Sunflower Heavy Metal Phytoextraction on Sewage Sludge

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Abstract: Sewage treatment results in two components: the effluent which is usually disposed of at the required regulatory standards; and sludge which is disposed of by utilization in Agriculture, tipping on controlled landfill sites, disposal at sea or by incineration. The application of sewage sludge to land is an effective disposal method. Not only does it provide a solution to the sludge disposal problem, but it is beneficial to agricultural productivity. Typically, large volumes of sludge are produced in sewage treatment plants which is sold to farmers at cheap prices. Despite the perception of sewage sludge being 'dirty fertilizer' it contains useful amounts of plant nutrients such as carbon, nitrogen and phosphorous. When used, less chemical fertilizers are required and the nutrients are released gradually for plant uptake as compared to the more soluble chemical fertilizers. On the other hand, sewage sludge contains toxic heavy metals that may have adverse effects to human life when consumed. Phytoextraction is a process in which certain plants have the ability to absorb, translocate and store toxic contaminants from a soil matrix into their root and shoot tissue. Conventional methods of removing heavy metals are locally inaccessible, phytoextraction is useful technology for local removal of heavy metals in manure sewage sludge. Atomic absorption spectroscopy analysis was used to determine the phytoextraction capability of sunflowers growing in controlled sludge amended soils. Results indicate a significant reduction in heavy metal levels after the phytoextraction process.

Keywords: Hyperaccumulator, phytoextraction, phytoremediation, sewage sludge, sunflower

INTRODUCTION

The use of sewage sludge as fertilizer can be dated as far back as 1550 in Bunzlau, Germany [11]. In the 1980's American sewage sludge used to be dumped into the Atlantic and Pacific Oceans. Later, scientists discovered that the practice was killing marine life. This led Congress to ban ocean dumping, forcing the country to find an alternative method for disposing of sewage sludge. The result was sewage sludge application to land as fertilizer [2]. Presently, sewage sludge is used as fertilizer in western countries in the form of bio solids, which is sludge that has been conditioned and processed for Agricultural reuse. Locally, sewage sludge has been used by farmers as a result of poverty. The average Kenyan farmer who lacks the ability to purchase commercial chemical fertilizers may opt for sewage sludge which is cheaper and is of good nutrient value.

Heavy metals in sewage are mainly as a result of industrial effluents. The use of sewage sludge as manure therefore may result in soil contamination with heavy metals. These heavy metals which accumulate in the soil when sewage sludge is used as fertilizer, get into the food chain and eventually into human and animal bodies leading to several health effects and even death of human beings and animals [33].

Reference [13] revealed that final effluents from Dandora Wastewater Treatment Plant contained cadmium, manganese and lead levels above the Kenya guideline standards of 0.01, 0.2 and 0.01 mg/L respectively. In his study, cadmium ranged from 0.025 to 0.033 mg/L, manganese concentrations were from 0.085 to 0.748 and lead concentrations were between 0.083 and 0.332 mg/L. A study by Maina David from the University of Nairobi, Kenya, showed that chromium, titanium, nickel, zinc, lead, gallium and rubidium were present in sewage sludge samples from Kariobangi sewage treatment works in excess of safe levels. Reference [20] discovered high levels of lead, mercury and cadmium contamination in soils in Dandora area. Reference [22] determined that extremely high levels of zinc, copper, lead, cadmium and mercury were present in sewage sludge from sewage treatment sites in Kariobangi, Dandora, Kiambu, Limuru, Kiserian and Ngong. However, in all the above studies, options that could be used locally to remove these heavy metals were not investigated.

Recently, several studies have demonstrated the potential of using plants in phytoextraction, a process that uses plants to remove contaminants from soils [9].

Phytoextraction is an accessible and cheap technology that could be used locally to remove heavy metals from sewage sludge.

PHTYOEXTRACTION AS A METHOD OF HEAVY METAL EXTRACTION

Phytoextraction also known as phytoaccumulation is a process that uses plants to remove contaminants from soil.

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The plants used for this process are called hyperaccumulators, which are plants that absorb unusually large amounts of contaminants in comparison to other plants. During phytoextraction, the plants absorb contaminants through their roots and store them within their roots or transport them into the stems. The plant continues to absorb contaminants from the soil until it is harvested. After harvest the soil contaminant levels are brought down. The harvested plants are usually incinerated with the ash disposed of in a hazardous waste landfill. The process may be repeated as necessary to bring the contaminant levels down to allowable limits.

Reference [3] used a tea herb, *Orthosiphon stamineus* B. for phytoextraction of heavy metals in soils amended with sewage sludge. A decrease in the concentrations of cadmium, chromium, zinc, copper and lead in the amended soils after the phytoextraction process was observed.

Reference [19] used water cabbage, *Pistia stratiotes* to study remediation of waters that had been polluted with heavy metals. The plant was grown in high concentration solutions of lead, nickel and chromium. The plants were grown in these solutions for 21 days before harvesting. Metal analysis was done using atomic absorption spectroscopy. Uptake of the metals 300 times over what is obtainable in normal plants was observed.

Reference [28] used anchored hydrophyte, *Hydrocotyle umbellata* L. for the removal of toxic metals from tannery sludge effluent obtained from a tanneries wastewater treatment plant. *Hydrocotyle umbellata* L. showed a good tolerance for prepared concentrations of wet tannery sludge. The plants were harvested after 30, 60 and 90 days. Accumulation of toxic metals in the plants were observed to have significantly increased, with a higher amount observed in the roots than in the shoots.

Reference [16] used willow, *Salix viminalis* L. in purifying sewage sludge treated soils. In the study, it was realized that willow could accumulate ten times more cadmium than was the concentration in sewage sludge or soil.
For a plant to extract heavy metals from soil the following processes take place:

- The metal is dissolved into a substance that the plant can absorb;
- The plant roots absorb the heavy metal;
- The plant chelates the metal to protect itself and to make the metal more mobile;
- The plant moves the chelated metal to storage;
- The plant adapts to damages caused by the metal's transportation and storage.

With the appropriate plant combination for sewage sludge remediation, nutrient content in the sewage sludge is maintained at favourable levels. Thereby, allowing for good potential in agricultural land application.

SUNFLOWER AS A PHTYOFILTER

Sunflowers may be used to extract heavy metals from sewage sludge due to their heavy metal uptake capability which is higher than that of other plant species [26], their adaption to soil and climate characteristics and the ease with which they are maintained. Reference [18] reported that the success of phytoextraction depends on the ability of the plant to tolerate large quantities of the toxins without affecting the plant's growth and productivity. All through the study, the sunflowers were observed to grow steadily and productivity was not affected. Reference [31] further reports that the success of phytoextraction depends on the ability of the plant to uptake and translocate toxins to its above ground biomass. Sunflowers used in the study were effective with this regard as a larger concentration of heavy metals was observed in the shoot than in the roots. As illustrated below, cadmium levels were observed to be higher in the shoots than in the roots.

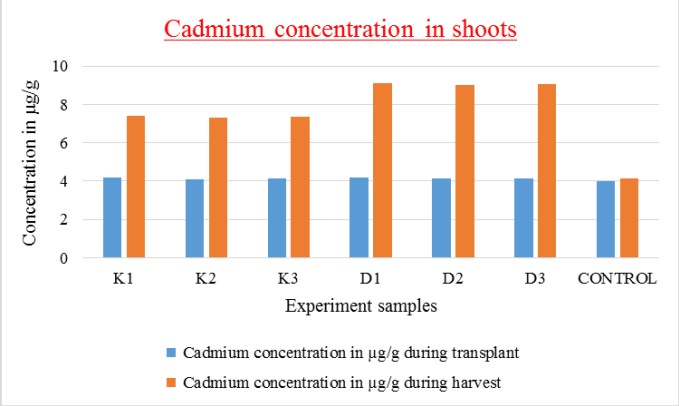

Fig 1 Cadmium concentration in shoots

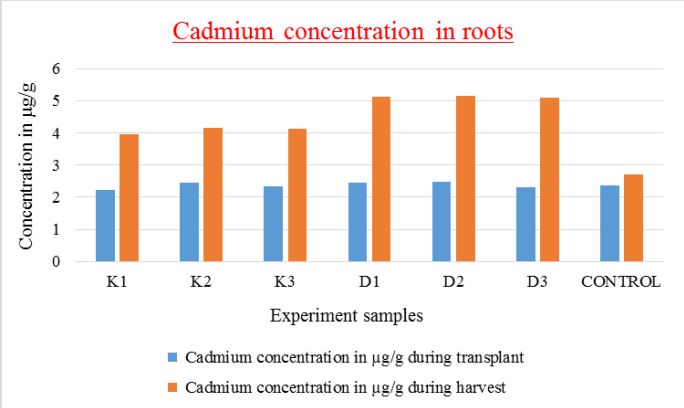

Fig 2 Cadmium concentration in roots

CONCLUSION

Sewage sludge can be considered as an organic fertilizer for agriculture and forestry because it contains high concentrations of nitrogen and phosphorus which are needed by plants. Sunflower phytoextraction of heavy metals in sewage sludge is a prosperous venture as the sewage sludge is made safe for Agricultural use by the sunflowers' ability to extract and store the heavy metals within their biomass. The overall efficiency was based on analytical findings in the study.

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