-specific background and bioaccessiblity data was demonstrated

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 8 October 2016
Received in revised form 5 January 2017
Accepted 5 January 2017
Available online xxxx

Editor: J Jay Gan

Keywords:
Health risk
Background level
Multiple lines of evidence technology
Oral bioaccessibility
Respiratory bioaccessibility

ABSTRACT

Risk assessment of Nickel (Ni) in a brownfield site contaminated was refined by incorporating the site-specific background level (SSBL) derived using multiple lines of evidence technology and bioaccessibility measured by the Unified Bioaccessibility Method (UBM) and Inhalation Bioaccessibility Method (IBM). The results revealed that the SSBL was 80 mg/kg, which was much higher than the general soil screening value (GSSL) (50 mg/kg) and more than two times regional background level reported for Tianjing (33 mg/kg). The average bioaccessibility for the gastric and intestinal phases was 24.2% (8.6%–54.4%) and 12.6% (7.7%–17.1%), respectively. In simulated lung fluid, only 2.1% (1.0%–4.6%) of Ni in the soil particle was bioaccessible. The amount of samples exceeding the acceptable level was reduced by 50% when SSBL, other than GSSL, was used as the screening value. Moreover, the site-specific target level (SSTL) under acceptable risk level was increased from 94 mg/kg to 283 mg/kg when bioaccessibility was considered, and the amount of samples above SSTL was reduced to 10%. The study indicated that incorporating site-specific background levels and bioaccessibility data of contaminants in a given site has the potential to support health risk assessment decisions and can reduce the remediation cost greatly.

1. Introduction

In April 2015, the soil quality bulletin issued by the Ministry of Environmental Protection of China (MEP) in conjunction with the Ministry of Land and Resource of China (MLR) stated that the concentration of

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http://dx.doi.org/10.1016/j.scitotenv.2017.01.036

Please cite this article as: Zhong, M., Jiang, L., Refining health risk assessment by incorporating site-specific background concentration and bioaccessibility data of Nickel in soi..., Sci Total Environ (2017), http://dx.doi.org/10.1016/j.scitotenv.2017.01.036

Nickel (Ni) in 4.8% of soil samples collected during the nation-wide soil quality investigation programme was above the national soil quality standard. Soil incidental ingestion and particle inhalation are considered to be the predominant non-dietary exposure pathways that can result in hazardous effects to human health. When assessing the health risk from exposure to contaminated soil, a tiered approach is always recommended to be followed. The first step is risk screening, and the concentrations of detected compounds are compared to their corresponding general soil screening levels (GSSL) issued by the local or national authorities. For those compounds with concentrations above GSSL, a site-specific quantitative risk assessment will be activated further.

Currently, the considered background values will become the new reference concentrations for risk screening purpose once the GSSL are below the native background values. However, an erroneous conclusion that an area has been contaminated with in-organics might be drawn due to the broad range in concentrations of naturally occurring in-organics. Therefore, recent worldwide investigations dealing with the metal background issue recognized that a site-specific upper background concentration (UBC) should be derived as a significant threshold or screening level to discriminate potential contamination (Chen et al., 1999; Chen et al., 2001; Chirenje et al., 2003; Salminen and Tarvainen, 1997). In addition, it is assumed currently that all heavy metals in the ingested and inhaled soils will be solubilised in the gastrointestinal and respiratory tract and absorbed. However, it is reported that only parts of metals in soil can be desorbed in human gastrointestinal and respiratory tract due to the higher pH in gastrointestinal and lung fluid of human beings than that used in the chemical extraction assay (Boisa et al., 2014; Das et al., 2008; Drysdale et al., 2012; Kang et al., 2016; Li et al., 2015a; Li et al., 2015b; Li et al., 2016; Vasiluk et al., 2011), resulting in an overestimation of the real health risk. Therefore, a consensus is reached among scientists and many environmental management authorities that the bioaccessibility of pollutants in soil, quantified using in-vitro extraction mimicking the dissolution of contaminants in the digestive and respiratory tract, should be considered in determining the actual health risk (Latawiec et al., 2010; Ruby et al., 1999). As to Ni, refining health risk assessment by incorporating its site-specific bioaccessibility data is still conservative enough although correlation between bioaccessibility and bioavailability was rarely reported. The reason is that the bioaccessible fraction is the maximal amount that can be adsorbed by human and that only about 30% of the water soluble Ni salt (nickel nitrate and nickel sulfate) added to drinking water and dosed to voluntary test groups can be adsorbed and the percentage is even lower when the compound was dosed with diet (Sunderman et al., 1989; Templeton et al., 1994).

The site specific background level of Ni in a brownfield site was explored using multiple lines of evidence technology while its oral and respiratory bioaccessibility were investigated using in vitro test methods. The ultimate objective of the paper was to demonstrate how to refine the health risk by incorporating the derived site-specific background level and bioaccessibility data using the current tiered evaluation approach. In addition, its implication on the risk management strategy of the site was also evaluated.

2. Materials and methods

2.1. Site background and sample collection

The study site, covering approximate 120,000 m^2, was located in the Jinnan District, Tianjing (Fig. 1), and industrial activities, including pharmaceutical production and waste recycling, were active within the site since the end of the last century. All production activities ceased by the end of 2010, and the site will be redeveloped as a living district in the future. In 2014, a site investigation and health risk assessment were implemented to verify whether the soil and ground water within the site were clean enough for redevelopment as a living district. Seventy soil samples were collected at different depths from 48 sampling locations (Fig. 1) according to the investigation guidelines issued by MEP (2014a) and MEP (2014b). The hydro-geological investigation results revealed that backfilling, mainly composed of clay and construction waste, was the main component of the soil from the ground surface to approximately 2.5 m, and below this level was silt clay until 10 m below the ground surface.

2.2. Sample preparation and chemical analysis

All of the collected soil samples were air-dried at room temperature; gently crushed to pass through a 2-mm nylon sieve to remove stones, coarse materials, and other debris; and then mixed homogeneously and stored in polyethylene bags. Portions of each sample were further sieved through a 0.25-mm nylon sieve for total metal analysis. In the present study, the total Ni contents in the soil samples were extracted using microwave-assisted digestion (CEM MRAS6, Germany) followed by quantification using ICP-AES (VARIAN 720ES, America).

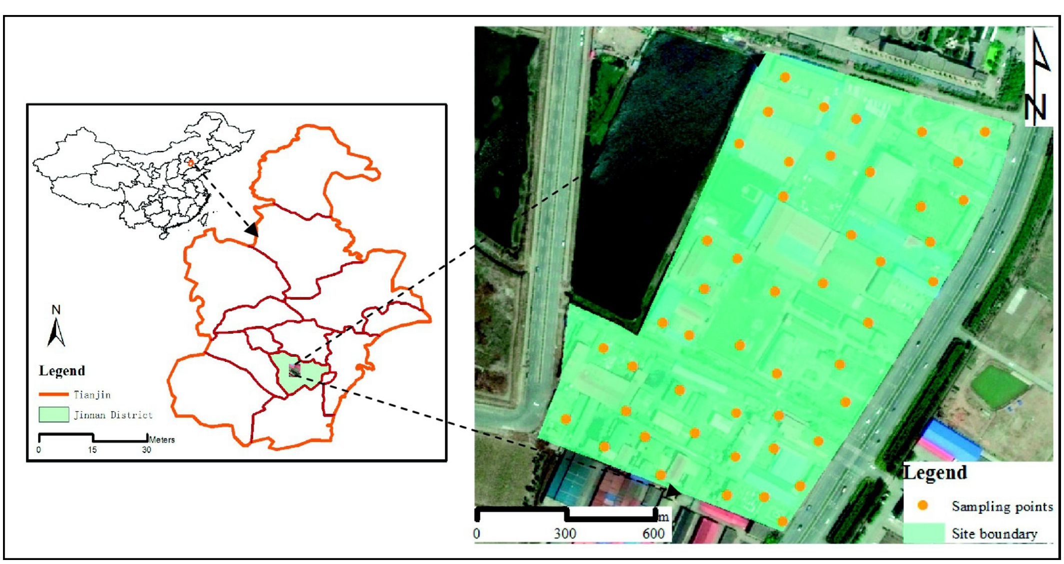

Fig. 1. Site location and layout of sampling points.