Current status, causes and harm of soil arsenic pollution

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Abstract. Soil arsenic pollution is a global problem that seriously threatens human health and environmental safety. Excessive arsenic content in the soil will inhibit the growth and development of plants, kill beneficial microorganisms in the soil, and damage human health after entering the human body through the food chain. This article describes the current status of soil arsenic pollution, the sources of arsenic pollutants, and the hazards of arsenic pollution to plants, microorganisms and human health. And the prospects for the treatment of arsenic pollution were prospected.

1. Introduction

Arsenic is an important non-metal element, and its content in the earth's crust is about 2~5mg/kg. With the development of science and technology, arsenic is widely used in human daily production and life due to its unique properties, such as alloy additives, doping elements in the semiconductor industry, and used in the manufacture of preservatives and pesticides due to its toxicity. With the increase in demand for arsenic, the scale of mining, smelting and processing, and trade of arsenic-containing minerals is increasing day by day. In the process of mining, processing and utilization of arsenic-containing compounds, a part of arsenic inevitably enters the surrounding environment, causing environmental pollution and endangering human health.

2. Current status of soil arsenic pollution

At present, many countries in the world have serious arsenic pollution problems. The area of cultivated land polluted by heavy metals such as cadmium, arsenic and lead in China is about 2.0×10^7 hm² [1]. The average arsenic content in soil in China is 11.2 mg·kg⁻¹, which is about twice the world average (6 mg·kg⁻¹) [2]. The soil arsenic content is distributed in a north-south direction. The soil arsenic content in higher altitude areas is higher than that at lower altitudes. It decreases from the Qinghai-Tibet Plateau, southwestern, and southern China to the northeast, and there is geochemistry between the eroded materials upstream contact. And the content of arsenic in the soil also has a distribution characteristic from high to low as the topography goes from high to low [3,4]. According to reports, 70% of the global proven reserves of arsenic resources are concentrated in China. China produces 500,000 tons of arsenic slag per year, and 2 million tons of arsenic slag has been hoarded [5]. However, the harmless treatment
and comprehensive utilization rate of arsenic slag is low and the idle and arbitrary stacking of arsenic-containing tailings ponds speeds up the release of arsenic into the soil. Therefore, the problem of soil arsenic pollution is particularly prominent in areas with intensive mining and smelting activities. The content of arsenic in the tailings of the Hatu gold mine in Karamay, Xinjiang is as high as 1100 mg·kg$^{-1}$, and the content of arsenic in the tailings of the Axi gold mine in Ili Kazak Autonomous Prefecture is above 1,000 mg·kg$^{-1}$, posing a serious threat to the local soil and groundwater [6]. At the Tieshiping arsenic refining site in Zhaigang Town, Liannan County, Guangdong Province, after the production was stopped in the late 1980s, 21.47 million tons of waste residue and tailings containing arsenic were stockpiled, covering an area of 1128 hm$^2$ [7]. The soil contaminated by arsenic in Guangxi and Hunan provinces is more than 100 km$^2$ [8]. The content of arsenic in agricultural soil near the mining area, smelting area and tailings area in Hunan is 14.95-363.19 mg·kg$^{-1}$, which is much higher than the background value of arsenic in Hunan soil [9].

There are also serious arsenic pollution problems abroad. According to the report [10], the average content of arsenic in soil in European topsoil is about 7.0 mg·kg$^{-1}$. In Województwo dolnośląskie province in southwestern Poland, where is rich in gold deposits, the arsenic content of the soil is as high as 18100 mg·kg$^{-1}$. The soil arsenic content in Minas Gerais, Brazil is 200-860 mg·kg$^{-1}$. The soil arsenic content in Esquina, Chile is 489 mg·kg$^{-1}$, and the soil arsenic content in Uttar Pradesh, India is 16-417 mg·kg$^{-1}$. The soil arsenic content is 2215-2675 mg·kg$^{-1}$ in the Lagunella region of Mexico. The soil arsenic content is 23 mg·kg$^{-1}$ in the Cenozoic Basin of the Douro River, Spain. The soil arsenic content of Simaf Plain in Turkey is 660 mg·kg$^{-1}$. According to the latest soil pollution survey report of the Japanese Ministry of Environment, among the 1,906 contaminated sites in Japan, arsenic contaminated sites accounted for 27%. In the Mississippi River Basin, more than half of the areas are in high-risk areas for arsenic pollution. There are more than 10,000 soil arsenic contaminated sites in Australia, among which the arsenic content in the soil of a village near a gold mine is as high as 9900 mg·kg$^{-1}$ [11].

3. Sources of arsenic contamination

The formation of arsenic pollution must be conditional on the abnormal distribution of arsenic. There are many kinds of arsenic compounds and their applications are extremely wide. Under the influence of various environmental forces, arsenic may be highly concentrated in local areas, causing abnormal arsenic content in soil or other media. The causes of abnormal arsenic can be divided into natural factors and human factors.

3.1. Natural factors

Natural factors refer to arsenic abnormalities caused by the original environment or non-human factors, and the arsenic poisoning phenomenon caused by them is called endemic arsenic poisoning. It includes two subcategories of water source type and geothermal field type.

1) Water source type

Natural water often contains different concentrations of arsenic. Under normal circumstances, the concentration is very low (5-50 μg·L$^{-1}$). When the arsenic in drinking water exceeds 0.05 mg·L$^{-1}$, it may cause human arsenic poisoning. When this kind of water is used to irrigate farmland, it will cause arsenic accumulation in the soil and endanger the growth and development of plants. It is reported that arsenic poisoning caused by arsenic abnormalities in water sources has occurred in Kuitun Reclamation Area in Xinjiang, parts of Inner Mongolia, Tainan County in Taiwan and other places in China. The formation may be due to the existence of arsenic-rich veins or lake-facies sediments in the area, or the existence of geological and hydrothermal conditions that are conducive to the occurrence and enrichment of arsenic. Diving, lake water and mineral water in these areas, especially local confined water (the source of human drinking water) is rich in arsenic, which forms water-source arsenic pollution

2) Geothermal field type

The arsenic content in hot springs, geysers, and hot water ponds in geothermal fields is usually high, which can easily cause arsenic abnormalities in nearby water bodies and soil, causing arsenic poisoning in humans and animals.
3.2. Human factors

Human factors refer to the redistribution of arsenic elements during the use of mineral resources by humans, resulting in large accumulations of arsenic elements in some areas, causing arsenic pollution. Natural arsenic, which exists in various ores in the form of inactive and low toxicity in nature, migrates with the strengthening of human activities, and its activity increases. According to the statistics of Nrigau et al., the total amount of arsenic input into the soil every year in the world is $0.94 \times 10^8$ kg, of which about 42% comes from the discharge of the “three wastes” in the mining and metallurgical processes.

1) Mining and smelting

When arsenic ore is burned and smelted, arsenic becomes vapor, rapidly oxidizes to As2O in the air, and condenses into solid particles that pollute the surrounding environmental factors such as the atmosphere, water and soil, and further harm human health. Arsenic and its compounds are often associated with non-ferrous metal and precious metal ores. These arsenic compounds are distributed in various intermediate products during the smelting process, which affects the product quality. When processing arsenic-containing raw materials, if reasonable Technical measures, a large amount of arsenic will be discharged into the surrounding environment.

2) Production and use of arsenic-containing preparations

Arsenic-containing preparations are usually by-products of smelting copper, lead, zinc and gold ores. A large part of the arsenic is in the state of As2O3. As2O3 is widely used in industrial and agricultural production, such as manufacturing arsenic pesticides. Long-term use of arsenic-containing preparations can cause abnormal arsenic in the environment, endangering the safety of humans and animals.

3) Fossil fuel combustion

Fossil fuels such as coal, oil, natural gas, etc. usually contain some arsenic. Among them, coal has the highest arsenic content, generally between 3 and 45 mg·kg$^{-1}$. After coal is burned, a large amount of arsenic will enter the environment, causing arsenic pollution.

4. Problems caused by arsenic pollution

4.1. The effect of arsenic on plant growth and development

It is generally believed that arsenic is not an essential element for plants, but plants actively or passively absorb arsenic from the external environment during their growth. Studies have shown that traces of arsenic in the soil can stimulate the growth and development of plants. The reduction effect of arsenic increases the activity of oxidase in plant cells, making the non-available phosphorus in the soil effective. Arsenic can kill or inhibit germs that harm plants, thereby reducing its harm to plants and benefiting plant growth. However, excessive arsenic harms the growth and development of plants, such as reducing transpiration rate, inhibiting root activity, and hindering plants from absorbing and transporting water and nutrients such as N, K, P, Mg, Ca. Excessive arsenic hinders the formation of chlorophyll and inhibits photosynthesis. The poison of arsenic is also manifested in its effect on the enzyme activity in crops. Arsenic has a very obvious inhibitory effect on several enzymes. For example, the highly accumulated arsenic in the roots inhibits the activity of catalase which can protect crops from excess hydrogen oxide poisoning. Decrease in catalase activity will adversely affect crop growth.

4.2. The effect of arsenic pollution on soil microorganisms

Arsenic can inhibit the number of fungi, bacteria, actinomycetes and nitrogen-fixing bacteria to varying degrees, among which bacteria and actinomycetes have the most obvious inhibitory effect. There is a significant negative correlation between the number of nitrogen-fixing bacteria in the soil and the total arsenic content of the soil, which indicates that arsenic pollution can cause changes in the number of beneficial microorganisms in the soil, which in turn affects the normal metabolic function of the soil.
4.3. The impact of arsenic pollution on human health
Arsenic is highly toxic. After entering the human body through the food chain, it will be toxic to the digestive system, urinary system, and nervous system. Long-term arsenic exposure can cause skin pigmentation, hyperkeratosis and skin cancer. Arsenic entering the respiratory system can damage alveolar macrophages, aggravate lung infections, and even increase the incidence of lung cancer. Damage to the digestive system can be divided into acute and chronic. Acute arsenic poisoning is manifested as nausea, vomiting, and rapid impairment of gastrointestinal function. Chronic arsenic poisoning is mainly manifested as liver damage. Damage to the urinary system is manifested as damage to the kidneys. The acute phase is mainly renal failure, renal interstitial and renal tubule congestion, edema, and swelling of both kidneys; chronic nephrotoxicity is mainly caused by vacuolar degeneration of renal tubule cells, increased inflammatory cells, and glomerular swelling and urinary system damage. Long-term exposure to high arsenic environments can lead to a significant increase in the risk of pregnant women's spontaneous abortion, stillbirth, premature delivery, and low birth weight.

5. Conclusion
As arsenic is an essential element in industrial and agricultural production, the problem of arsenic pollution is very common worldwide. In areas with more serious arsenic pollution, endemic arsenic poisoning symptoms often appear, which seriously threatens human health and environmental safety. At present, there have been many studies on the remediation of arsenic-contaminated soil, including leaching remediation technology, bioremediation technology, stabilization remediation technology, etc., but they cannot fundamentally solve the problem of arsenic pollution. At present, in addition to further strengthening the development of high-efficiency repair technologies, we should also reduce the generation of arsenic pollutants from the source and look for alternatives to arsenic-containing substances to reduce the application of arsenic-containing substances.

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Reference
[1] Huaiman C. Heavy metal pollution in soil-plant system. Beijing: Science Press, (1996)71-85.
[2] Fusheng W, Jingsheng C, Yanyu W, et al. Study on the background contents on elements of soil in China. Chinese Journal of Environmental Science, 4 (1991) : 12 — 19.
[3] Shengke Y, Wenke W, Wei Z, et al. Study on ecosystem effect and the remediation methods of arsenic pollution in water and soil system. Journal of Earth Science and Environment, 26.3 (2004): 69-73.
[4] Huanxin W, Xiaoyu Z, Lejun Z, et al. Natural existence of arsenic in soil of China and its cause of formation. Journal of Zhejiang University, 34.1 (2000): 88 -92.
[5] Chao S, Liqin J, Wenjun Z. A review on heavy metal contamination in the soil worldwide: situation,impact and remediation techniques. Environmental Skeptics and Critics, 3.2 (2014): 24-38.
[6] Jie L, Chengcheng Z. Solution of soil arsenic contamination. Outlook, 32 (2008): 7.
[7] Changluo Z, Mingwei C, Hualun L. Advances in the study on the prevention and control in the arsenic-modified mineral development. Multipurpose Utilization of Mineral Resources, 5 (2005): 31-34.
[8] Jianmin Z, Hongxi Z, Jianyi K. Review of arsenic pollution and treatment progress in nonferrous metallurgy industry. Advanced Materials Research, 634-638 (2013): 3239-3243.
[9] Changli M, Fengchang W, Zhiyou F, et al. Primary investigation in the pollution state of the antimony,arsenic and mercury in the agricultural soil of the antimony ore distric in the Xikuangshan. Acta Mineralogica Sinica, 2013, 33(3): 344-349.
[10] Rachana S, Samiksha S, Parul P, et al. Arsenic contamination, consequences and remediation
techniques: a review. Ecotoxicology & Environmental Safety, 112 (2014): 247-270.

[11] Jasim U A M, Abdul G. Heavy metal contamination in water, soil, and vegetables of the industrial areas in Dhaka, Bangladesh. Environmental Monitoring and Assessment, 166.1-4 (2010) : 347-357.