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Absorption and Accumulation of Heavy Metal Pollutants in Roadside Soil-Plant Systems – A Case Study for Western Inner Mongolia

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1. Introduction

Soil - plant system is the biosphere and pedosphere whose the basic structural unit of soil is the main target. Soil - plant systems enable human productivity but suffer from pollution damage caused by humans. Currently, the annual loadings of harmful metals in soil are (10^4 t / a): Hg 0.83, Cd 2.2, Cr 89.6, Pb 79.6, Ni 32.5, Cu 95.4, Zn 137.1, As 8.1, Se 4.1 [1,2]. Contaminated soil will directly, or by amplifying through the food chain, affect the normal function and growth of plant and even human health. At the same time, the ecosystem, through a series of physical, chemical and biological processes in the environment, provides a purification of pollutants. Beyond the loading capacity of the environmental pollution load capacity and super-threshold, its biological production will be affected, resulting in severe loss of productivity and may even directly or indirectly endanger human life and health. Phytoremediation is considered a green technology for the removal of heavy metal pollution in the ascendant [3]. With the rapid development of the national economy and the subsequent traffic pollution, negative environmental effects are becoming increasingly apparent, especially for roadside soil - plant systems. The the evidence is apparent in Shanxi Province where 5,000 km of roadside farmland was polluted by coal dust, reducing food productivity by 2 800 × 10^4kg [4]. In recent years, car exhaustion and road dust caused heavy metal pollution on the soil-plant systems on both sides of the roads, and consequently, the heavy metal content has brought stress on the structure and function of ecosystem, which increasingly exposed agricultural issues. Currently, research on the domestic and international distribution of heavy metals in soil

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on both sides of the road have been reported [5-10]. At the same time, studies on heavy metal pollution on soil-plant systems on both sides of the road have been carried out [11-17], but only limited studies are conducted on the heavy metal absorption and accumulation on the highway [18]. With the rapid development of the regional economy, the western region of Inner Mongolia produces more coal, building materials, and chemical products, and the rapid increase in traffic and road transport vehicles increased significantly [19]. In 1992, the average traffic in the Inner Mongolia Autonomous Region were 731 vehicles per day. By the end of 2004, the average number of traffic had increased to 5 171 per day, of which 2 533 are State Roads with G109 vehicles / day, G210 are State Roads with 4946 vehicles / day, and G110 are National Roads with 6 739 vehicles / day. With heavy road traffic and associated problems of automobile exhaust emissions becoming more evident, it is necessary to have studies on the accumulation of heavy metals and the potential ecological risk assessment. Therefore, in this study western Inner Mongolia Transport heavy G110 National Road, G210 National Highway and the G109 National Road are selected as study objects, along with highway green vegetable pine (*Pinus tabulaeformis* Carr.) and lobular Yang (*Populus simonii* Carr.) Heavy metal absorption and accumulation and heavy metals in rhizosphere soil and the relationship between distribution and morphology to the road along the soil - plant system bioremediation of heavy metals are investigated to provide theoretical reference.

2. Material and methods

2.1 Material

2.1.1 Characteristics of the study area

According to the study area (106 º 35 '~ 111 º 36'E, 38 º 56' ~ 42 º 28'N) and vegetation characteristics, soil type and parent material conditions, the different sampling points are divided into three types (Figure 1). Specifically: Hohhot - Baotou - Wuyuan - Linhe - Dengkou located Tumochuan and Hetao plains, there it is high underground water level and high salinity, vegetation intrazonal Salt meadow-based, low land vegetation,and zonal soil type is meadow soil, and now most of the land has been opened Cultivated as farmland: Wuhai - Uda - Etuog County - Hangjin County there the vegetation dominated by grassland desertification, desert region in western China is a special area, zonal soil type is brown soil; Dongsheng - Zhunger, Yijinhuoluo - Dongsheng - Dalate located Ordos Plateau in the east, the vegetation's Stipa (*Stipa bungeana*) constructive species of warm temperate typical steppe, but the long-term cultivation, overgrazing, native natural vegetation has been destroyed, therefore, there is only a broken hilly slope, hills, zonal soil type is chestnut soil [20].

2.1.2 Sample collection and processing

The 192 copies of simonii green vegetables' roots, stems, leaves from three loose sides of the road and samples of 384 (2 × 192) copies from the area around the root rhizosphere soil [12] were collected in the western region of Inner Mongolia National Highway G210, G110 and G109 within 20 m on both sides of the plant and soil samples by plum-shaped distribution (Figure 1).

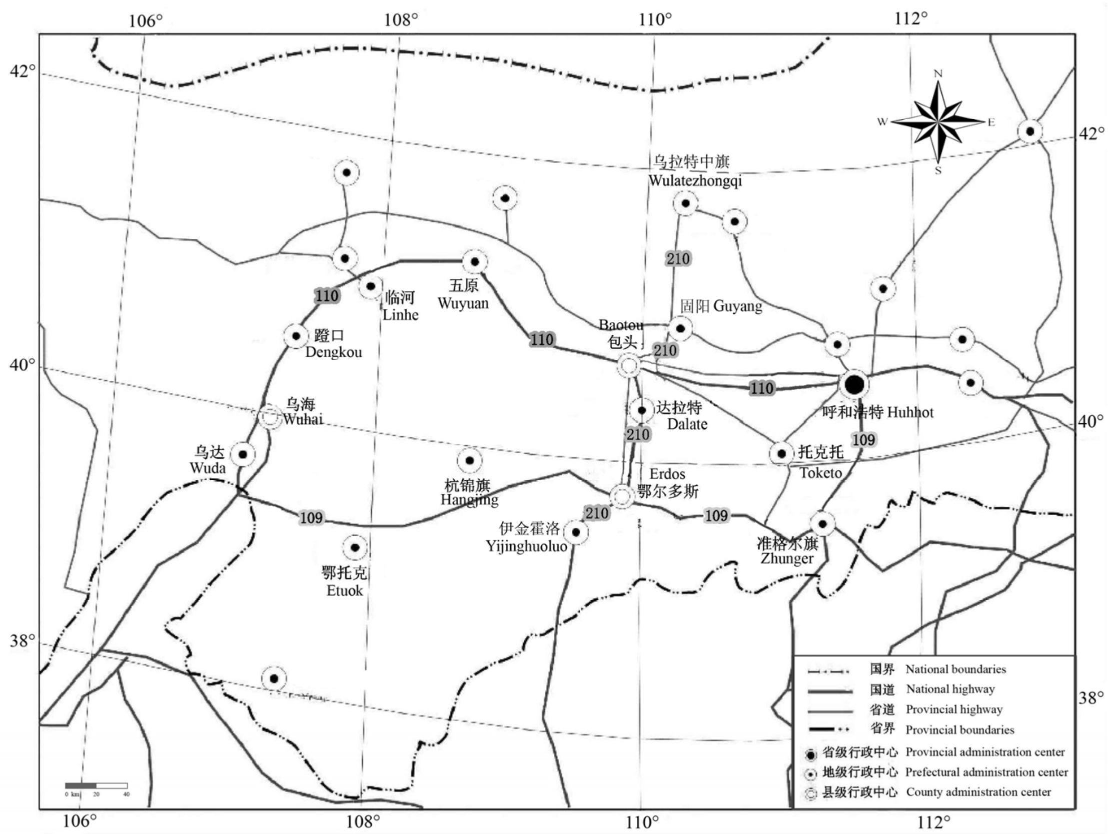

Fig. 1. The map of the sampling station.

And the simultaneous acquisition of the plants as control (CK) is from relatively clean area around the off-road and industrial pollution. Samples of plants was washed with distilled water. Plant roots, stems, leaves and rhizosphere soil samples were naturally air-dried, ground, sieved, bagged, spared, and cold stored [21].

2.1.3 Determination

Plant (roots, stems and leaves mixed sample, and overall) and soil heavy metal content was assessed by using atomic absorption spectrophotometer Spectr AA DUO, AF 610A, atomic fluorescence spectrometer; traces of heavy metals Cd, Pb, Cu, Zn, Ni, Cr were determined by dry ash method, and perform GB/T5009 in Cd, Pb, Cu, Zn, Ni, Cr atomic absorption spectrometry determination in a muffle oven 500°C dry ashing, with 1:1 nitric acid dissolved in 2 ml. The way of metal determination is as follows: the plant samples adopt nitric acid - perchloric acid digestion, atomic fluorescence spectrometry; Hg uses aqua regia digestion, atomic fluorescence spectrometry; Se uses nitric acid - perchloric acid digestion, atomic fluorescence spectrometry; rhizosphere soil of heavy metals Cu, Zn, Pb, Ni and Cr speciation experiment uses synchronized Tessier sequential extraction method [22] for the determination of the specific processes shown in Figure 2. Soil pH measured with pH meter method, the soil and water ratio of 1:1 [21].

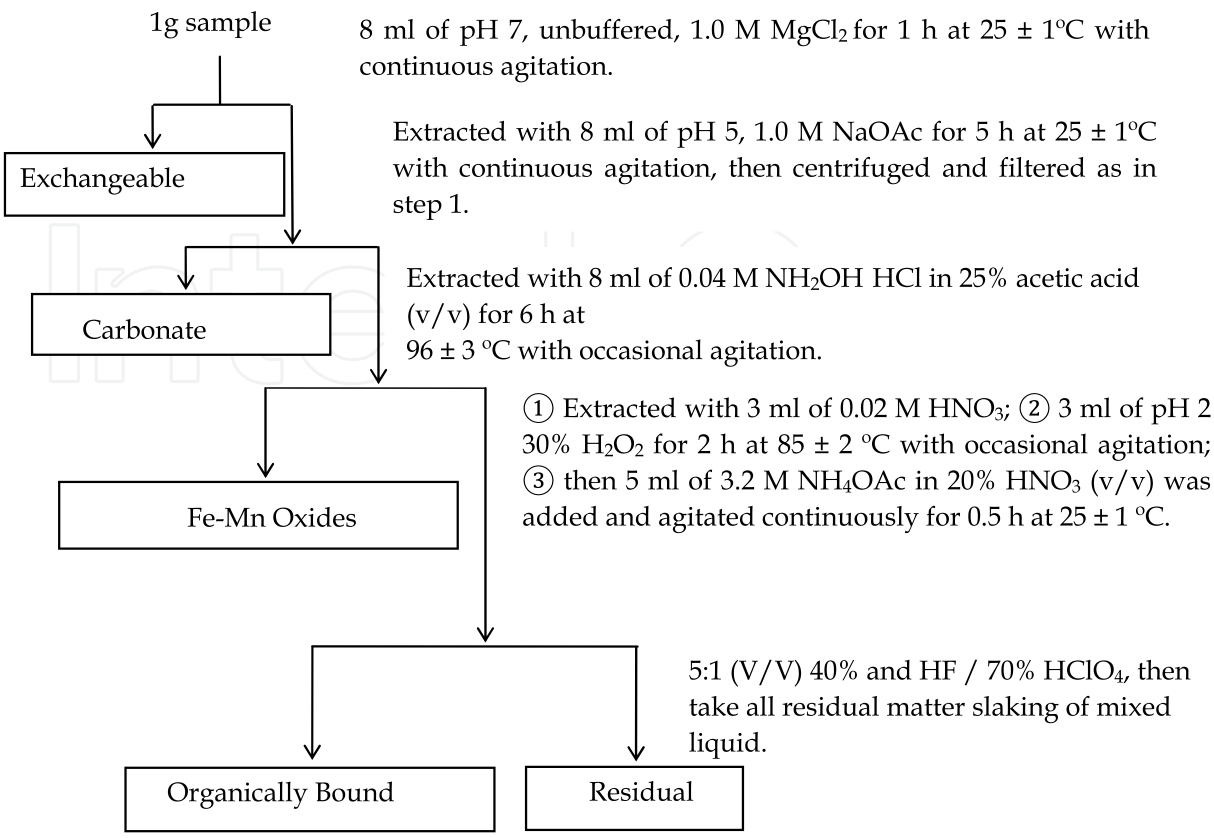

Fig. 2. Sequential extraction procedure for the speciation of heavy metal in sediment.

3. Results and analysis

By comparison among the main green vegetable's mixed samples of roots, stems, leaves in pine and poplar along the highway from the western Inner Mongolia with heavy metals in the background medium value of plants' rhizosphere soil [23, 24] , the heavy metals of Cr, Ni, Cu, As, Pb levels in pine and poplar is below the world soil median chemical composition. Meanwhile, the results display the character, that is, the determination value is less than Chinese soil (A level) element of the background value and is less than Inner Mongolia's background value of soil elements and also less than different soil types in study area (meadow soil, brown soil, and chestnut soil). But Zn content (110.82 mg·kg^{-1}) of poplar is significantly higher than the world median chemical composition of soil (9.0 14 mg·kg^{-1}) and China Soil (A level) element of the background value (74.2 mg·kg^{-1}), as well as Inner Mongolia soil element background values (59.1mg·kg^{-1}). Simultaneity, Zn content of poplar is significantly higher than the study area in different soil types (such as meadow soil (59.10 mg·kg^{-1}), brown soil (56.2 mg·kg^{-1}) and chestnut soil (66.9 mg·kg^{-1}) ; While Zn content of the pine (77.48 mg·kg^{-1}) is close to the Chinese soil (A level) element of the background value, but it is higher than different types of soil meadow in the study area.

Average concentration of heavy metals Zn and Hg in green plants and rhizosphere soil is similar, while other elements shown in the rhizosphere soil are higher than average levels in plants, for example, Cu in the soil content of plant is 1.6 times; The content of Pb and As in the soil is 7 times the plant; Cd, Cr, Ni in the soil are 10 times as in plants. The soil is alkaline in study area where the soil pH is 8.1. Heavy metals in different plants are relevant to soil pH and to the plant's selective absorption of different heavy metals and to the certain speciation of heavy metals in the soil [25]. Delorme *et al* [26] state that the excess accumulation of blue food is a plant containing the rhizosphere of *Thlaspi caerulescens* than *Trifolium pratense* rhizosphere microorganisms, including heavy metals Cd and Zn-resistant bacteria more than is due to lower pH of the rhizosphere.

There are differences in the content of heavy metals in different organs of plants, and this is also reflected in differences between different plants. For lobular, Hg distribution in stems and leaves and roots is more consistent. Cd, Cu, Zn, As and Se content is higher in the leaf stems and leaves than the roots; For pine, Hg content is evenly distributed among the stems, leaves and roots; Pb, Cr, Ni, Cu in the stems and leaves were higher than in the root; Cd, Zn and As were higher than in the roots stems and leaves. This difference displays the direct relationship between the elements in the soil and speciation of metals and the plant's selective absorption of various elements.Generally, contents of heavy metals in different organs at different levels of plants follow the heirarchy of Zn> Cu> Ni, Cr, As, Pb> Cd> Hg.

The same plant in different organs were also exhibit different degrees of heavy metal enrichment in its different organs. the content ratio of the three kinds of heavy metals Cr, Ni and Pb in simonii is greater than 1 but the content ratio of Cu, Zn, As and Cd in the of stems and leaves and roots is less than 1.(roots). while the content of Cr, Ni and Pb in the above-ground parts of simonii (stems and leaves is stronger than that in the underground parts (roots).Meanwhile, the aerial parts (stems and leaves) of Cu, Zn, As and Cd enrichment is weaker than the underground part (root). As previous studies showed, Cu, Zn, Pb, Cd accumulated in the aerial parts of woody plants is greater than the amount seen in underground parts, and the cumulative amount of Mn element is greater than the underground part of the aerial parts [27]. The primary organ to observe heavy metals in plants is the root, and when the presence of heavy metals in air pollution is high, the plant's leaves can also absorb a significant amount of metal [28].

There is a large difference in heavy metals distributed over different species, and absorption and utilization behavior varies over different environments and different plant cell types [29-34]. Exchangeable, carbonate bound, Fe-Mn oxides and organic matter bound heavy metals in plants can be directly or in a certain redox conditions, absorbed and utilized [35-37].

4. Discussion

Along the highway of western Inner Mongolia, studies on the main green vegetable, leaf pine, rhizosphere Yang , heavy metal content, distribution, morphology and soil heavy metal bioavailability draw the following conclusions:

1. The green plants in roadside of heavy metals content for Cr, Ni, Cu, As, Pb is lower than the background value. However, Zn content was significantly higher than background values. Rhizosphere soil of heavy metals adsorption of Cd was the highest.
2. There are some differences in heavy metals perceived in the plant content of different organs of the body, but this is also reflected in the difference exhibited between different plants. With the increasing atomic number (Cr → Pb), two kinds of heavy metals in the roots and stems of poplar and pine have shown "N" shaped changing

tendency. and In addition, heavy metals in different plants and in the different organs have the tendency of Zn> Cu> Ni, Cr, As, Pb> Cd> Hg.

3. The different organs of the same plant have various degrees of enrichments in the different heavy metals. Five kinds of heavy metals' availability phase in the plants' rhizosphere soil are different in the total amount of the percentage in sequence and heavy metals in different organs of the different plants.
4. The study reveals that the plants' absorption and utilization of heavy metal in rhizosphere soil is relevant to the percentage of availability phase, that is to say, the greater the percentage of availability phase is, the bigger enrichment of the heavy metal in the plants appears under a certain environmental condition where plants' transpiration pull and the transportation of water and nutrient shows the equal characteristics along the highway of western Inner Mongolia.

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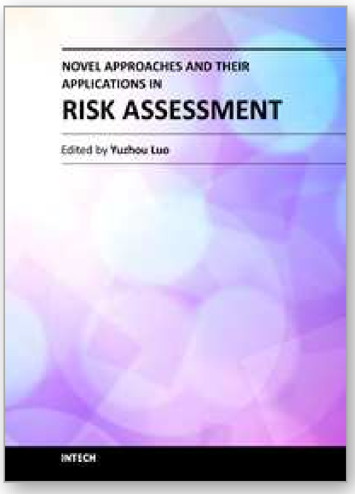

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Risk assessment is a critical component in the evaluation and protection of natural or anthropogenic systems. Conventionally, risk assessment is involved with some essential steps such as the identification of problem, risk evaluation, and assessment review. Other novel approaches are also discussed in the book chapters. This book is compiled to communicate the latest information on risk assessment approaches and their effectiveness. Presented materials cover subjects from environmental quality to human health protection.