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Lead anthropogenic transfer and transformation in China

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Abstract: Information on lead redistribution and speciation changes in anthrosphere can help to analyze the whole lead cycle on the earth. Lead life cycle was traced based on the concepts of anthropogenic transfer and transformation. Lead transfer and the distribution of chemical species throughout the anthropogenic flow were identified in 2010 in China. The results show that 1.85 Mt lead ore was consumed (besides 1.287 Mt imported concentrated ore and 1.39 Mt lead scraps. After undergoing transformations, 3.53 Mt lead entered end services in chemical species of Pb, PbO_2 and $PbSO_4$, altogether accounting for over 80% of the total lead products. Finally, 2.10 Mt ore was emitted into the environment in such species as $PbSO_4$ (26%), PbO (19%) and Pb (15%). Lead transfer begins in primary raw material sectors, and then transfers to manufacturing sectors. Lead provides services mainly in such industrial sectors as transportation, electrical power and buildings or construction.

Key words: lead element; transfer; transformation; anthrosphere; redistribution; industrial sectors; chemical species; life cycle

1 Introduction

Humans have increasingly altered the physical and chemical processes on the earth's surface over the last several centuries. However, it is only within the past several decades that the impact of humans on the earth has begun to widely attract the attention of scientists [1]. Human activities have changed the mobilization and transformation processes of many elements in the nature, including the heavy metals such as lead [2]. Specifically, the scale of anthropogenic lead cycle is much greater than the natural cycle [1]. As anthropogenic activities have increasingly disturbed the earth's natural system, lead anthropogenic transfer and transformation become integral parts of its biogeochemical cycle. As one of the most poisonous metals in human civilization, lead poses great threats to eco-security as well as human health [3]. Therefore, research on lead transfer and transformation is desperately pressing. Currently, many studies have outlined the characteristics of anthropogenic lead cycle by quantifying the flows of lead [4−7]. Those reports have established a foundation for a further study of lead cycle whereas some shortcomings still exist. Studies on transfer and transformation seem to be limited at present. Some studies on lead transfer have mainly focused on the transfer processes occurring in nature, such as the metal transfer in soil-plant system and the mass transfer between different media [8−10], and others focus on toxicology studies [11,12]. Lead transformation studies have been generally limited to the changes caused by technical innovations [13,14] or natural process such as that in the soil [15,16]. Therefore, lead redistribution and speciation after anthropogenic input are not fully understood, and this knowledge is essential to clarify human interference as well as understand the complex processes of pollution formation.

We pay special attention to the anthropogenic lead flow in China in 2010. China has become one of the largest lead producer and consumer all over the world [17]. Additionally, with the booming economy and rising social demands, the scale of lead transfer and transformation in China will continue to increase in future [18]. Therefore, lead cycle in China is a representative case study to examine lead redistribution and speciation change after anthropogenic input.

2 Methodology

2.1 Basic concepts

Practically, the changes such as product features, chemical species or locations [19] occur consistently in

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the anthropogenic lead flow. We will explain some key concepts and give a brief retrospect in the following part because those concepts are not widely understood now.

2.1.1 Anthropogenic transfer

Anthropogenic transfer normally refers to the mobilization and corresponding virtual redistribution of substances in the anthrosphere. They are driven by the social demands and are accomplished under human activities [20]. The natural transfer of pollutants refers to the moving processes of pollutant in the environment, which normally leads to the enrichment, dispersion or disappearance of the pollutants [21]. The differences between the anthropogenic transfer and the natural transfer are as follows: 1) the driving forces behind anthropogenic transfer are social demands other than the natural forces, which motivate the natural transfer; 2) the anthropogenic transfer occurs in the hybrid socio-economic system, although this system is often related to the natural environment.

Anthropogenic transfer can be classified into two categories: transfers in physical space and in virtual space. Physical transfer involves the transfers between different regions or the earth's spheres, i.e., the lithosphere, hydrosphere, atmosphere and anthrosphere. For example, lead is transferred from the lithosphere to the anthrosphere after lead ores are mined from the earth. The virtual space transfer refers to the transfer between different industrial sectors, which are conceptional but essential for knowing lead movement in the whole society. In this work, we will focus on the virtual anthropogenic transfer, regardless of the plentitude of studies on physical transfer [22,23].

In this work, we will focus on the transfer in the virtual space. Based on lead life cycle, lead transfer can be further classified into the transfer at production, fabrication and manufacture (F&M), use and waste management and recycling (WMR) stages. Each transfer at a certain life stage can be further subdivided into different industrial sectors. Also, according to different purposes, lead transfer can be divided into the flow to satisfy production needs, the flow to manufacture product and the flow to meet the demand of humans as a finished product. For example, lead flow from the lithosphere to refining industry belongs to the flow to satisfy production needs.

In the framework (Fig. 1), the detailed acronyms for

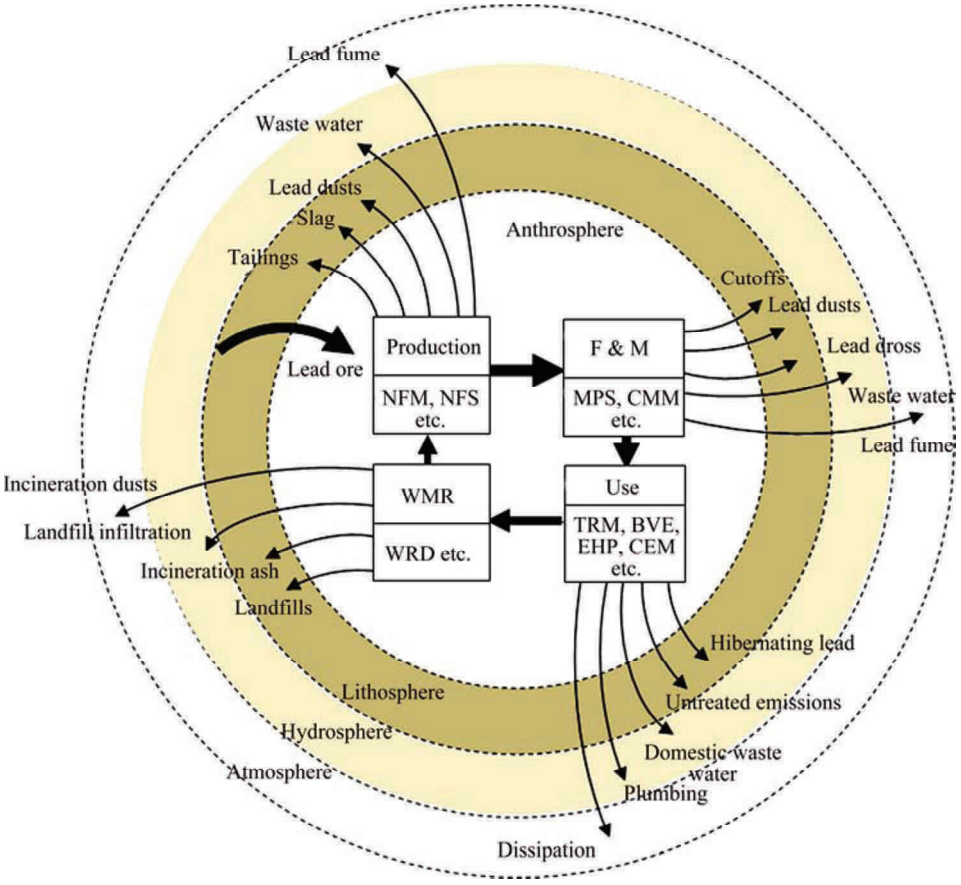

Fig. 1 Schematic diagram of anthropogenic transfer of lead (Acronyms for industrial sectors: NFM—Nonferrous metal mining; NFS—Nonferrous metal smelting; MPs—Metallic products and parts supplement; CMM—Chemical material manufacturing; TRM—Transportation manufacturing; BVE—Building and vihicle engineering; EHP—Electricity and heating power; CEM—Computer and electronics manufacuturing; WRD—Waste resources and discard recycling)