

Research Status of Heavy Metal Remediation Diatomite Materials

Haoran Duan

Chengdu University of Technology, Sichuan, 610059, China

Abstract: The quality and safety of soil environment is closely related to human production and life. Human activities have had a great impact on the accumulation, diffusion and transfer of heavy metals in soil, seriously endangering the ecological environment and human health. This paper focuses on the latest progress of diatomite materials, and introduces the commonly used synthesis and modification methods of materials. The performance changes of modified materials under different conditions, as well as their functions and advantages in dealing with heavy metal pollution, are systematically described, and the problems and limitations in practical application are summarized. Finally, based on the above analysis, the future development direction of diatomite materials is prospected.

Keywords: Diatomite, Heavy metal pollution, Clay material.

1. Introduction

With the development of the global economy, the process of urbanization and industrialization requires a large amount of steel, which will increase the demand for the mining of mineral resources. Excessive mining will cause numerous accumulation of waste generated in the mining and beneficiation process[1, 2]. Solid waste is generally stacked in the open air and hard to be effectively used as soon as possible. Under the influence of weather, such as windy weather, the tailings powder will diffuse to the downwind. Heavy metal ions in the tailings will migrate to soil or even deeper groundwater with the leaching of rainfall, causing more pollution hazards[3]. The content of heavy metals in the surrounding environment in mining areas is significantly higher than that in non-mining areas[4]. There is significant potential ecological and human health risk associated with accumulation of solid waste[5]. Plants that grow in soil contaminated by heavy metals will also accumulate heavy metals in different parts, and eventually enter the human body with the food chain, threatening human health[6].

Diatomite is a biogenic siliceous sedimentary rock, as a promising natural material is mainly composed of the exoskeleton of ancient diatoms[7]. Diatomite is composed of a unique three-dimensional structure of amorphous SiO₂ and the silanol group on its surface, making it easy to functionalize[8, 9]. Benefit from the diatomite's unique physical characteristics, such as high specific surface area, low density, high porosity, excellent mechanical strength, and nontoxicity[10]. Diatomite can be used as a load material for many purposes[11]. Some researchers found that Diatomite modified by hydrolyzed polyacrylamide (PAM) can be used as an adsorbent for methylene blue(MB) and reactive yellow(RY)[12], and polyethyleneimine surface modified diatomaceous earth can effectively removal dyes in textile wastewater[13]. In medical materials, diatomite incorporated with novel chitosan based composite membranes were fabricated for bone tissue engineering applications as possible bone regeneration membrane[14]. Moreover, in heavy metal removal, diatomite has been used as a carrier for nano-adsorption particles to reduce the agglomeration of nanoparticles and reduce the production cost of materials[15,

16].

2. Status of Heavy Metal Pollution in Soil

Heavy metal elements usually refer to cadmium (Cd), mercury (Hg), copper (Cu), arsenic (As), lead (Pb), chromium (Cr), vanadium (V) and other atomic mass greater than 20 and relative density greater than 4.5g/cm³ of metals and metalloid elements. Due to the low content of these elements in the earth's crust, they are also called trace elements. However, natural and human activities can lead to the migration and accumulation of such elements. Especially when heavy metal elements accumulate in farmland soil, crops, as an important part of human diet, will affect the health of consumers[17]. Heavy metals in farmland soil will have a certain impact on plant growth. For example, the toxicity of lead (Pb) in plants will lead to slow plant growth, chlorosis of leaves, reduced nutrient absorption, and decreased yield. Legumes cannot fix molecular nitrogen and cause Metabolic disorders[18]. Excessive intake of cadmium (Cd) in the human body can cause cardiovascular and cerebrovascular diseases, and damage bone calcium and cause osteoporosis; excessive vanadium (V) can lead to abnormal cholesterol metabolism in the human body and cause damage to human heart and lung function; Lead (Pb) will directly damage human brain cells and affect intellectual development, and the damage of lead to the human body is irreversible. In addition, the accumulation of elements such as copper, nickel and cobalt in the human body will also have a serious impact on human health[19-21].

The toxicity of vanadium (V) and chromium (Cr) pollution in soil to organisms has gradually attracted attention to heavy metal pollution in recent years. have many adverse effects. High concentrations of V in soil can affect plant growth activities, such as water transport, mineral absorption, enzymatic activity, photosynthetic activity, and ultimately reduce plant biomass. The results of past studies have also confirmed that the increase of V content in plants can trigger oxidative damage in plants, and the induction of reactive oxygen species (ROS) can affect the production of macromolecules and organelles such as DNA, proteins, and

lipids. Therefore, the control of V pollution in soil is a problem that needs attention in current environmental problems [22, 23]. Cr is considered to be a dangerous environmental pollutant due to its use in steel refining and industrial applications. With the in-depth study of this topic by scholars, the pollution of Cr in soil and water has also received more attention. Since plants lack a specific Cr transport system, it is usually transported by carriers such as sulfate or iron ions. Therefore, it will migrate to various parts of the plant along with the transportation process, slow down the germination process and the growth of roots, stems and leaves, and affect the yield and quality of the plant. At the same time, Cr also affects the physiological functions of plants, such as photosynthesis, nutrient transport, and water uptake [24, 25].

The main sources of heavy metals in soil are natural and human activities. Natural causes include migration and redistribution of soil debris and soil parent rock migration with high background values under weathering; anthropogenic factors include mineral extraction, gob waste accumulation, fertilizer and pesticide application, and sewage irrigation [26-28]. Among them, mining areas and industrial areas contribute significantly to the content of heavy metals in the surrounding soil [29]. Through the analysis of soil samples from cities around the mining area, the abnormal phenomenon of heavy metal content is caused by the accumulation of natural and human factors. The work will continue to produce continuous accumulation of heavy metals in the soil of surrounding cities[30].

Human activities have had a great impact on the accumulation, diffusion and transfer of heavy metals in soils. Due to the needs of industrial development and the demand for resources in mechanized work, unreasonable land planning, non-standard soil use, and weak awareness of environmental protection have led to different degrees of soil pollution around the world. Remediating contaminated soil to a usable state and restoring its original function is one of the important approaches for integrated soil management[31].

3. Research Status of Diatomite

Diatomite is a biogenic siliceous sedimentary rock. It is mainly composed of the remains of ancient diatoms. The main component is SiO_2 , and contains a small amount of Al_2O_3 , Fe_2O_3 , CaO , MgO , etc. and organic matter. Diatomite can be used as an adsorbent and an additive for building materials due to its high yield, porous structure, low density and high specific surface area. Diatomite particles carry negative charges on the surface in solution, and the surface micropores contain hydrogen bonds and silanol groups, which can be used as modification sites [8]. Using it as an environmental restoration material is one of the feasible methods for environmental restoration work at present. Scholars use the purification process to achieve the target requirements by changing the surface properties of diatomite. The main purpose of diatomite purification is to reduce impurities in the components and increase its specific surface area[11]. The purification methods can be divided into physical purification, chemical purification and physical-chemical purification. Physical purification method can be divided into scrubbing method and roasting method; chemical purification method can be divided into acid leaching method and alkali leaching method; physical-chemical purification method can be divided into microwave-acid leaching purification, ultrasonic-acid leaching purification and thermal flotation-

Magnetic separation-acid leaching method [32]. The purified diatomite also has a certain improvement in the adsorption effect of heavy metals due to the increase of its specific surface area or the decrease of the impurity content. In addition, continuing to modify the purified diatomite can increase the modification sites on its surface, thereby improving the properties of the modified material. At present, in the modified diatomite for the treatment of heavy metals in water or soil, it is more common to use Fe(II) as a modifier[33]. And it is fixed in the porous structure of diatomite by electrostatic adsorption, thereby reducing the harm of heavy metals to the environment [16]. Due to its special redox and replacement reactions, iron and manganese oxides can have a good removal effect on heavy metal elements in the solution. At the same time, the replaced metal elements are the constant elements required for plant growth, and have obvious positive effects in farmland use, which can be used for the treatment of heavy metal-contaminated soils[34]. Due to the characteristics of diatomite, it has a very broad prospect in the field of heavy metal treatment.

In terms of solving soil erosion, modified diatomite can be used as an excellent soil water retention agent. For example, scholars[35]used acrylic modified diatomite to improve its water retention performance, because polyacrylic acid hydrogel contains Hydrophilic groups, which are capable of forming hydrogen bonds with water molecules, which can hold water molecules in the material. In addition to the chemical properties of the material itself, its internal physical structure can also increase the water storage capacity of the material. The cross-linking between acrylic monomers forms a multi-dimensional network structure, so that water molecules can rely on the voids between macromolecules in the material to transport and store through the capillary effect, and can slowly release water to the surrounding environment[36]. In addition, after the modified diatomite absorbs water, due to the electrostatic interaction between the soil and the material, the soil particles can agglomerate around the material to form soil aggregates, and the capillary action generated during the slow release of water from the material can further make the soil particles. Produce agglomeration and form soil aggregates to reduce the overall compaction effect of the soil. Therefore, in the face of complex soil problems, modified diatomite-based materials can provide new solutions.

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