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Use of Natural Organic and Synthetic Chelating Agents for Efficient Phytoremediation

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Abstract: Heavy metals are the major toxicant in the soil that cannot be broken down in non toxic form. Phytoremediation is the promising method for reclamation of soil contaminated with toxic metals by using hyper accumulator plant. The efficiency of these plants can be increased by adding chelating agents. Different Chelating Agents: Organic such as amino acids and synthetic such as EDTA, NTA, DTPA, MGDA, EDDHA enhance heavy metal uptake from the contaminated area and show diff efficacy. Different chelating agents are applied at diff doses in intervals of time at variant pH for the maximum uptake of heavy metals. This paper deals with various chelating agents used in phytoremediation. Their effects, advantages, disadvantages in the chelation.

Keywords: Phytoremediation, Chelating agent, Heavy metals, Organic agents, synthetic agents.

1. Introduction

Phytoremediation uses plant for remediation of soils and water polluted with heavy metals. It is a cost effective and non invasive method .This approach has emerged as an innovative tool with great potential .Phytoremedeation is energy efficient, cost efficient, aesthetically pleasing technique exploiating naturally occurring hyperaccumulator plants or genetically engineered plants. A rising method for polluted area is phytoextraction. Phytoextraction is the uptake of pollutants by plant roots and translocation within plants. Plants play a vital role in removal of metal through absorption, cation exchange, filtration and chemical changes through root. The efficiency of hyper accumulation can be increased by the introduction of chelating agents. Chelation refers to the process of attaching a specific organic molecule called legend, to a mineral ion at two or more sites to form a ring structure. Chelation has its origin in the Greek word chele depicts the concept of clinging or holding with a strong grip. Chelating agent can be either synthetic or natural. Solubility in water is essential for absorbtion by plant. The material must be soluble through the surfaces into the cells of plant. Heavy metals, insoluble minerals, cannot absorbed by plants. When liquid solutions of heavy metals are introduced to the plant, they simply coat the outer surface inhibiting the penetration. Therefore chelatimg agents are introduced for the uptake of heavy metals by plant. Chelating agents are capable of binding to toxic metal ions to form complex structures which are easily excreated from the body removing them from interacellular or extracellular spaces. Chelating agents possess ligand binding atoms that form either two covalent linkages or one covalent and one co-ordinate or two co-ordinate linkages in the case of bidenate chelates. Bidenate or multidenate form ring structures that include the metal ion and two ligand atoms attached to the metal. They help transport nutrients throughout plants and can be very useful any time, heavy metals need to be broken down, isolated or moved.

Hyper accumulator Plants-plants that are capable to grow in soils with very high concentration of metals, absorbing these metals through their roots and concentrate extremely high levels of metals in their tissues. They extract the metal from the soil at a higher rate, transfer it quickly and store in large amounts in leaves and roots therefore possessing the ability to extract metals from soils of contaminates sites. More than 400 plants are listed as hyper accumulator for ex-Brassica juncea, Saarcosphaera coronaria, Pteris vittata, Agrostis castellana, Agrostis Capillaries, Salvinia molesta, Helianthus annuus etc.

1.1 Organic Chelating Agent

Proteins, polysaccharides and poly nucleic acids are excellent polydenate ligands for many metal ions. Organic compounds such as malate, organic diacids such as malate, polypeptides such as phytochelation also act as chelators. Some of naturally occurring organic chelating agents are-

1.2. Citric acid

Citric acid is a weak organic acid with formula $C_6H_8O_7$. Is an excellent chelating agent and binding metals used to remove heavy metals, by chelating the metals in hard water .Due to its small size molecule, it can easily penetrate into the roots of plants and adsorbed fastly.

1.3. Gluconic acid

Gluconic acid is an organic compound with molecular formula $C_6H_{12}O_7$. Occurs naturally in fruit, honey, kombucha tea and wine .In aqueous solution at neutral pH, gluconic acid forms the gluconate ion. It is used in cleaning products where it dissolves mineral deposits, especially in alkaline solutions. The gluconate aminochelates Ca^{2+}, Fe^{2+}, Al^{3+}.

1.4. Homo Citric acid

Homo citric acid is an organic compound .The tri carboxylic acid occurs naturally as a component of the iron molybdenum cofactor of certain nitrogenase protein .The molecule is related to citric acid by addition of one methylene unit.

1.5. 2,3-Di Hydroxy Benzoic Acid

It is a natural phenol found in Phyllanthus acidus. It is a dihydroxy benzoic acid ,a type of organic compound. It is introduced into various siderophores, which are molecule that strongly complex iron ions for adsorption. It is a potentially iron chelating agent.

2. Synthetic Chelating Agents

2.1. DOTA

1,4,7-tetra aza cyclo dodecane 1,4,7,10-tetra acetic acid is an organic compound .the molecule consists of a central 12-membered tetra aza ring. DOTA is used as a complexing agent, especially for lanthridine

2.2 EDTA

Ethylene diamine tetraacetic acid is an amino poly carboxylic acid and a colourless ,water soluble solid. It helps in chelation of Ca^{2+} and Fe^{2} .After binding EDTA, metal ions remain in solution but exhibit diminished reactivity. EDTA is universally most accepted chelating agent replacing Citric acid. EDTA is introduced into different doses at different intervals for efficient phytoremediation.

2.3 EDDS

Ethylene diamine –N, N'-disuccinic acid is an amino polycarboxylic acid. it is a colourless solid that is used as chelating agent that may offer a biodegradable alternative to EDTA ,low toxic chelate with a strong chemical affinity and produces benign degradation products. EDDS was first synthesized from maleic acid and ethylene di amine.

2.4. DTPA

Pentetic acid or diethylene tri amine penta acetic acid is an amino poly carboxylic acid consisting of diethylene tri amine backbone with five carboxy methyl groups. The conjugate base of DTPA has high affinity for metal cations.

Chelation is 100 time constant than those for EDTA.DTPA wraps around a metal ion by forming upto eight coordinate bonds. After forming a complex with a metal, DTPA still has the ability to bind to other reagents.

2.5. EDDHA

Ethylene diamine –N-N'-bis is an iron chelating agent. fe EDDHA- was first introduced commercially and agriculturally viable were made by Dr. Ramesh Patel of Agricon Chemicals, a leading plant nutrionist and industrialist from India.

3. Increasing Efficiency Of Synthetic Agents

Each diff chelating agents act efficiently at diff ph. Suitable conditions should be provided to them. All chelates act best at dec soil pH which can be achieved by application of mineral or Organic Acids. The acidic pH can be obtained by the application of Sulphur. Sulphur decrease soil pH & increases the solubility of heavy metals in soil. First lowering soil pH and then addind chelating would be effective strategy to maintain the phytoextraction.

4. Naturally Organic Vs Synthetic Chelating Agents

1) Naturally occurring organic agents shows more penetration rate than synthetic chelates, due to larger molecules such as EDTA, DTPA, EDDHA penetrate at slower rate.

2) Natural chelates are biodegradable and non-toxic to the environment. On the other hand synthetic chelating agents can be toxic to the environment. for ex-

- EDTA forms chemically and microbiologically stable complexes that poses a threat of underwater contamination.
- Under natural conditions, EDTA has been found to convert to ethylene di amine tri acetic acid and then cyclize to diketopiperidize, which accumulates in environment as a persistant organic pollutant.

Remedy- The toxic effect of synthetic chelating agents can be reduced by placing a horizontal permeable barrier below the layer of treated soil. Barrier were composed of reactive materials that facilitate microbiological degradation of EDDS-heavy metal complex.

3) Naturally occurring chelates can be used as a food source to the micro-organisms while the synthetic cannot.

4) Naturally occurring chealating agents are more stable in comparison to synthetic chelating agents.

Conclusion

Use of naturally occurring chelating agents are more favorable for the phytoextraction of metals due to their non-toxic and biodegradable property.

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