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REVIEW ARTICLE

SOIL POLLUTION AND REMEDIATION METHODS

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ABSTRACT

Agriculture is closely associated with the survival of not only of human being but it influences other living organisms too. Soil provides necessary anchorage to the crop plants and a source of food and water as well. Since all animals depend on the plants for their livelihood. So, directly and indirectly they depends on the soil. It is obvious that, all agricultural activities directly or indirectly depend on the quality of soil. Natural soil is a mixture of several things like mineral matter, humus, water, air, animals and unicellular organisms including bacteria. Due to some manmade calamities this natural treasure, soil is becoming polluted and converting in to deserts. The percentage of fertile soil is decreasing day by day. With the help of different physical, chemical and Biological techniques, the polluted soil can be converted in to fertile one. In the present article different remediation methods are discussed.

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INTRODUCTION

Agricultural development is very important for the survival of human being as it is a source of food, shelter and clothing and is closely associated with it. All living beings including plants and animals depend on their particular environment for their metabolic activities including, to remain alive, to thrive and to reproduce. All green plants including our farm crops require productive and non polluted soil for their steady growth. Soil provides anchorage and supplies all essential material like nutrients, water, air and also contains life supporting bacteria, which plants need for their growth. Since all animals depend on the plants for their livelihood. So, directly and indirectly they depends on the soil. It is obvious that, all agricultural activities directly or indirectly depend on the quality of soil. Soil is a mixture of several things like mineral matter, humus, water, air, animals and unicellular organisms including bacteria (Akinrinde, 2004). In order to meet the global challenges of feeding the world's growing population, conserving the environmental capital stocks (soil, water, etc.) and reducing poverty, an agricultural transformation was very essential. The world population is expected to exceed 8 billion by 2025, an increase of 2.5 billion in 25 years (Anonymous, 2000). The Nobel laureate, Dr. Norman Borlaug calculates that "to meet projected food demands, by 2025 the average yield of all cereals must be 80 per cent higher than the average yield in 1990. This increase will have to be achieved in increasingly complex circumstances (Banerjee and Sanyal). To meet the needs of increasing population, in present day agriculture considerable emphasis is given to the inorganic nutrition of the plants. It includes overuse of chemical fertilizers, weedicides, insecticides and pesticides, which adversely affect the soil flora leading soil quality depletion. Besides above reasons of soil contamination there are so many things responsible for the contamination of soil. The common sites which may give rise to possible contamination of soil includes, fast growing urbanization and problems related to it such as asbestos work, chemical works, garages and service stations, gas works, incinerators, iron and steel works, metal fabrications shops, paper mills, tanneries, textile plants, Construction sites, timber treatment plants, railway yards, accidental oil spills, acid rains and waste disposal sites. All these contaminants are responsible to cause some severe health issues of plants and animals and deteriorate the quality, texture and mineral contents of the soil which leads to disturb the biological balance of the organisms in the soil. In India soil pollution is mainly due to pollution concentration in urban areas and unplanned development of industries. It has been estimated that the urban population of India produces about 15 million tones of solid waste per annum causing pollution. In India, during 1980-2000, due to urban growth, about 600000 hectares of land was transformed in to urban centers. About 57% of the total land area is under some form of degradation and a greater part of the lands is severely affected by soil erosion problem. According to the National wasteland Development Board, about 175 Million hectares (53 %) of the country's total geographic areas degraded (Parikh and Parikh, 2004). In the olden days, farmers would keep as much livestock as their land could support. The cattle, sheep, pigs, chickens and other

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animals were fed natural diets, which was supplemented by the waste left over from the crops. As a result, the animals contributed to keeping the farm healthy as well. As of now, livestock is grown in cramped conditions where it is fed unnatural diets and sent to slaughter houses on a regular basis. As a result, they add to the process of agricultural pollution by way of emissions.

To repair the contaminated soil first important attempt to make is to stop overuse of all the above contaminants. Secondly the soil already contaminated by various pollutants should be purified by using some modern advanced techniques. Different remediation techniques evolved in the developed countries can be adopted variously to control the percentage of various pollutants. The choice of method and the determination of the final remediation standard will always be chiefly governed by cite specific factors including intended use, local conditions and sensitiveness, potential risk and available time frame. The currently available processes for soil remediation can be broadly divided in to following categories.

1. Physical Treatment
2. Chemical Treatment
3. Biological Treatment

1. Physical Remediation

This involves the physical removal of contaminated materials and pollutants most often by concentration and excavation, for further treatment or disposal. This method is cost effective hence favored for remediation. Since no any reagents are used for remediation, this method significantly reduces the risk of secondary contamination. The physical remediation can be mainly done by different methods discussed below briefly. The soil replacement is a cover systems provide a stabilization mechanism using clean soil to replace or partly replace the contaminated soil. This will help to minimize the pollutant concentration, increase the soil environmental capacity, and thus remediate the soil (Qian, 2000). The soil replacement is also divided into three types, including soil replacement, soil spading and new soil importing. Soil replacement is removing the contaminated soil and putting into new soil. This method is suitable for contaminated soil with small area. Besides, the replaced soil should be treated feasibly, or else it will incur the second pollution. Soil spading is deeply digging the contaminated soil, making the pollutant spread into the deep sites and achieving the aim of diluting and naturally degrading. New soil importing is also known as capping is addition of lots of clean soil into the contaminated soil, covering it at the surface or mixing to make the pollutant concentration decreasing (Zhitong *et al*., 2012). The soil replacement can effectively isolate the soil and ecosystem and thus decrease its effect on environment (Zhitong *et al*., 2012) However, this technology is large in working volume, costs a lot and is suitable for soil with small area and polluted severely (Zhou *et al*., 2004). The thermal desorption is on the basis of pollutant's volatility and heat the contaminated soil using high temperatures (usually below 400° C) to make the pollutant (e.g. Hg, As) volatile. The volatile heavy metals are then collected using the vacuum negative pressure or carrier gas and achieve the aim of removing the heavy metals (Li *et al*., 2010). The method is done in the absence of oxygen and uses temperatures much less than that required for combustion. Thermal desorpion offers several advantages over incineration including a reduced amount of gases produced, thereby reducing the size of the off-gas handling system. Studies indicate that minimum conditions for desorption are a temperature of 300° C and a residence time of 30 minutes. These conditions will result in the removal of 99% or more of contained polynuclear aromatic hydrocarbons (PAHs) and volatile compounds (Ayen *et al*., 1994).

Incineration technique of physical remediation of soil includes use of variety of incinerators including the rotary kiln, infrared furnaces, liquid injection, plasma arc, fluidized bed and the multiple hearths. Hazardous wastes can be volatilized and combusted in incinerators at temperature that ranges 870-1200° C in presence of oxygen. Incineration at these temperatures can break the chemical bonds of organic compounds and other substances. Vitrification is another physical method of remediation in which process includes melting of contaminated soil, wastes in order to make them nonhazardous. This process is based on the concept of heating the soil electrically to temperatures as high as 1600 to 2,000° C. Not only the melting of soil but many other applications like process sludge, mill tailing, sediments, process chemicals and other inorganic matters may also be treated effectively. The process of vitrification reduces the toxicity, mobility and volume of the soil contaminants. While the vitrified product has superior long term characteristics and permanence, it is an expensive method to employ (Oma, 1994). Soil Washing is another novel attempt to remediate the polluted soil. Soil washing uses liquids (usually water, occasionally combined with solvents) and mechanical processes to scrub soils. Solvents are selected on the basis of their ability to solubilize specific contaminants, and on their environmental and health effects. The first stage of process includes removal of coarse soil (Physical washing) and then relies on a multiple stage chemical extraction process for washing contaminants from the fine soil (Less than 2 mm size). A volume of reduction washing unit first heats the soil to 200° F and then washes it with water and surfactant or other additives. Particle size separation then occurs where the large fraction (greater than 2 mm) is assumed to be clean. Many other steps are the followed in the process to remove contaminants in the soil (Masters et. al., 1991). Several stages of particle size separation, surfactant washing, ion exchange separation, and air drying can be performed by a mobile washing system (Kim, 1993).

Soil flushing is an important innovative remediation technology that floods contaminated soils with a solution that moves the contaminants to an area where they can be removed. Soil flushing is accomplished by passing an extraction fluid through in-place soils using an injection or infiltration process. Contaminated groundwater and extraction fluids are captured and pumped to the surface using standard groundwater extraction wells. Recovered groundwater and extraction fluids with the adsorbed contaminants may need treatment to meet the appropriate discharge standards before being recycled or released to local, publicly owned, wastewater treatment works or receiving streams (Khan *et al*., 2004). This technique can be apply for all types of soil contaminants. Stabilization / solidification method of physical remediation generally refers to reduce a chemical of radiological hazard by converting the waste into its least soluble, mobile or toxic form. Stabilization generally refers to the process that reduces the risk posed by a waste by converting the contaminant into a less soluble, immobile, and less toxic form. Solidification refers to a binding or encapsulation of the waste in to a high –integrity structure (Khan *et al*., 2004).

Vapor stripping technology involves the poisoning of a well through the contaminated region and use of a vacuum to draw air down through soil and up the well. This technology is applicable to the removal of volatile and semi volatile organic compounds from the soil. The air extracted from the well is routed through a demister to remove excess water and then a bank of filters to remove the volatile organics, after which it is vented to the atmosphere. The environmental impacts of this technique are low and the costs are typically much lower than other technologies (Wilson and Clarke, 1994). `Electrokinetic remediation is one of the new physical remediation technologies. I this, electrodes are implanted in the soil and a direct current is imposed. Ionic species and charged particles in the soil water migrate toward one of the electrodes; the bulk water tends to migrate toward the cathode. Contaminants arriving at the electrodes then may be removed from the soil by method such as adsorption onto the electrode, precipitation at the electrode, pumping of water near the electrode (Lindgren *et al*., 1994). Electrokinetics offers the possibility of inducing a greater flow through fine-grained soils, creating contamination movement that could not otherwise be achieved (Swartzbaugh *et al*., 1990).

2. Chemical Remediation- Chemically contaminated soils can be remediated by using some advanced techniques as follows. Chemical leaching is one of the important and advanced methods of chemical remediation in contaminated soil can be washed by using fresh water, chemical reagents and other fluids and gases (Tampouris *et al*., 2001). All these helps to leach the pollutants from the soil. The heavy metals present in the soil are transferred in to liquid phase through the ion exchange, precipitation, absorption and chelation and the recovered from the leachate. Studies show that, Phosphoric acid proved to be most effective extractant of arsenic from the soil. Similarly sulphuric acid also used as a good extractant. A variety of soil pollutants including, arsenic, chromium, Zinc, cadmium, copper etc can be removed by using EDTA from the soil with ph of various ranges. The tea saponin can effectively remove acid soluble and reductive metals, which will greatly reduce the environmental risk. Chemical fixation is adding reagents or materials into the contaminated soil and using them with heavy metals to form insoluble or hardly movable, low toxic matters, thus decreasing the migration of heavy metals to water, plant and other environmental media and achieving the remediation of soil (Zhou *et al*, 2004).

The soil conditioning materials used include clays, metallic oxides, biomaterials, etc. Hodson *et al* (2004) evaluated the ability of bone meal additions to immobilize pollutant metals in soils and reduce metal bioavailability through the formation of metal phosphates has been evaluated. Zhang *et al*. (2009) evaluated the chemical fixation efficiency of phosphate rock, furfural dreg and weathered coal on the contaminated soil. The results showed that three conditioning agents could reduce the concentration of Cu, Zn, Pb and Cd at some degrees. The chemical fixation could remediate the soil with low concentration contaminant, however, the bioavailability of fixed heavy metals may be changed with the environmental condition changing (Bolan *et al*., 2003). In addition, the use of conditioning agents could change the soil structure at some degrees and have effects on the microbes in soil. In situ Chemical Immobilization can be carried out by introducing treatment chemicals into the ground by various means. If soluble chemicals are used, they can be applied by saturating the soil with the chemical solution. This fluid application may be carried out at a high rate by surface flooding the site or more gradually by spraying and allowing the solution to drain freely into the soil. The variation in application rate will affect the period of soil exposure to the treatment material, the degree of void filling accomplished, and the amount of air present in the soil during the treatment period. A complementary confinement or pumping system may be appropriate if the soluble treatment chemical has undesirable environmental effects or is worth recycling due to high chemical costs (Czupyrna *et al*., 1989)

Chemical extraction is a remediation method which does not destroy wastes but is a means of separating hazardous contaminants from soils, sludges, and sediments, thereby reducing the volume of the hazardous waste that must be treated. Physical separation steps are often used before chemical extraction to grade the soil into coarse and fine fractions, with the assumption that the fines contain most of the contamination. Physical separation can also enhance the kinetics of extraction by separating out particulate heavy metals, if these are present in the soil. Acid can also be used as the extractant. Acid extraction uses hydrochloric acid to extract heavy metal contaminants from soils. In this process, soils are first screened to remove coarse solids. Hydrochloric acid is then introduced into the soil in the extraction unit. The residence time in the unit varies depending on the soil type, contaminants, and contaminant concentrations, but generally ranges between 10 and 40 minutes. The soil-extractant mixture is continuously pumped out of the mixing tank, and the soil and extractant are separated using hydrocyclones. When extraction is complete, the solids are transferred to the rinse system. The soils are rinsed with water to remove entrained acid and metals. The extraction solution and rinse waters are regenerated using commercially available precipitants, such as sodium hydroxide, lime, or other proprietary formulations, along with a flocculent that remove the metals and reforms the acid. The heavy metals are concentrated in a form potentially suitable for recovery. During the final step, the soils are dewatered and mixed with lime and fertilizer to neutralize any residual acid.

Oxidation, in waste remediation, refers to the movement of a contaminant to a more oxidized or more environmentally benign state. Oxidation technologies form part of the many treatment alternatives that have the capability to reduce or eliminate both the volume and toxicity of contaminants. Photodegradation with Uranium Recovery technique of chemical remediation was developed by Dodge and Francis (1994). This is a process to recover toxic metals including uranium from soils using citric acid and visible light photodegradation. The studies of Dodge and Francis showed that, although the uranyl citrate complex is not biodegradable, the photochemical degradation results in the precipitation of uranium as an insoluble oxide. The citric acid and contaminated soil or sludge is first treated with bacteria which degrades, free of complexed citric acid, to carbon dioxide and water. The supernatant containing the uranium-citrate complex is then separated and subjected to photodegradation for uranium recovery.

3. Biological Remediation- The polluted soil are treated and remediated by using biological components including plants, animals and microorganisms is known as biological remediation. It includes phytoremediation, bioremediation and the combining remediation.

The phytoremediation is the use of living green plants to fix or adsorb contaminants, and cleaning the contaminants or making their risk reduction or disappearance. It is an expanding area of environmental science that holds great promise for cleaning up the contaminated soils. Phytoremediation could be achieved by three common methods, phytostabilization, phytovolatilization and phytoextraction (Zhitong *et al*., 2012). Phytostabilization is fixing heavy metals by plants through the adsorption, precipitation and reduction of root, and thus reducing their migration and bioavailability and preventing them migrating into the groundwater and food chain (Wang *et al*., 2009). Phytovolatilization is transferring the heavy metals into volatile state or adsorbing the metals and transferring into gaseous matter, using special matters secreted by root (Watanabe, 1997). Bizily *et al*. (1999), genetically engineered the plant *Arabidopsis thaliana*, in order to make it more resistant to mercury contamination. It was achieved by inserting a bacterial gene merBpe in to the plant. It was found that the plants possessing the above gene have shown resistance to mercury while, Plants lacking the merBpe gene were severely inhibited or died at the same mercury concentrations.

Phytoextraction is adsorbing the heavy metals using tolerant and accumulating plants, and then transferring, storing at the overground parts. Studying the adsorption characterization of different plants and screening high uptake plants is the key of this technology. Controlling the contamination by using microorganisms is the method of biological remediation. The microorganisms cannot degrade and destroy the heavy metals, but can affect the migration and transformation through changing their physical and chemical characterizations. These remediation mechanisms include extracellular complexation, precipitation, oxidation-reduction reaction and intracellular accumulation. Microbial leaching is a simple and effective technology for extracting valuable metals from low-grade ores and mineral concentrates. Microbial leaching has some potential for remediation of mining sites, treatment of mineral industrial waste products, detoxification of sewage sludge and for remediation of soils and sediments contaminated with heavy metals (Bosecker, 2001). Animal remediation is according to the characterization of some lower animals adsorbing heavy metals, degrading, migrating the heavy metals and thus removing and inhibiting their toxicity. The earthworms are the effective animal used for the same. Studies showed that, the earthworm could accumulate Pd effectively. The accumulation amount increased with the Pb concentrations increasing (Kou, 2008).

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