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Evaluation of toxicological risk of foodstuffs contaminated with heavy metals in Swat, Pakistan

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ABSTRACT

This study aimed to assess the concentrations of heavy metals such as cadmium (Cd), chromium (Cr), copper (Cu), manganese (Mn), nickel (Ni), lead (Pb) and zinc (Zn) in the available foodstuffs (crops, milk and water), their bioaccumulation in human body and potential human health risks in Swat valley, northern Pakistan. Heavy metal concentrations in foodstuffs and human blood (adults (18-above) and children (1–12 years)) were analyzed using atomic absorption spectrometer. The results revealed high level of Mn in foodstuffs followed by Cr > Cu > Zn > Ni > Cd > Pb, which significantly increased the levels of heavy metals in the adult's blood as compared to that of children in the order of Cr > Zn > Mn > Ni > Pb > Cu > Cd. Principal component analysis showed that selected foodstuffs were the possible sources of metal contamination in human blood, while correlation analysis revealed that the concentrations of Cr, Cu, Mn, Ni, Pb and Zn in foodstuffs significantly correlated with that in human blood. Moreover, risk assessments for individual metals via foodstuffs were found within safe limits, except for Cd (HQ > 1); Whereas, for aggregate multiple metals the risk was calculated as 3.97E+00 (HI > 1), in which water and milk were perceived as the greater contributors (81 percent) to HI; while fruits, grains and vegetables contributed 5 percent each, and pulses 4 percent.

1. Introduction

Pollution of heavy metals such as Cd, Cr, Cu, Mn, Ni, Pb and Zn in foodstuffs including food crops, milk and water is one of the detrimental health issues in the world due to their non-biodegradable and persistent nature (Sekomo et al., 2011; Ali and Malik, 2011; Donaldson et al., 2010). The dietary intake of metals through contaminated foodstuffs is the main route of exposure to heavy metals for human beings, which can cause serious health hazards (Amin et al., 2013; Rahman et al., 2014). Usually, human beings are exposed to metals at trace levels either voluntarily through supplementation or involuntarily through intake of contaminated foodstuffs (Farid et al., 2004). Through food ingestion nutrients and trace metals are assimilated into blood which acts as a transport medium to and from the tissues; and provides rapid and reliable information about the heavy metal metabolism in living body (Pasha et al., 2010). The level of metals in blood depends on the bio-accessibility rate and is considered as an index of biologically active metals in the body reflecting the environmental exposure of a population (Jan et al., 2011).

Heavy metals i.e. Cd, Cr, Ni and Pb are very toxic contaminants, their excessive bioaccumulation can cause profound biochemical changes inside living bodies and produce both chronic and acute health consequences, including kidney dysfunction, polycythemia, bone fracture, respiratory illness, memory deterioration, asthma, heart problems and various kind of cancers (Fischer et al., 2003; Kavcar et al., 2009; Khan et al., 2010; Mijal and Holzman, 2010; Zhao et al., 2012; Er et al., 2013).

Whereas, metals i.e. Cu, Mn and Zn are essentially required for body growth and functions, they may be harmful above certain levels (Huang et al., 2008; Amin et al., 2013; Hu et al., 2013; Rahman et al., 2014). Cu is a redox-active metal and can cycle between its oxidized cupric (Cu^{2+}) and reduced cuprous (Cu^{+})

Abbreviations: ANOVA, analysis of variance; CAS, Chinese Academy of Sciences; CDI, chronic daily intake; HI, hazard index; HQ, hazard quotient; PCA, principle component analysis; RfD, oral reference dose; TWAS, The World Academy of Sciences

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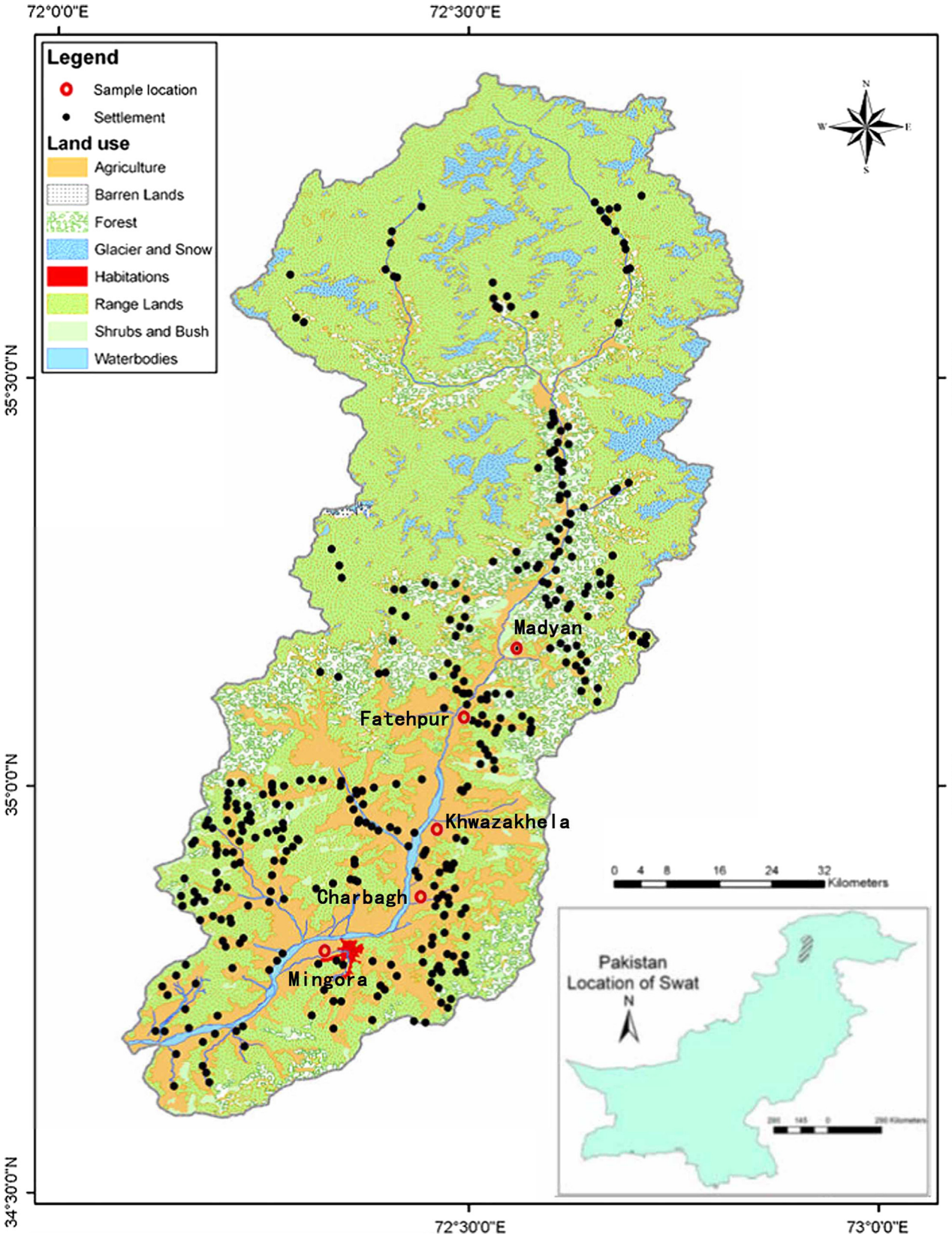

Fig. 1. Location map of the study area showing the sampling sites and different land-use classification in Swat valley, northern, Pakistan.

forms. Its excessive intracellular accumulation can induce growth proliferation, cancer and neurological diseases, while its deficiency can lead to normocytic, hypochromic anemia, leukopenia and neutropenia (Pasha et al., 2010). Similarly, Mn is essentially required as a co-factor for arginase enzyme in liver, pyruvate carboxylase enzyme in gluconeogenesis and astrocyte and glutamine enzymes in brain, but over exposure to Mn can cause permanent neurodegenerative damage (Bocca et al., 2011). While,