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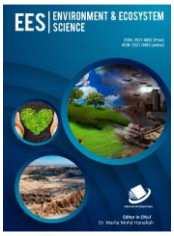

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SHORT COMMUNICATION PAPER

NANOTECHNOLOGY DEVELOPMENT FOR *IN-SITU* REMEDIATION OF HEAVY METAL(LOID)S CONTAMINATED SOIL

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ABSTRACT

Soil contamination by with heavy metal(loid)s (HMs) has been a major environmental challenge for decades and escalating with industrialization development which is considered as a hindrance of socioeconomic development. Nevertheless, cost and time-effective, and sustainable in-situ remediation technologies remain facing technical and operational lacking. Magnetic nanomaterials have shown promising means of an innovative in-situ remediation strategy for the removal of PTMs contaminated soil. Magnetic adsorbent having high efficiency and capacity towards the removal of PTMs, and enormous reusability. Also, magnetic nanocomposite has improved with functionalization of groups on their large surface which increase the adsorption capability of the adsorbent. Nanotechnology development sector or enterprises as lack of field application of magnetic nanomaterials at commercial scale due to non-availability of required tools and materials. This information may support further environmental nanotechnology for contaminated soil.

KEYWORDS

soil remediation, magnetic nanomaterials, nanotechnology, heavy metal(loids)

1. INTRODUCTION

Soil contamination is recognized as threats to environmental/ecological risk, human health risks, and sustainable urban and agricultural development. Inorganic pollutants contamination which includes: Arsenic (As) metalloid, Cadmium (Cd), Chromium (Cr), Cobalt (Co), Copper (Cu), Mercury (Hg), Nickel (Ni), Lead (Pb), and Zinc (Zn) metals are known as heavy metal(loid)s (HMs). Natural known as geochemical background and anthropogenic sources are caused of soil contamination. Globally over 5 million contaminated sites are covering 20 million ha, while in China alone 100 million ha of land in which soil is polluted by PTMs [1]. In addition, the presence of HMs in urban soil (and dust) could be a risk to ecosystem especially human health, animals and plants (organs) via bioaccumulation due to their toxicity and environmental persistence nature [2]. Thus, the restoration of HMs contaminated soil becomes binding to remediation for urban development.

Remediation of PTMs contaminated soil done *in-situ* and *ex-situ* strategies which includes physical, chemical, bioremediation or combined approach. *In-situ* remedies have advantages over *ex-situ* remedies which do not require excavation and transportation of the contaminated soil to off-site treatment, which significantly reduced the cost, strategies include surface capping, encapsulation, electrokinetic extraction, chemical immobilization or phytoremediation. Applicability of soil remediation techniques is project specific influenced by contamination characteristics, remediation objectives and efficiency, cost-effectiveness, period and social acceptability. *In-situ* remediation of HMs contaminated soil have facing challenges, time frame (lengthy period), low permeability and complex composition of soil minerals, heterogenous of subsurface conditions, mobilization of metal ions from soil, sustainably of remediation threat on the climatic and weather condition, correct disposal/mishandling of analyte and above all cost reduction is key challenge [3,4]. Phytoremediation, which is the most common bioremediation method required a long time period [5]. Therefore, few techniques of remediation have been commercially used for the treatment of PTMs due to geochemical reactions of contaminates with soil as a results conditions of HMs removal from soil becomes different from water.

Developing nanotechnology has a wide range of application form life sciences to environmental sciences, computer sciences to artificial intelligence. In short, nanotechnology playing an important role in the modern development era. Nanomaterials (which also include nanoparticle/nanostructure/engineering particle) are considered as an essential and integral part of nanotechnology. These materials used as efficient adsorbent and catalysis to overcome the environmental issue and technology development in this perspective known as environmental Nanotechnology. Enormous types of adsorbent have been used for the removal of HMs from soil such as artificial clay (kaolinite, zeolite, bentonite), biochar, natural allophane, nanocomposite or nanoparticle, and many others. Magnetic nanomaterials have several advantages over other materials such as smooth operation, high efficiency, reusability of adsorbent and above all economically favorable for in-situ remedies [6]. Cai et al, also highlighted that nanomaterials can be used for nanotechnology development of in-situ remediation [7]. However, other material can changed the reclaimed properties of reclaimed soil [8]. Magnetic nanomaterials are emerging in the physiochemical remediation approach to ease or simplified their application process into soil remedies. Continues development in the magnetic nanomaterials giving boost due to the large surface area, cost-effective, and environmentally friendly alternative to chemical and physical methods of production [9]. Technology advancement can overcome the future crisis to eradicated the environmental issues such air, water and soil pollution [10,11]. These adsorbent getting attention due to functionalized with an abundant surface group supported by nanocarbon sphere (NCS) on the magnetic materials which increase the adsorption efficiency and capacity [12]. Magnetic separation, enrichment, chemical stability, high saturation magnetization and super-paramagnetism and reusability of adsorbent gives the acceptability to their application into the soil.

Recently, magnetic nanomaterials by functionalized nanocarbon sphere/ nanostructured materials on the spherical sphere has drawn increasing interest due to their physiochemical properties and potential of diverse application in the fields. In this review, 1) generalized fabrication/synthesis and characterization of magnetic nanomaterials for the removal of HMs; 2) give the appraisal to the development of new nanotechnology for in-situ application of magnetic nanomaterials and marks the industrial collaboration support for the commercial scale development of remediation technology.

2. FABRICATION/SYNTHESIS AND CHARACTERISTICS OF MAGNETIC NANOMATERIALS

Solvothermal and hydrothermal synthesis method are commonly used for the preparation of magnetic nanomaterials at a high-temperature range of 100-1000°C (usually performed below super critical temperature of water for hydrothermal condition) and pressure range of 1-10000 atm [13]. The procedure for the synthesis is not specific it varies according to the nature of the nanomaterials or purpose to be used either for the adsorption and desorption or immobilization/mobilization of metal ions in the soil environment. Three step procedure to be followed during the preparation of functionalized magnetic nanocomposite via liquid phase.

Step-I: raw precursor soaked into acidic solution (usually HCl, H_2SO_4) or washed with deionized water/ethanol solution to clean and make the structure of surface area spongy or rough type.

Step-II: nanocarbon sphere or flowered structure layer coated on the surface of the resulting system under controlled temperature in the autoclave using carbon sources such as polyethylene, sucrose or their derivative either alone or presence of catalyst. Recently, Green tea extract also used for the coating of nanocarbon spheres. Spherical shape not only limited to Fe_3O_4 but ceramsite, clay powder (zeolite, kaolinite and many others), silica materials are also used for coating of nanocarbon sphere on their surface. The sphere can be formed with core material to carbon chains/flakes/layers parallel or perpendicular and porous surface functionalized.

Step-III: resulting system functionalized with carboxyl, hydroxide, amino and many other it depends upon which derivative family of hydrocarbon considers for the treatment of resulting system after coating of nanocarbon layered.

Finally, the functionalized magnetic nanomaterials prepared for the adsorption of HMs. Metal ions have a positive charge in the state of ionization or aqueous state. Meanwhile, the final product of fabrication ought to be negative charge functional groups on the surface area. These opposite ions attraction will immobilize the analyte after adsorption and make the separation easy for reuse of the material. Morphology observed using scanning electron microscope (SEM) and transmission electron microscope (TEM) which highlights the pore space on the surface of precursors before and after the treatment carried. Structural or chemical interaction among precursor, NCS, and functionalized material are obtained by carrying X-ray diffractometer (XRD) analysis which highlights the typical peaks in the XRD spectrum. Fourier transmission infra-red (FTIR) spectra used to identify the chemical interaction of functional groups in the functionalized magnetic nanocomposite system. Adsorption isotherms, kinetics and thermodynamics of adsorbent also analysis by applying respective models. In addition, effect of pH, adsorbent dosage and amount of soil on adsorption analyzed. Fabricated magnetic nanomaterials usually used to adsorb one or two metal due to lack of capacity and inefficient for other metals. Multi-metal(loids) adsorbent required that could adsorb different metals simultaneously, which could be another direction for the future development of magnetic nanomaterials.

3. DEVELOPMENT OF NANOTECHNOLOGY FOR *IN-SITU* REMEDIATION

Magnetic nanocomposite has been recommended as promising and effective adsorbent materials and has extended efficient capacity for reducing the HMs in contaminated soil. However, any technology can be a double edge sword though potential environmental risk should be neglected due to wide application nanomaterials. Once conveyed into soil their separation is not easily separation after soil restoration which can cause secondary pollution [7]. To eliminate the threat of nanocomposite and continuous development are needed to improve the implication and separation mechanism preventions. Thus, the implication of magnetic nanomaterials and their separation required new technology development for soil remediation.

Direct application of magnetic nanocomposite on the upper surface of contaminated soil is very easy and simple for the adsorption of HMs for in-situ remediation strategy. Magnetic nanocomposites are evenly spread by conventional method or mechanically to the soil after irrigation, then soil tilled using a rotary tiller to enhance the contact of magnetic nanocomposite with HMs in soil. In due course, an industrial scaled magnetic rotary tiller fabricated of 10-20 magnetic plates which can be inserted into soil for about 20-30cm deep shall be used to separate and collect the magnetic nanocomposite driven by ordinary tractor. Afterward, magnetic nanocomposite could easily scarp off by a scraper from magnetic dishes.

The concept of integrated-fabric development is a novel approach to use magnetic nanocomposite for in-situ remediation strategy. Magnetic nanocomposite will be fixed in the spaces between minimum three-layered fabric having a width of 50-100-cm along the length. Distribution number of magnetic nanomaterials depends upon the initial concentration of contaminants and depth of soil to insert nanofabric This integrated fabric named as nanofabric after incorporated nanocomposite. Afterward, this integrated fabric the insert into the soil using a mechanical mechanism, which could be based potato harvester machine. Nanofabric inserts into contaminated soil under the gap of cutting edge which creates due to tilt angle (the angle between the plane of the cutting edge and the vertical line). Tilled soil will facilitate the settlement of nanofabric into the soil and increase the mobility of HMs into the soil after irrigation. Applying water could enhance HMs mobility and generate leachate. Before insertion of nanofabric into the soil, drainage or perforated pipes placed in the soil by machine to collected leachate. This approach could be combined with soil flushing method due to leachate collection mechanism. As both above-mentioned application new and implication of this only possible by the development of required technology which would have great potential to make industrialization of these remediation technologies. The interest of nanotechnology development industry can give a boost to implement this approach to in-situ remediation of contaminated soil. Industrial coordination and interest required in three fields: i) development of magnetic separation system; ii) development of a machine system to insert nanofabric into the soil; and iii) development of nanofabric. Multi-metal(loids) adsorbent can boost this remediation technology.

4. CONCLUSION AND FUTURE PERSPECTIVE

Soil contamination by HMs is an unanimously global environmental concern for urban development. The development of new technology under the "Nanotechnology" platform can provide a novel in-situ soil remediation approach using magnetic nanocomposite. Conclusion of this review and future possible direction are the following:

- The solvothermal and hydrothermal method is used for fabrication/synthesis of magnetic nanomaterials which contains three steps; make the spongy or rough surface, coating of nanocarbon sphere, and functionalization.
- Characterization of magnetic nanomaterials does by morphological observation and chemical interactions using advanced analysis and computation.

- Magnetic nanomaterials can give a boost to the development of remediation technology
- Development of magnetic separation system, nanofabric, and associated machinery technology, and multi-metal(loids) novel nanomaterials required for future.

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