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The absorption and accumulation of mercury by forests

Jian Li

[1]Shaanxi Provincial Land Engineering Construction Group Co., Ltd., China

[2]Institute of Land Engineering and Technology, Shaanxi Provincial Land Engineering Construction Group Co., Ltd., China

[3]Key Laboratory of Degraded and Unused Land Consolidation Engineering, The Ministry of Natural Resources, China

[4]Shaanxi Provincial Land Consolidation Engineering Technology Research Center, China

[5]Land Engineering Technology Innovation Center, Ministry of Natural Resources., China

Abstract

Mercury is extremely toxic and can be transported through the atmosphere for long distances in a gaseous form. It is designated as a global pollutant and has long attracted great attention from the international community and academia. As the largest terrestrial ecosystem, forest ecosystems are one of the most active regions in the global biogeochemical cycle. This article includes three aspects including the absorption and release of mercury by vegetation, the migration and transformation of mercury in litter, and the accumulation process of mercury in forest soils. Etc., introduced the important role that forest ecosystems play in the atmospheric transport and transformation of mercury.

Keywords

Mercury; Forest Soil; Litter.

1. Introduction

Mercury (Hg) is a global pollutant that travels through the atmosphere over long distances and across borders in the environment [1]. Mercury is extremely toxic and can accumulate in organisms along the food chain. Because of its special physical and chemical properties, mercury can exist in the atmosphere in a gaseous form.

The biogeochemical cycle of forests is very active, which is very important for the transmission and transformation of atmospheric mercury. However, at present, whether forests play the role of "sink" or "source" in the biogeochemical cycle of mercury in terrestrial ecosystems has not yet been determined. In early studies, forests are used as mercury sources to emit to the atmosphere through plant leaf surface transpiration [2-3]. At the same time, the estimation results in some studies indicate that the mercury released by forests has a great impact on regional or global mercury, accounting for 75% of natural source emissions from all terrestrial ecosystems [4-7], and some studies indicate that leaves The absorbed mercury is stored in itself, and the mercury accumulated on the surface with the fall process and dry and wet precipitation, that is, the absorption capacity of the forest to atmospheric mercury is far underestimated [8-9].

2. The absorption and release of mercury by forest vegetation

Mercury in the atmosphere enters the forest mainly through dry and wet deposition (RGM and PBM) and absorption by plants (mostly Hg^0), and the absorption of mercury by forest plants from the environment usually includes the following: Absorb mercury in the soil. The mercury

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absorbed by plants through roots is limited [10]. Mercury will combine with humic acid and organic matter in the soil to form inert compounds, which inhibits the migration and transformation of mercury [11]. The mercury absorbed by plants from the soil through roots is due to various The barrier mechanism between the tissues is difficult to move upwards, but stays in the roots of the plants. When the retention reaches saturation, it will limit the roots' absorption of mercury in the soil [12]. ② Plants use respiration to absorb mercury in the environment through the stomata on the leaf surface. ③ Plant leaves adsorb and fix atmospheric dry and wet precipitation Hg^0, Hg^{2+} and particulate mercury. It is now generally accepted that mercury in plants is mainly absorbed from the atmosphere. Plant leaves absorb mercury into the body through respiration, and use the adsorption capacity of the plant leaf surface to store mercury in the leaves. Some studies have done indoor control experiments using plant growth boxes that can control environmental factors, and the results show that the mercury in plant leaves almost entirely comes from the atmosphere [13-16]. The absorption of atmospheric mercury by plant leaves is not one-way, but a two-way exchange process. Plant stomata and leaf epidermis can exchange gaseous elemental mercury (Hg^0) with the atmospheric interface [17-19]. When Hg^{2+} in the air settles on the leaf surface, part of it will be absorbed by plant leaves, and the other part will be retained by the forest canopy. It turns into elemental mercury and returns to the atmosphere [9,20]. The transpiration of plants will transfer part of the mercury in the interstitial water of the soil to the leaves, and directly release to the atmosphere in the form of Hg^0, and the other part of Hg^{2+} will pass through It is reduced and discharged into the atmosphere [21].

Different parts of plants have different absorption capacities for mercury, and plant species, plant characteristics, and mercury content in the soil environment and atmospheric environment will also affect the plant's ability to absorb mercury. The limitation of mercury migration in plants and the difference in the absorption of mercury by different parts of plants make the distribution of mercury in plants not uniform. The mercury released by plants is mainly transmitted through the transpiration of the surface of the plant leaves, the natural death of plants or being cut and burned, and the food chain between organisms. Studies have found that the global mercury released by forest vegetation contributes a lot to atmospheric mercury, about 850-2000t/a[2]. Hanson et al. used a mercury flux box to study the mercury release flux from bark of different tree species. The results showed that the bark's low mercury release flux to the atmosphere is not enough to be regarded as the main source of mercury release. 10% of the total mercury release flux, the release of mercury from plant leaves is the main way for plants to release mercury [22]. The mercury content in plants is directly related to the mercury in the atmospheric environment. If the mercury content in the environment is high, the mercury will accumulate in the plants in a large amount, and the mercury in the plants will also be higher. At the same time, it is undesirable The environment will increase the absorption of mercury by plants [23-24]. Plant leaves show that the absorption and release of mercury is a dynamic process with changes in environmental factors. Studies have shown that there is a mercury exchange compensation point between plants and the atmosphere. When the atmospheric mercury concentration is higher than the compensation point, mercury accumulates in the plant; when the atmospheric mercury concentration is lower than the compensation point, the mercury changes to emissions[13 ,25]. Research by Yang Xuechun and Mou Shusen in Chongqing found that acid deposition also affects the absorption of mercury by plants. Acid deposition can make the cell membrane of plant leaves more permeable, making it easier for mercury to enter the plant body, thereby promoting the absorption of mercury by plant leaves. Natural plant apoptosis and man-made felling and burning will also cause plants to release large amounts of mercury. After the plant dies, the plant body is gradually decomposed by microorganisms, which will convert the mercury in the plant body into various forms and enter the nature. Some will enter the forest soil, and some will directly enter the air.

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If plants are burned, the mercury stored in their internal storage will be almost completely released into the atmosphere[26]. According to a study of forest fires, foreign scholars have estimated that the global contribution of atmospheric mercury to forest fires is about 800t/a. Domestic research by Ouyang Kam found that mercury stored in plants will migrate along the food chain, and even eventually enter the human body, causing harm to human health.

3. Migration and transformation of mercury in forest litter

Litter is a key part of the material flow and energy cycle of the forest ecosystem, and its decomposition process is very important for the nutrient cycle of the forest ecosystem. Litter has a unique ecological function. It maintains the fertility of the soil and provides nutrients for plants during the growth process, forming a material cycle between organisms and the soil. The decomposition rate of litter will have a direct impact on forest biomass, soil nutrient content and soil physical and chemical properties. With the decomposition process of litter, its energy and nutrients are input into forest soil, which is also the main source of energy and material for animals and microorganisms in forest soil. Most of the atmospheric mercury deposition is retained in the forest canopy and absorbed by plant leaves rather than roots, while part of the mercury absorbed by vegetation leaves is released into the atmosphere, and part is stored in the leaves and retained in the leaf tissue. Mercury will eventually reach the surface as the leaves senesce and fall. Plant leaves will undergo photosynthesis when they grow on the tree. The organic matter produced by photosynthesis will decompose into the forest soil as the leaves fall. Therefore, the decomposition process of litter will provide a large amount of required elements for forest soil, and the decomposition process of litter The changes in organic matter such as carbon and nitrogen will also reflect the use of organic matter by soil and forest vegetation. As the litter decomposes, heavy metal elements including mercury will be released and re-absorbed by the litter and the soil. Therefore, mercury in the litter will have a gradual accumulation effect during the decomposition process.

As the decomposer and regulator of forest material, a large number of microorganisms in litter are very important for the control of forest nutrient cycle. Under the action of microorganisms, Hg^{2+} in the litter will combine with various inorganic ligands such as CN^-, OH^-, Cl^-, and S^{2-} to form stable compounds. Studies have found that microorganisms contribute to the diffusion of mercury into the atmosphere, and several different forms of organic mercury, such as methylmercury and ethylmercury, which are more biologically toxic, can be converted into each other. Because in the forest ecosystem, it is temporarily impossible to directly measure the dry deposition of mercury, but the mercury accumulated in the litter formed by leaf senescence can reflect the net flux of mercury in the exchange process between the atmosphere and plant leaves, so there is research The mercury deposition flux of litter and the difference of mercury wet deposition are used to replace the dry deposition of mercury in forest ecosystems [9,27]. Wang Xun established a model to estimate the dry precipitation of mercury on a global scale. The results show that the dry precipitation of mercury accounts for 75%-80% of the total precipitation, which is the most important method of atmospheric mercury deposition in the forest system [28], of which approximately 75% comes from the contribution of litter mercury deposition. Therefore, mercury deposition in litter is very important for forest ecosystems. According to the comparison of the estimation results of the establishment of a global model, due to the high atmospheric mercury background value and litter biomass in China, the litter mercury deposition in China's forests is higher than that in Europe and America, especially in China's subtropical evergreen broad-leaved forests. Mercury sedimentation reached 220μg·m^{-2}·yr^{-1} [29-32]. Research on evergreen broad-leaved forests in Ailao Mountain, Yunnan, China shows that the correlation between litter mercury flux and litter biomass is significantly higher than the correlation with litter mercury concentration, and the seasonality of litter mercury

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deposition flux The change characteristics are consistent with the characteristics of litter biological flux [33].

4. Accumulation process of mercury in forest soil

Mercury at the soil-atmosphere interface is also bidirectional, and the mercury in the soil undergoes a process of redox and absorption and desorption. On the one hand, Hg^{2+} in the soil can be reduced to form elemental mercury through light, microbial action and organic matter. On the other hand, elemental mercury will also be complexed and oxidized by the reducing sulfur groups of the organic matter in the soil [34-37]. In addition, the adsorption and desorption process of elemental mercury in the soil will also affect the mercury emission from the soil to the atmosphere. The mercury in the soil surface mainly comes from atmospheric deposition, that is, through rain and litter mercury deposition. Since litter mercury deposition is the main forest mercury deposition, the size of soil mercury is also directly affected by litter mercury deposition. Studies have shown that in areas where the flux of litter mercury deposition is high, soil mercury sinks will also be significantly higher [38]. Therefore, many scholars at home and abroad want to track the dynamic changes of mercury in litter to understand mercury in soil. The accumulation process. According to experimental studies, there is a significant loss of mercury in the initial stage of litter decomposition[33, 39], which may be related to the process of carbon mineralization and the hydrophilic compounds formed during the decomposition of litter mercury. As a result, mercury will accumulate in the remaining litter. At present, it is not clear how mercury accumulates in the degradation process of litter. Some scholars believe that there are enough mercury binding sites in plant leaves before litter fall. , So that mercury can be adsorbed during the degradation process [40], and some people believe that the carbon in the litter will fix the mercury in the original litter during the process of mineralization, and as the litter degrades , Some organic functional groups can continue to absorb mercury from the external environment [41-44]. Studies in the subtropical evergreen broad-leaved forests in Yunnan of China have shown that the loss and absorption of mercury in the decomposition process of litter are all related to the binding forms of O/N and reducing sulfur organic functional groups [33].

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