Reference Inventory of $^{210}$Pb in Soils of Chinese Mainland

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Abstract. Naturally occurring fallout $^{210}$Pb is strongly adsorbed by soils and has been widely used as a tracer to soil erosion and deposited sediments in various sedimentary environments. The determination of reference inventory is the premise and basis of soil erosion research using this technique, it is directly related to the accuracy of erosion rate calculation. This paper starting reports from the selection of $^{210}$Pb reference inventory sampling points, the distribution of $^{210}$Pb reference inventory in Chinese mainland is summarized. It is pointed out that the reference inventory is mainly affected by the location of land and sea, climate, topography and other factors.

1. Introduction

In the early 20th century, using of $^{137}$Cs to tracer soil erosion started in the United States, and in recent years it has been widely used in the study of soil erosion and accumulation in many parts of the world. However, $^{137}$Cs is not a tracer nuclide that exists in nature. It is an artificial radionuclide produced by nuclear tests or nuclear leakage in the 1950s and 1970s. The inventory of $^{137}$Cs in the soil decreased with the development of time, and the difficulty of testing continued to increase. And the low $^{137}$Cs inventory in the southern hemisphere makes testing more difficult. The nuclear elements that can trace the rate of soil erosion in the medium and long term will be gradually replaced by $^{210}$Pb [1-7].

$^{210}$Pb is a natural product of $^{238}$U decay series with a half-life of 22.26 years, and its parent $^{222}$Rn is an inert gas. The $^{210}$Pb that settle through the atmosphere and are absorbed by soil particles are often referred to as "non-carrier sources". $^{210}$Pb$_{ex}$ and $^{137}$Cs are both environmental radionuclides, and the tracer principle is very similar. The tracer method is as follows: by comparing the inventory of $^{210}$Pb$_{ex}$ at the sampling point with the inventory of nearby undisturbed or fixed reference inventory, the percentage of decrease and increase of $^{210}$Pb$_{ex}$ at each point is obtained. The reduced sample points indicate the occurrence of soil erosion, and the increased sample points indicate the occurrence of soil deposition, Then the percentage decrease or increase of $^{210}$Pb$_{ex}$ is converted into soil erosion or deposition through quantitative model [8].

The precondition of applying $^{210}$Pb$_{ex}$ technology to soil erosion research is to determine the $^{210}$Pb$_{ex}$ reference inventory of the research area scientifically and accurately. The reference inventory of $^{210}$Pb$_{ex}$ can be defined as the atmospheric deposition flux of $^{210}$Pb$_{ex}$ per unit area or the area concentration of $^{210}$Pb$_{ex}$ of undisturbed soil in a certain area. Based on the existing literature in China, this study combed the data of $^{210}$Pb$_{ex}$ background value in the soil. To explore the reference inventory and distribution characteristics of $^{210}$Pb$_{ex}$ in soils of mainland.
2. Selection of Reference Inventory Sample Points
The location of the reference inventory is the key to success. The ideal reference inventory area is one with neither soil loss nor soil deposition. The total merely reflects the decay of radionuclides directly fed into the atmosphere over time. The reference inventory selects an area with flat terrain and long-term vegetation coverage. In general, choose flat grass and low grass near the sampling point. An average of a certain number of sample points is usually required to represent the reference inventory of 210Pbex well [8].

The 210Pbex in the soil comes from atmospheric deposition, and the atmospheric deposition of 210Pb in a specific area is mainly related to precipitation. Therefore, there are seasonal differences, but the annual settling flux of 210Pb is relatively consistent over a long period [9-10]. Assuming that 210Pb deposited from atmosphere are retained in the topsoil, only by radioactive decay. Therefore, by collecting rainwater samples to measure the atmospheric settling flux, we can also calculate the amount of 210Pbex in the stable soil, as the reference inventory.

3. Spatial Distribution of 210Pb Reference Inventory in Chinese Mainland

3.1. Horizontal Distribution
Using 210Pb to tracer study conducted by Zhang Xinbao et al. found that the reference inventory of 210Pb on the Loess Plateau is 5730Bq/m². In Chinese mainland, the reference inventory increases from northwest to southeast. The high inventory area is concentrated in Yingtan of Jiangxi and Zhenjiang of Jiangsu, the lower values are in the Qinghai-Tibet Plateau and the Loess Plateau. On the one hand, it is consistent with the variation trend of precipitation in mainland China. On the other hand, it also accords with the trend that the deposition flux of 210Pb increases from west to east on land [11].

The data from the study in Yingtan, Jiangxi province, showed that were larger. The author explains several reasons: (1) Discard some samples during the pretreatment before sample testing, however, most of these samples are coarse particles with low bonding degree, leading to high test value; (2) There are errors in the process of reading test data; (3) The activity of standard source used in experimental measurement is high; (4) During the measurement, marin cup is used to fill the soil so that the center of gravity of the test sample is higher, which affects the detection efficiency.

3.2. Vertical Distribution
He and Walling et al. (1997) showed of profiles of some permanent meadows in the UK. The 210Pb profile distribution depth is above 15cm, the concentration of 210Pb decreases as the depth increases [10]. Zhang X B et al. also found in the Loess Plateau that the nuclide concentration in the upper part of the soil profile was the highest and decreased exponentially downward [7]. In the loess plateau region of China, the 210Pb deposit depth in the loess grassland soil profile is 24 cm, there is an exponential decrease from surface to depth. Data from Jiangsu and Jiangxi provinces in China suggest the same.

4. The Main Factors Influencing the Distribution of 210Pb Reference Inventory in Chinese Mainland

4.1. Location of the Land and Sea
It is believed that the annual deposition flux of 210Pb is less because the land-borne 210Pb is carried over the ocean only by air mass movement, to some extent, the 210Pb deposition increases from west to east on a continent, the reference inventory of 210Pb in terrestrial soils increased from west to east. As shown in table 1, Jiangsu and Jiangxi province, which are located in the eastern part of Chinese mainland, have a high 210Pb reference inventory. The westernmost Qinghai-Tibet Plateau and the Three-Rivers Headwaters region are the lowest.
Table 1. Reference inventory of $^{210}$Pb in parts of Chinese mainland.

| Study area                              | Reference inventory (Bq m$^{-2}$) | Mean annual precipitation (mm) | Researcher       |
|-----------------------------------------|-----------------------------------|--------------------------------|------------------|
| Zhenjiang, Jiangsu Province             | 29068.26                          | 1006                           | Wang [12]        |
| The Three-Rivers Headwaters region      | 2612-7377                         | 86-786                         | Li et al. [2]    |
| Xilin Gol League, Inner Mongolia        | 8112                              | 365                            | Hu et al. [1]    |
| Northeast Qinghai-Tibet Plateau         | 4617.76                           | 300-580                        | Hu [13]          |
| Kunming, Yunnan Province                | 21207.94                          | 785                            | Duan [14]        |
| Yingtian, Jiangxi Province              | 44383.83                          | 1842                           | Cui [15]         |
| Jianyang, Sichuan Province              | 12589.9                           | 850                            | Zhang et al. [4] |
| Neijiang, Sichuan Province              | 18902.2                           | 1064                           | Zhen et al. [6]  |
| Keshan, Heilongjiang Province           | 6600                              | 499                            | Wang [16]        |
| Zhaogou, Loess Plateau                  | 5730                              | 517                            | Zhang et al. [7] |
| Changchun, Jilin Province               | 8950                              | 642                            | Yang [5]         |

4.2. Climatic Factor

After several years of precipitation in the atmosphere, $^{210}$Pb reached the surface and reached equilibrium in the soil. Since the $^{210}$Pb inventory in soil is derived from atmospheric wet deposition and dry deposition, the dry deposition in each region is settled into the soil by the movement of atmospheric circulation. Assuming that the amount of $^{210}$Pb reaching the ground through dry deposition is the same everywhere. The variation of $^{210}$Pb reference inventory in the soil is mainly determined by the wet precipitation, namely the annual average precipitation. Chen et al. found that $^{210}$Pb atmospheric deposition flux is mainly related to precipitation. Its expression is: $y=16.598xe^{0.0019x}$. This indicates that atmospheric wet deposition is one of the main factors affecting the $^{210}$Pb reference inventory in the soil.

In the measured data of $^{210}$Pb reference inventory in Chinese mainland, the highest reference inventory is 44383.83Bq/m$^2$ in Jiangxi province, and the annual rainfall of 1842mm is also the maximum value of all measured sites. The Three-Rivers Headwaters region and the Qinghai-Tibet Plateau region have the lowest rainfall and lowest background values.

In addition, the $^{210}$Pb reference inventory is also related to rainfall type, topography, soil characteristics and other factors. In a specific region, the $^{210}$Pb reference inventory is a combination of many influencing factors, the influence degree of each factor needs to be further studied.

5. Conclusions

The spatial distribution of $^{210}$Pb reference inventory is unbalanced in Chinese mainland, appearance from west to east and from north to south gradually increased. There is an exponential decrease from surface to depth in the soil profile. The size of $^{210}$Pb reference inventory is affected by the location of land and sea, climate and so on.

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