HEAVY METAL CONTAMINATION IN SOIL: EFFECTS, SOURCES AND REMEDIATION TECHNIQUES

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Heavy metal contamination refers to the excessive deposition of toxic heavy metals in the soil caused by human activities. Heavy metals in the soil include some significant metals of biological toxicity, such as mercury (Hg), cadmium (Cd), lead (Pb), chromium (Cr), arsenic (As), etc. They also include other heavy metals of certain biological toxicity, such as zinc (Zn), copper (Cu), nickel (Ni), stannum (Sn), vanadium (V), etc. In recent years, with the development of the global economy, both type and content of heavy metals in the soil caused by human activities have increased gradually, resulting in the deterioration of the environment. Heavy metal pollution of soil has become a worldwide environmental issue that has attracted considerable public attention, largely from the increasing concern for the security of agricultural products. Heavy metals enter the soil agro-ecosystem through natural processes derived from parent materials, and through anthropogenic activities. Heavy metal pollution poses a great threat to the health and well-being of organisms and human beings due to potential accumulation risk through the food chain.

In the past, soil contamination was not considered as important as air and water pollution, because soil contamination was often with wide range and was more difficult to be controlled and governed than air and water pollution. However, in recent years the soil contamination in developed countries come to be serious. Heavy meals thus paid more and more attention and became a hot topic of environmental protection worldwide.

CHARACTERISTICS OF HEAVY METAL CONTAMINATION OF SOILS

- ***Strong latency heavy metal contamination is colorless and odorless, so it is difficult to be noticed***.

Heavy metals do not explicitly damage the environment in a short period. Nevertheless, when it exceeds the environmental tolerance, or when environmental conditions have changed, heavy metals in the soil may be activated and cause serious ecological damage. So heavy metal contamination is usually chemical Time Bombs.

- ***Irreversibility and remediation hardness***

If the air and water are polluted, the pollution problem can be reversed certainly by dilution and self-purification after switching off the sources of pollution. However, it is difficult to use dilution or self-purification techniques to eliminate heavy metal contamination and to get soils improved. Some soils contaminated by heavy metals are likely to take one or two hundred years to be remediated. Therefore, heavy metal contamination needs relatively high cost of remediation and the remediation cycle is relative long.

- ***Complex heavy metal contamination***

In the past, soil contamination was mainly caused by a single heavy metal. However, in recent years more cases are found to be caused by a variety of heavy metals. The complex

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contamination caused by a variety of heavy metals will always amplify the contamination by heavy metals separately.

SOURCES OF HEAVY METALS IN SOIL

Excess heavy metals in the soil originate from many sources, which include atmospheric deposition, sewage irrigation, improper stacking of the industrial solid waste, mining activities, the use of pesticides and fertilizers, etc.

- ***Atmosphere to soils pathway***

Heavy metals in the atmosphere are mainly from gas and dust produced by energy, transport, metallurgy and production of construction materials. Excepting mercury, heavy metals basically go into the atmosphere in the form of aerosol and deposit to the soil through natural sedimentation and precipitation, etc.

- ***Sewage to soils pathway***

Wastewater can be divided into several categories, sanitary sewage, chemical waste water, industrial mining wastewater and urban mining mixed sewage, etc. Heavy metals are brought to the soil by irrigative sewage and are fixed in the soil in different ways. Th heavy metal contamination caused by sewage irrigation must be paid enough attention. Quality of irrigative sewage must be strictly controlled within the national quality standard for irrigation water.

- ***Solid wastes to soils pathway***

There are a variety of solid wastes which have complex composition. Of which mining and industrial solid waste contamination is the most serious. When these wastes are in the process of being piled or governed, heavy metals move easily due to the facilitation of sunlight, raining and washing. And they spread to the surrounding water and soils at the shape of funnel and radiation. With the development of industry and the acceleration of urban environmental construction, sewage treatment is continuing to be strengthened.

- ***Agricultural supplies to soils pathway***

Fertilizers, pesticides and mulch are important agricultural inputs for agricultural production. Nevertheless, the long-term excessive application has resulted in the heavy metal contamination of soils. The vast majority of pesticides are organic compounds, and a few are organic - inorganic compound or pure mineral, and some pesticides contain Hg, As, Cu, Zn and other heavy metals. Heavy metals are the most reported pollutants in fertilizers. Heavy metal content is relatively low in nitrogen and potash fertilizers, while phosphoric fertilizers usually contain considerable toxic heavy metals. Heavy metals in the compound fertilizers are mainly from master materials and manufacturing processes. The content of heavy metals in fertilizers is generally as follows: phosphoric fertilizer> compound fertilizer> potash fertilizer> nitrogen fertilizer. Cadmium is an important heavy metal contaminant in the soil. Cadmium is brought to soils with the application of phosphoric fertilizers. Many studies showed that, with the application of a large amount of phosphate fertilizers and compound fertilizers, the available content of Cadmium in soils increases constantly, and Cadmium taken by plants increases accordingly.

IMPACT OF HEAVY METAL CONTAMINATION OF SOILS

- ***Impact on soil microorganisms and enzymatic activity***

Microbial activity and enzymatic activity of the soil can sensitively reflect the quality of the soil. The microbial biomass of the soil was an important indicator of determining the

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extent of soil contamination. Microbial activity is inhibited significantly in the heavy metal contaminated soil. The microbial biomass in the soil contaminated by Cu, Zn, Pb and other heavy metals were inhibited severely. The soil's microbial biomass near the mine was significantly lower than that far away from the mine. The activities of almost all enzymes in the soil were significantly reduced by 10 to 50 times with the increase of the concentration of heavy metals.

- ***Impact on the plants***

Low concentration of soil heavy metals, regardless of necessary or unnecessary to plants, will not affect the growth of plants in a certain range. But if the concentration is too high, the content of heavy metals enriched by the plant exceeds its tolerance threshold, and thus the plant will be poisoned and it even leads to death of the plant. Cadmium may interfere in crop photosynthesis and protein synthesis, and may cause membrane damage, etc.

- ***Impact on humans***

Existing research showed that heavy metals in urban soils may go into the human body through skin absorption and inhalation of dust, etc., and thus directly damage, especially children's health. They also affect the urban environmental quality and damage human health indirectly through polluting the food, water and atmosphere. Cadmium may damage the metabolism of calcium, which will cause calcium deficiency and result in cartilage disease and bone fractures, etc. Agency for Toxic Substances Management Committee has listed Cadmium as the sixth most toxic substance that damages human health. Lead mainly enters human body through the digestive tract and respiratory tract, and then goes into the blood circulation in the form of soluble salts, protein complexes or ions, etc. 95% of the insoluble phosphate lead accumulates in bones. Lead is strongly pro-organizational. It affects and damages many of the body organs and systems, such as kidney, liver, reproductive system, nervous system, urinary system, immune system and the basic physiological processes of cells and gene expression. Cu, Zn and Ni are essential trace metals in the human body, but if the body takes excessive Cu, Zn and Ni from the outside environment, they will damage human health. Ni and Cu are tumor promoting factors, whose carcinogenesis effect has attracted global concerns. Workers who are in close contact with the nickel powder are more likely to suffer from respiratory cancer, and the content of Ni in the environment is positively correlated with nasopharyngeal carcinoma.

REMEDIATION OF HEAVY METAL CONTAMINATED SOILS

Remediation using chemical, physical, and biological methods has been adopted to solve the problem. Phytoremediation has proven to be a promising alternative to conventional approaches as it is cost effective, environmentally friendly, and aesthetically pleasing.

Engineering remediation

Engineering remediation refers to using physical or chemical methods to control heavy metal contamination of soils.

- ***Replacement of contaminated soil, soil removal and soil isolation***

Replacement of contaminated soil means adding large amount of clean soil to cover on the surface of the contaminated soil or to blend with the latter. Soil removal refers to remove the contaminated soil and renew it with the clean soil, which is necessary for the seriously contaminated soil with little area. Soil isolation means that to isolate the contaminated soil from the uncontaminated soil, but to completely remedy it still needs other auxiliary

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engineering measures. All of these methods will cost large amount of manpower and material resources, so they can only be applied to small area of soils.

- ***Electrokinetic remediation***

Soil electrokinetic remediation is a new economically effective technology. The principle is that the DC-voltage is applied to form the electric field gradient on both sides of the electrolytic tank which contains the contaminated soil; contaminants in the soil is taken to the processing chamber, which is located at the two polar sides of electrolytic cell, through the way of electro-migration, electric seepage or electrophoresis, and thus reduce the contamination. The method performs well in the soil with low permeability.

- ***Soil leaching***

The principle of soil leaching is to wash the heavy metal contaminated soil with specific reagents and thus remove the heavy metal complex and soluble irons adsorbed on the solid phase particles. By using this method, heavy metals are separated from the soil, and heavy metals are then recycled from extracting solution.

- ***Adsorption***

Adsorption method is based on the fact that almost all heavy metal ions can be fixed and adsorbed by clay mineral, a steel slag, furnace slag, etc.

- ***Other methods***

Other engineering methods include washing and compounding, heat treatment, physical solidification, chemical improvers, chemical curing lamp remediation, etc.

Bioremediation

- ***Phytoremediation***

Grow specific plants in the soil contaminated by heavy metals. These plants have the certain hyper-accumulation ability for the contaminants in the soil (accumulated mainly in the root or above the root). When the plants are ripe or reach certain enrichment level of heavy metals, remove heavy metals in the contaminated soil layer thoroughly by harvesting, burning and curing plants. Using plants and their coexisting microbial system to remove heavy metals is a new technology. The key of the method is to find the suitable plants with strong ability for heavy metal accumulation and tolerance.

- ***Microbial remediation***

Microbial remediation refers to using some microorganisms to perform the absorption, precipitation, oxidation and reduction of heavy metals in the soil. Fungi could secrete amino acids, organic acids and other metabolites to dissolve heavy metals and the mineral containing heavy metals. Fungi, Gomus intraradices, may improve the tolerance and absorption of Chromium to sunflower. Cultivating microorganisms that have degradation capacity on heavy metals by using biotechnology (genetics, genetic engineering, etc.) are one of the current focuses in this area.

- ***Animal remediation***

Some animals living in the soil (maggots, earthworms, etc.) can take heavy metals in the soil. Modern civilization is completely dependent on a large range of metals for all aspects of daily life. There is a long history of association between metals and human development. Copper has been used since about 8000 b.c., initially as native copper, but smelting of copper

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from oxide ores is thought to date from about 6000 b.c. Lead was used before 5000 b.c., zinc and mercury by about 500 b.c., and nickel in alloys by 200 b.c. Cadmium was discovered comparatively recently. Regardless of the carcinogenic or non – carcinogenic risk, children were found to be more susceptible to the potential health risk; children were therefore likely under a higher health risk than adults. There were no significant carcinogenic and non – carcinogenic risks for adults, while children showed significant non – carcinogenic effect.

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