Science of the Total Environment 557–558 (2016) 438–444

Contents lists available at ScienceDirect

Science of the Total Environment

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

Arsenic speciation in locally grown rice grains from Hunan Province, China: Spatial distribution and potential health risk

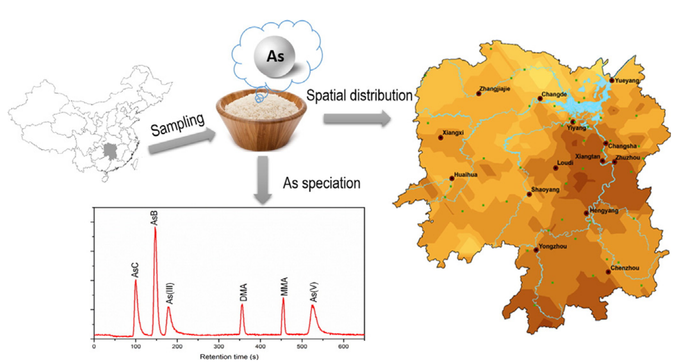
Li Ma [a], Lin Wang [a,*], Yuyu Jia [a], Zhaoguang Yang [a,b,**]

[a] College of Chemistry & Chemical Engineering, Central South University, Changsha 410083, China
[b] Center for Environment and Water Resources, Central South University, Changsha 410083, China

HIGHLIGHTS

- Locally grown rice grain samples were collected from forty counties in Hunan Province.
- As(III) and DMA were significant positive correlated with tAs in rice.
- The percentage of As(III) decreased with the total arsenic concentration in rice.
- Spatial distribution map of tAs in rice was obtained using kriging interpolation.
- Great health risk was suggested to local rice consumers in Hunan Province.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 21 December 2015
Received in revised form 15 February 2016
Accepted 8 March 2016
Available online xxxx

Editor: D. Barcelo

Keywords:
Arsenic speciation
Rice
Hunan Province
Spatial distribution
Estimated daily intake
Health risk assessment

ABSTRACT

Arsenic contaminations have been evaluated in rice grains from Hunan Province, China. Forty-three locally grown rice samples were collected from 40 counties. Arsenic species including As(III), As(V), MMA and DMA were separated and determined by HPLC-ICP-MS method. The mean concentration of total arsenic in rice samples was 129.4 ± 49.2 μg/kg, lower than the Chinese maximum contaminant levels of inorganic arsenic in rice (200 μg/kg). The dominant species detected in rice samples was As(III), following DMA, As(V) and MMA. The Pearson's correlation analysis indicated significant positive relationships between As(III) and total arsenic ($r = 0.939$, $p < 0.01$), and DMA and total arsenic ($r = 0.761$, $p < 0.01$). However, the percentage of As(III) decreased with the total arsenic concentration in rice ($r = -0.515$, $p < 0.01$). Spatial distribution map of total arsenic concentration in rice samples from Hunan Province was obtained using kriging interpolation. High levels of total arsenic in rice grains were observed in south and east regions associated with mining activities and urbanization process. The cancer risk and hazard quotient were employed to estimate the potential human health risk. The results suggested great carcinogenic risk and high potential non-carcinogenic risk to people consuming local rice in Hunan Province.

1. Introduction

Paddy rice (*Oryza sativa L.*) and rice products are produced and consumed in many parts of the world and are the staple food in South and Southeast Asia (Lin et al., 2015; Naito et al., 2015). Compared to other cereals and most terrestrial-based foods, the rice grain is more

* Corresponding author.
** Correspondence to: Z. Yang, College of Chemistry & Chemical Engineering, Central South University, Changsha 410083, China.
E-mail addresses: linwang@csu.edu.cn (L. Wang), zgyang3@gmail.com (Z. Yang).

http://dx.doi.org/10.1016/j.scitotenv.2016.03.051

efficient in accumulating arsenic (As) (Carey et al., 2010). That is because the rice plant cultivated in flooded soil takes up As from irrigated water more easily than other crops (Lomax et al., 2012; Williams et al., 2007; Zhu et al., 2008). Therefore, exposure to As from rice consumption has attracted a lot of attention in recent years (Abedin et al., 2002; Syu et al., 2015). Arsenic considered as one of the most dangerous carcinogens and neurotoxin to human being is also toxic to plants and animals (Kaur et al., 2011; Mandal and Suzuki, 2002). The bioavailability and toxicity of As highly depends upon its chemical forms. The predominant As species in rice are arsenite (As(III)), arsenate (As(V)) and dimethylarsinic acid (DMA) (Nookabkaew et al., 2013; Rahman et al., 2014). Also, other organic arsenic compounds (e.g., monomethylarsonic acid (MMA), arsenobetaine (AsB) and arsenocholine (AsC)) are occasionally detected in some literatures (Lin et al., 2015; Mihucz et al., 2007; Pizarro et al., 2003). Inorganic arsenic (iAs) including As(III) and As(V) is the most toxic form of arsenic regulated as a class 1 non-threshold carcinogen. In contrast, DMA, a metabolite of iAs, is far less genotoxic. However, it plays a role in the carcinogenesis of iAs because of its ability to generate reactive oxygen species (Kenyon and Hughes, 2001).

Arsenic contamination in rice originates from two main sources: natural processes and anthropogenic activities, such as ore mining and

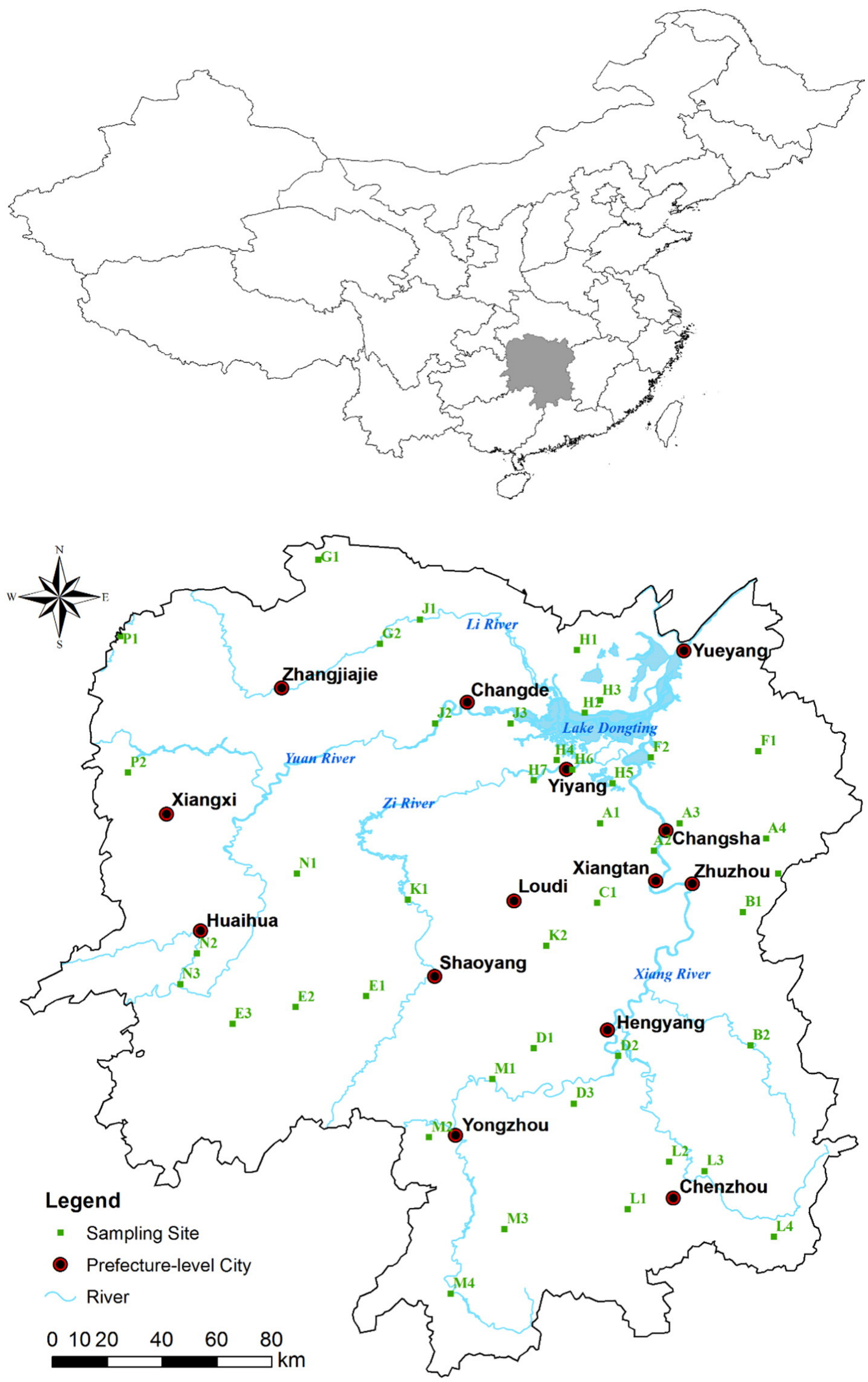


Fig. 1. Distribution of sampling sites in Hunan Province.