Bioremediating Activity of Sunflower (*Helianthus Annuus l.*) on Contaminated Soil from Challawa Industrial Area, Kano-State Nigeria

***A.A.H Adejube., A.Anteyi., F.H.Garba., O.A.Oyekunle, & F.O.Kudaisi.**
Nigerian Institute of Leather and Science Technology,
P.M.B 3329, Kano Extension Centre,
Zawaciki, Kano-State
*adejubehenrynilest@gmail.com

Abstract
Industrial waste water affects the quality of the soil. Great efforts have been made to reduce pollution sources and remediating the polluted soil and water resources. Phytoremediation is an effective and affordable technological solution used to extract or remove inactive metals and metal pollutants from contaminated soil and water. This technology is environmental friendly and potentially cost effective. The common organisms used are bacteria, fungi, algae, planktons, protozoan and plants. This paper aimed to provide information on the potential of sunflower in remediating contaminated soil by heavy metals for a period of 30 days, 60 days and 90 days. The results showed that the removal of heavy metals in the polluted soil varied based on the duration of sunflower plant (30days<60days<90days).The concentration of accumulated heavy metals levels in the plants tissues (root, stem and leaves) for the conducted research were ''Leaves>Stems>Roots''. This shows the potential of the phytoremediating activity of sunflower for the treatment of contaminated soil by heavy metals.

Keywords: *Bioremediation, hazardous chemicals, organisms, pollution, soil and water.*

1. Introduction

Soil remediation is the return of soil to a state of ecological stability with regard to the plants communities it supports or supported prior to the condition /disturbances. Conventional technologies involve the removal of heavy metals from polluted soils by transportation to laboratories, soil washing with chemicals to remove toxic elements, and finally substitute the soil at its original location or disposing it off as hazardous waste [2, 3].

Land and water are natural resources on which the anthropogenic activities and civilization of mankind depend upon; they have been subjected to maximum exploitation and severely degraded or polluted due to industrial activities. The pollution includes point sources such as emission, effluents and solid discharge from industries, vehicle exhaustion and metals from smelting and mining, and nonpoint sources such as soluble salts (natural and artificial), use of insecticides/pesticides, disposal of industrial and municipal wastes in agriculture, and excessive use of fertilizers [4,10]. Each source of contamination has its own damaging effects to plants, animals and ultimately to human health, but those that add heavy metals to soils and waters are of serious concern due to their persistence in the environment and carcinogenicity to human beings. They are not biodegradable but only converted from one organic complex state to another [6, 7].

Continuous efforts have been made to adopt technologies that are easily affordable for soils and water to free from pollution. Physicochemical approaches have been widely used for remediating polluted soil and water, especially at a small scale. A lot of difficulties are being encounter due to high costs and side effects for a large scale of remediation. The use of plant species for cleaning polluted soils and waters named as Phytoremediation is a cheaper technology. Numerous plant species have been identified and tested for their traits in the uptake and accumulation of different heavy metals. Mechanisms of metal uptake at whole plant and cellular levels have been investigated. Progressive attention has been made in the mechanistic and practical application aspects of Phytoremediation. [8, 9, 11, 14].

Heavy metals that have been identified in the contaminated environment include Cu, Cd, Pb, Cr, Mn, Fe and Zn. The presence of heavy metals may vary from site to site, depending upon the source of individual pollutant. Excessive uptake of metals by plants may produce toxicity in human nutrition, and cause acute and chronic diseases. For instance, Cd and Zn can lead to acute gastrointestinal and respiratory damages and acute heart, brain and kidney damages. High concentrations of heavy metals in soil can negatively affect crop growth, as these metals interfere with metabolic functions in plants, including physiological and biochemical processes, inhibition of photosynthesis, and respiration and degeneration of main cell organelles, even leading to death of plants [6, 23].

The techniques of remediating heavy metals from contaminated soils are the most difficult task, particularly on a large scale. The soil is composed of organic and inorganic solid constituents, water and mixture of different gases present in various proportions. The mineral components vary according to parent materials on which the soil had been developed under a particular set of climatic conditions. Therefore, soils vary enormously in physical, chemical and biological properties. Soil water movement is controlled by physical properties, such as soil structure and texture. The soil moisture has great bearing in controlling solute movement, salt solubility, chemical reactions and microbiological activities and ultimately the bioavailability of the metal ions. Different approaches have been used or developed to mitigate/reclaim the heavy metal polluted soils and waters including the landfill/dumping sites. These may be broadly classified into physicochemical and biological approaches. [10, 23].

The physicochemical approach includes excavation and burial of the soil at a hazardous waste site, fixation/inactivation (chemical processing of the soil to immobilize the metals), leaching by using acid solutions or proprietary leachate to desorbs and leach the metals from soil followed by the return of clean soil residue to the site, precipitation or flocculation followed by sedimentation, ion exchange, reverse osmosis and microfiltration [20, 21].

Biological approaches of remediation include: (1) use of microorganisms to detoxify the metals by valence transformation, extracellular chemical precipitation, or volatilization [some microorganism can enzymatically reduce a variety of metals in metabolic processes that are not related to metal assimilation], and (2) use of special type of plants to decontaminate soil or water by inactivating metals in the rhizosphere or translocating them in the aerial parts. This approach is called Phytoremediation, which is considered as a new and highly promising technology for the reclamation of polluted sites and cheaper than physicochemical approaches [6, 19].

Phytoremediation, also referred to as botanical bioremediation (involves the use of green plants to decontaminate soils, water, sediments and air; such plants are called pollution mitigators. It is an emerging technology that can be applied to both organic and inorganic pollutants present in the soil, water or air [1, 5, 20]. However, the ability to accumulate heavy metals varies significantly between species and among cultivars within species, as different mechanisms of ion uptake are operative in each species, based on their genetic, morphological, physiological and anatomical characteristics. There are different categories of bioremediation which include phytoremediation, phytoextraction, phytofiltration, phytostabilization, phytovolatization and phytodegradation, depending on the mechanisms of remediation. Phytoremediation is the use of green plants to remove hazardous waste from contaminated site. Phytoextraction involves the use of plants to remove contaminants from soil. The metal ion accumulated in the aerial parts that can be removed to dispose or burnt to recover metals. Phytofiltration involves the plant roots or seedling for removal of metals from aqueous wastes. In phytostabilization, the plant roots absorb the pollutants from the soil and keep them in the rhizosphere, rendering them harmless by preventing them from leaching. Phytovolatization involves the use of plants to volatilize pollutants from their foliage such as Se and Hg. Phytodegradation means the use of plants and associated microorganisms to degrade organic pollutants. Some plants may have one function whereas others can involve two or more functions of bioremediation [4, 6, 17, 19, 20, 22].

Sunflower (*Helianthus annuus* L.) is one of the most promising environmental crops that is being used in diverse situations for environmental clean-up since it grows very fast, have large number of biomass and it can hyper accumulate heavy metals [14,22].Sunflower has been a popular ornamental. However, in recent years its importance as environmental crop is being increasingly recognized, dehulled seeds are used as poultry feed. Agronomic experiments conducted on a farm research site in India using recycles organic manure from integrated farming system (cows, goats, poultry, etc…) have substantially increased the growth and yield. Agronomic trials in typical Mediterranean climate where winter precipitation averages about 500 mm, brackish water irrigated sunflower crops performance and productivity are satisfactory contributing to sustainable agriculture and also find alternative solution to drought [14, 18, 22].

This research focus on the phytoremediating activity of sunflower on soil collected from a contaminated area within Challawa industrial estate to remove heavy metals (Cu, Cd, Pb, Cr, Mn, Fe, and Zn).The 30, 60 and 90 days period of monitoring were carried out in greenhouse.

2. Materials and Methods

The study area is Challawa Industrial Estate (Lat.11^{o}52' 41''N,Long.08^{o} 28' 09''E) 515m above sea level. It is located in Kumbotso Local Government area of Kano - State (Lat.11^{o}59' 18.3'' N, Long.08^{o}32' 05.8''E) 418m above sea level in the northern part of Nigeria. Challawa Industrial Estate is one of the place in Kano where most of industrial activities is in practises amongst are; tanneries, textile, cosmetics, polyvinyl chlorides (PVC) products, food and packaging industries. The soil sample was collected at a depth of 0-20 cm from the study site and kept in a big pot plastic container and transported to the laboratory for experimental analysis. The soil in the plastic container was sealed immediately after collection from the field such that the soil moisture could be maintained. The soil was incubated in the greenhouse at a temperature interval of 18-25^{o}C for some weeks. Soil moisture was adjusted to 80^{o}C of water holding capacity and maintain by periodical addition of water after weighing the pot. After incubation and bringing the soil to equilibrium, the soil was air-dried, grounded and sieve to pass through a 2 mm mesh.

The measurement of soil particle size was done by hydrometer method (Day, 1965), soil organic content by Walkley and Black Method (Olsen & Sommers, 1982), the exchangeable acidity by NaOH titration method was used (Mclean, 1982), the exchangeable bases by ammonium acetate method was used (Thomas, 1982), the soil pH was determined by electronic P^{H} meter (Mclean, 1982), total nitrogen N was measured by Kjeldal Method (Bremer, 1996).The total concentration of heavy metals in the experimental and control soil by Aqua Regia method and measured by Atomic Absorption Spectrophotometry (AAS).

2.1 Phytoremediating Tests

The research was carried out in greenhouse (Figure 3).The sunflower seeds were planted directly in the contaminated soil. The pots used in this experiment had a surface area of 900 cm^2, 500 cm^3 of industrial effluents were added to each pot with five seeds being planted in

each. After seeds germination and one of the seedlings in each pot attained a height of 20 cm, the plants were thinned to one per pot.
The phytoremediating tests were studied for 30, 60 and 90 days respectively of which the soil moisture content was maintained at 80% of water holding capacity. At the end of 30,60 and 90 days, the plants were harvested for analysis. The plants dry analysis was performed in an oven at a temperature of 60^{O}C for four days. All the results from the phytoremediating activity were expressed as an average of triplicate.

Fig.1: Sunflower

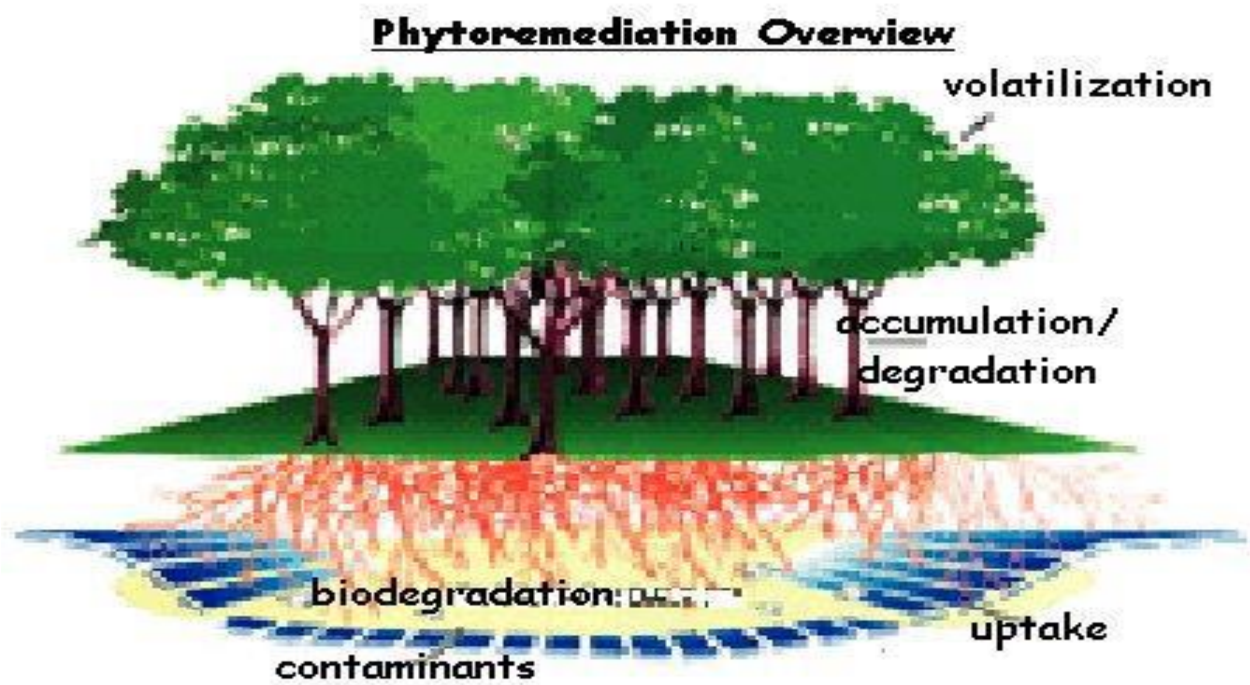

Fig.2: The mechanisms of heavy metals uptake by plant through phytoremediation technology.

Fig. 3: Greenhouse's views

''3. Result and Discussion''

Table 1 and 2 show the physical, chemical and heavy metals present in the experimental soil and control. The soil was sandy-silty with a P^H of 7.25 in water. The water holding capacity was low with insignificant clay content. The soil nutrient such as phosphorous and nitrogen serve as means of nutrition to the plants. Heavy metals in the contaminated soil (*Cd, Mn, Cr, Cu, Fe, Pb and Zn*) were beyond the threshold limit compared to WHO standard set for industrial activities.

After 30, 60 and 90 days of monitoring, the plants were harvested for analyses, the efficiency of heavy metals removal from the soil by sunflower were 90>60>30 days respectively due to the duration of the plants in the contaminated soil. The levels of accumulation of heavy metals in the plants system were represented in (fig.4a, 4b and 4c).The study reveal that heavy metals were more concentrated in the leaves follow by stem and lastly root as a result of volatilization, accumulation/degradation (fig.2).According to the study carried out by some researcher's shoot biomass and root of sunflower were significant less in contaminated soil. Heavy metals accumulation and distribution in plants depends on different factor such as environmental, type of element, chemical form, bioavailability, oxidation-reduction potential, pH ,cations exchange capacity, solute oxygen, temperature and root distribution [2, 13].

The study conducted by Chen et al [26] for 53 days also express the removal of heavy metals by sunflower for phytoremediation as (Zn=13%,Cu=16%,Cd=23% and Pb=4%) respectively. Research work was also studied by Usman and Mohamed on using sunflower for soil phytoremediation for 60 days. They showed that the percentage removal of heavy metals (Zn=2&4%, Cu=1.6&3%, Cd=2.6&4%, and Pb=0.4&1.3%) were varied [1].In this study, the duration of phytoremediating activity of sunflower on contaminated soil was achieved and suggestion of sunflower for contaminated soil protection.

Table 1: Experimental Soil Properties

	VALUE	UNITS
SOIL CHARACTERISTICS		
Soil texture	**Sand silt**	
Sand	**45.5**	**4.32 %**
Silt	**34.5**	**3.28 %**
Clay	**6.75**	**0.64 %**
CEC	**40.00**	
P^H^	**7.24**	**Molkg^{-1}**
EC	**833.00**	**µs^{-1}**
OC	**120.00**	**Mgkg^{-1}**
Total Nitrogen	**6.00**	**Mgkg^{-1}**
EXCHANGEABLE CATION		
Potassium (K) **Calcium (Ca)** **Magnesium (Mg)** **Sodium (Na)** **Aluminium (Al)**	**0.45** **2.50** **1.60** **0.32** **1.20**	**Mgkg^{-1}** **Mgkg^{-1}** **Mgkg^{-1}** **M gkg^{-1}** **M gkg^{-1}**
TOTAL HEAVY METALS CONCENTRATION		
Iron (Fe) **Manganese (Mn)** **Copper (Cu)** **Zinc (Zn)** **Cadmium (Cd)** **Lead (Pb)**	**40.10** **1.60** **13.35** **20.50** **25.00** **12.00** **30.00**	**Mgkg^{-1}** **Mgkg^{-1}** **Mgkg^{-1}** **Mgkg^{-1}** **Mgkg^{-1}** **Mgkg^{-1}** **Mgkg^{-1}**

Chromium (Cr)		

Table 2: Control Soil Properties.

	VALUE	**UNITS**
SOIL CHARACTERISTICS		
Soil texture	**Sand silt**	
Sand	**30.50**	**3.50 %**
Silt	**25.00**	**2.90 %**
Clay	**5.50**	**0.60 %**
CEC	**30.00**	**$Molkg^{-1}$**
P^H	**7.20**	
EC	**700.00**	**μs^{-1}**
OC	**90.00**	**$Mgkg^{-1}$**
Total Nitrogen	**8.00**	**$Mgkg^{-1}$**
EXCHANGEABLE CATION		
Potassium (K)	**3.00**	**$Mgkg^{-1}$**
	4.50	
Calcium (Ca)	**2.65**	**$Mgkg^{-1}$**
	2.50	
Magnesium (Mg)	**1.60**	**$Mgkg^{-1}$**
Sodium (Na)		**$M gkg^{-1}$**
Aluminium (Al)		**$Mgkg^{-1}$**
TOTAL HEAVY METALS CONCENTRATION		

Iron (Fe)	**25.10**	**$Mgkg^{-1}$**
Manganese (Mn)	**1.00**	**$Mgkg^{-1}$**
Copper (Cu)	**10.30**	**$Mgkg^{-1}$**
Zinc (Zn)	**15.50**	**$Mgkg^{-1}$**
Cadmium (Cd)	**15.00**	**$Mgkg^{-1}$**
Lead (Pb)	**9.50**	**$Mgkg^{-1}$**
Chromium (Cr)	**20.00**	**$Mgkg^{-1}$**

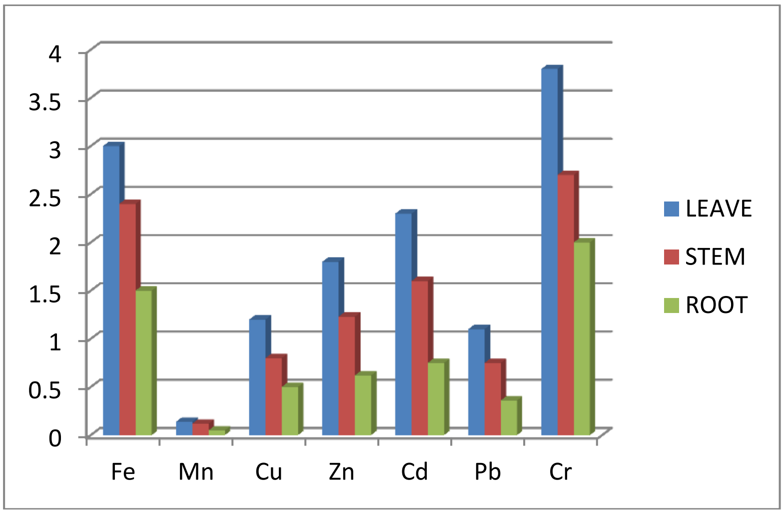

Fig.4a: Accumulation of heavy metals in plant tissues after 30 days.

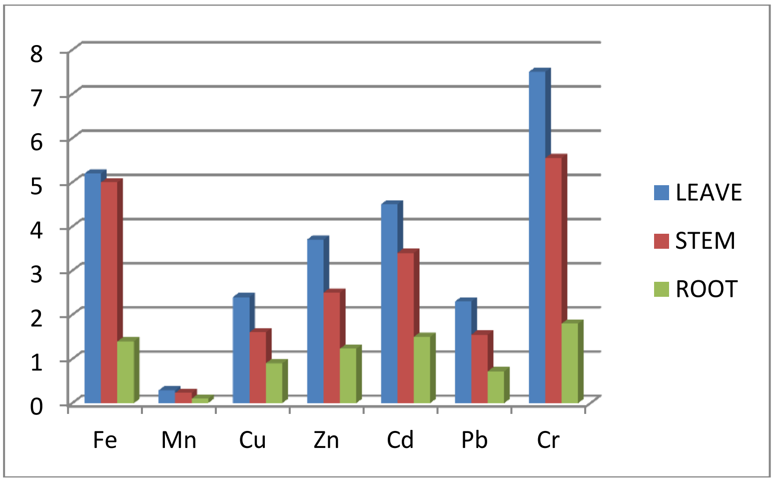

Fig.4b: Accumulation of heavy metals in plant tissues after 60 days.

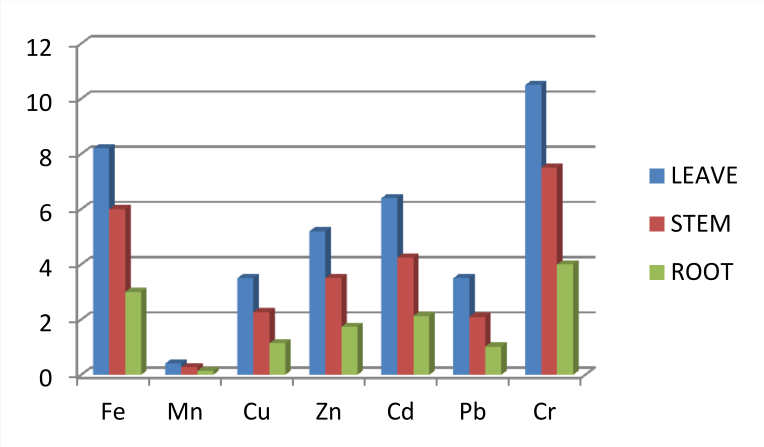

Fig.4c: Accumulation of heavy metals in plant tissues after 90 days.

Conclusion

Sunflower is regarded as significant plant for phytoremediation of polluted soil by heavy metals and control their concentration since it has ability to grow very fast, have large number of biomass and it can hyper accumulate heavy metals. The heavy metals removed from the contaminated soil were varied based on the duration of sunflower plants in the soil. Phytoremediating activity of sunflower had proved to be low cost, convenient, and efficient for the control of polluted soil. However, the application of native and cultivated plants for the remediating of polluted soils with industrial waste need to be taking into cognisance with more research and future evaluations.

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