Heavy Metals Contamination in a Soil-Rice System: Identification of Spatial Dependence in Relation to Soil Properties of Paddy Fields

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INTRODUCTION

Heavy metals have attracted a great deal of attention worldwide and have been the focus of numerous environmental studies because of their non- biodegradability and persistence in soils. Heavy metal contamination in agriculture lands poses a potential threat to safe crop production in China and worldwide. Therefore heavy metals contamination in agriculture soils and their transfer in a soil-rice system have been of increasing concern.

The overall goals of this study were to quantify heavy metals concentrations and spatial patterns in surface soils as well as their bioavailability to rice plants grown on these soils. The specific objectives were (1) to study the spatial variability of heavy metals of surface soil and rice grains; (2) to investigate the spatial dependence and correlation of heavy metals in the soil and rice; (3) to determine soil factors influencing heavy metal availability for rice.

MATERIALS AND METHODS

This research was carried out in the city of Wenling, which is located in the southeast Zhejiang province, China (Fig. 1). It covers with an area of 926 km^2. The major soil groups in the study area are acrisols, anthrosols, cambisols, lixisols, regosols and solonchaks. Different soil types were grown to aquatic rice, however, anthrosols were the dominant soil type in the landscape. So the term "paddy soil" in this study is related to land use and not to any strict definition of soil in the pedological sense.

At harvest (October 2006), 96 pairs of rice and soil samples at same location were collected from Wenling. Rice in this study was focused on the rice grain. Sample locations was focused in plain rice-production regions; mountainous and downtown areas were avoided (Fig. 1).

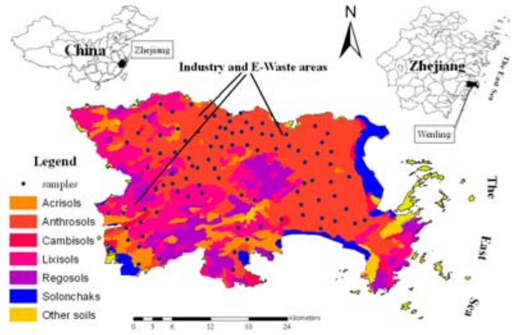

Fig.1. Location of samples and distribution of different soil types in the study area.

Soil properties (including pH, organic matter, electrical conductivity and particle size distribution) and heavy metal concentration (Cd, Cu, Ni, Pb and Zn) were analyzed according to the national standard methods in China.

Geostatistical methods were applied in this study. In geostatistics, semivariogram was used to quantify the spatial variability; Kriging was used for spatial interpolation; The cross-correlogram was applied to determine spatial correlation.

RESULTS AND DISCUSION

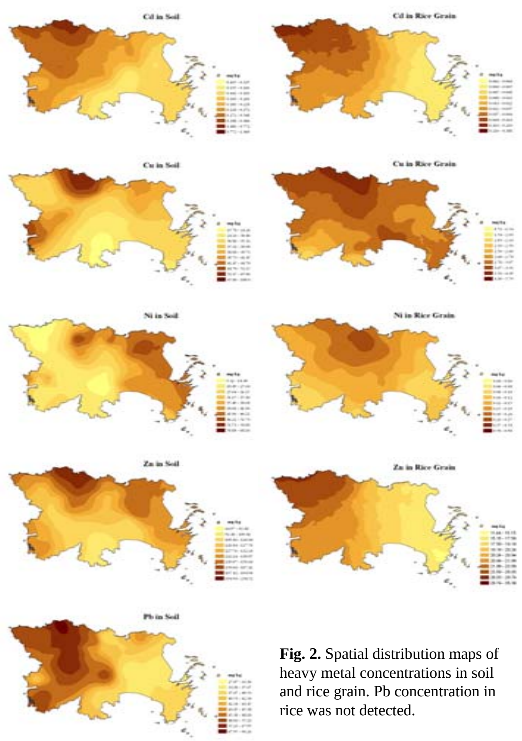

Fig. 2. Spatial distribution maps of heavy metal concentrations in soil and rice grain. Pb concentration in rice was not detected.

Generally, the high concentration for Cd, Cu, Pb and Zn were all located in the north and west of the study area. This may because of numerous industries which are distributed in this region (Fig. 1). This includes machine and electric production, leather and plastic production, dye, among others. Particularly, some small and open specialized E-waste recycling shelters or yards appeared in the north and west areas (Fig. 1). E-wastes contain several heavy metals including Cd, Cu, Pb, Hg and Zn.

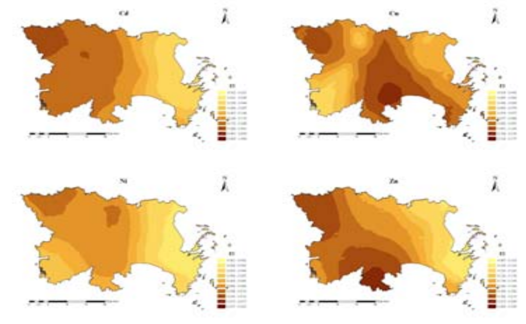

Fig.3. Spatial distribution of the enrichment index (EI) heavy metals between soil and rice

Enrichment index (EI) was determined in this study, which was defined as the metal concentration in rice divided by that in soil.

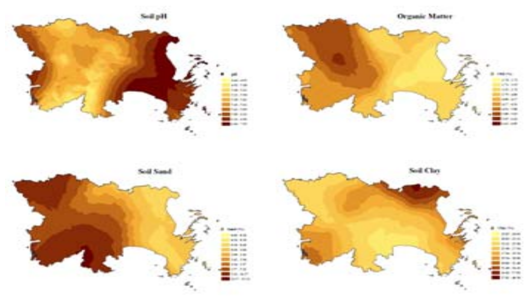

Fig.4. Spatial distribution maps of selected soil properties (soil pH, organic matter, sand and clay content) in the paddy fields

Fig.3 shows that the EI for Cd, Ni and Zn exhibited similar spatial variability and the pattern was that high value decreased from west to east; for Cu, the high value was concentrated in the centre and northwest part of the study area.

Compared to the distribution of soil properties (Fig.4), EI of Cd and Ni (Fig.3) showed similar spatial structure with soil pH and OM; EI of Zn was very similar with soil sand content in structure.

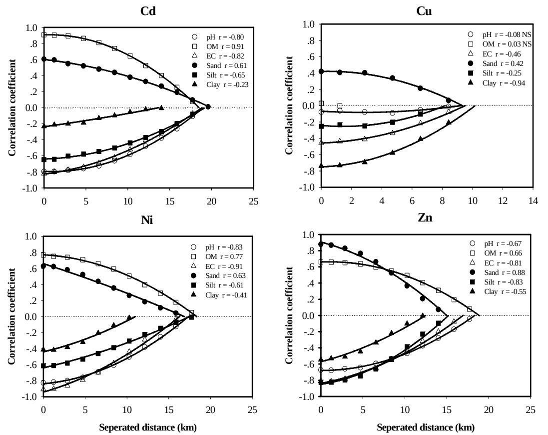

Fig.5. Cross-correlogram for each heavy metal between enrichment index and soil properties. The r values mean the cross-correlogram value at the separated distance zero, which are equal to the Pearson's coefficients. The r were significant at the 0.01level, while NS means not significant.

The EIs of Cd, Ni and Zn were significantly (P<0.01) spatial correlated with all soil properties, especially with pH and OM. However, the cross-correlation for Cu was relatively weaker within the range of 10 km than those for Cd, Cu and Zn within the range up to 20 km. soil pH and OM were not spatially correlated with EI for Cu.

CONCLUSIONS

Due to industrialization and to some extent human activities, heavy metals were accumulated located in the north and west areas.

Soil pH and OM generally had most noticeable interaction on the availability of most heavy metals in rice in paddy fields. Relatively weak effect Soil pH and OM on Cu availability was observed, however.