©IDOSR PUBLICATIONS
International Digital Organization for Scientific Research ISSN:2550-794X
IDOSR JOURNAL OF SCIENTIFIC RESEARCH 2(3) 36-42, 2017.

Phytoremediation: The Best and Immediate Panacea to Lead Toxicity in Enyigba Derelict, Nigeria

Oti, Wilberforce J. O.

Department of Industrial Chemistry, Ebonyi State University, Private Mail Bag 053, Abakaliki, Ebonyi State, Nigeria. E-mail: drwilberforceoti@gmail.com

ABSTRACT

Samples of water and soils from Enyigba lead mine derelict is characterized by high levels of lead and other toxic metals. This is as a result of anthropogenic activities involving extraction and processing of lead. Presence of lead in the water, soil and plants pose a big threat to man as a member of the ecosystem. Toxicological effects of lead on humans include inhibition of hemoglobin formation, sterility, hypertension and mental retardation in children, among others. Remediation of polluted land involves physical methods such as excavation and mechanical separation processes, chemical method such as extraction, liming, pH stabilization, complexing, oxidation and reducing processes and biological methods such as bioremediation and phytoremediation. Many of these remediation processes are too expensive and time consuming. Of all these processes, phytoremediation which employs the engineered use of green plants and their associated micro biota for the in-situ treatment of contaminated soil and ground water is considered one of the best remedies. It is cost effective, and aesthetically pleasing as the plants can be easily monitored and metals absorbed by the plants may be extracted from harvested plant biomass and then recycled. This paper reviews phytoremediation as a solution to lead toxicity in Enyigba lead mine derelict located in Ebonyi State, Nigeria.

Keywords: Phytoremediation, lead, Enyigba, toxicity and environment

INTRODUCTION

The effect of industrialization leads to extraction and distribution of mineral substances from theirnatural deposits to other places as a result of anthropogenic activities of man. Metals environmentally speaking are classified into trace and heavy metals. Unlike organic pollutants, metals are non-biodegradable as they bioaccumulate and biomagnify from one trophic level to another [1]. In many Nigerian cities and rural areas, there is inefficient environmental control system which encourages contamination of immediate surroundings and the ground water with heavy metals. Heavy metals such as lead has been mined, smelted and used in other industrial processes in different locations in Nigeria. The tailings, smelter slag and other wastes left behind often pollute the agronomic soil and also surface and ground water. In addition metal contaminants are carried with soil particles swept away from the initial areas of pollution by wind and rain [2].

Indiscriminate mining is predominant in Nigeria, especially in the rural and sub-urban areas where the miners rarely follow government policies for environmental preservation. This is the exact picture of the lead-zinc derelict mine at Enyigbalocated about 14km South of Abakaliki, the capital of Ebonyi State, Nigeria. Mining commenced in 1925 and later stopped due Nigerian civil war and unfavourable business climate, among other factors [3]. Since then, land within the mine vicinity has been converted to cultivable soils by local inhabitants. As at the moment, farmers are still actively cultivating their crops around the mine waste and children are seen fetching water from the pit and playing around the mine and this may predisposed them to lead related health problem. Aside direct contact of humans to lead, lead in the soil may undergo a biochemical processes which mobilizes it metals in the soil to pollute water supplies and impact on food chains. Plants growing in apolluted environment can accumulate the toxic metals at high concentrations causing serious risk to human health when consumed.

Metals: They are, generally, natural components of the Earth’s crust and therefore are major constituents of soil.Not all traces of heavy metals in plants and animals are the results of human activity. Some arise through the absorption processes of naturally occurring soil components, as has been shown for cadmium in particular. Purely theoretically, every 1000 kg of normal soil contains about 200g chromium, 80g nickel, 16g lead, 0.5g mercury and 0.2g cadmium [4].

Heavy metals: Heavy metal is not well defined (John, 2002). Many different definitions have been proposed based on parameters such as density (>5g/cm^3), atomic number or atomic weight, and chemical properties or toxicity [2]. It includes the transition metals, some metalloids, lanthanides, and actinides. Heavy metals such as lead, cadmium, iron and manganese are always part of life due to nature and human activities [5]. Heavy metals are very harmful because of their non-biodegradable nature, long biological half-lives and their potential to accumulate in different body parts. Edible plants absorb these metals from the soil as well as from the deposits on the parts of vegetables and fruits exposed to air from polluted environment. Even low concentrations of heavy metals in the food chain have damaging effects to man and animals because there is no effective mechanism for their elimination from the body. For example, heavy metals such as Pb, Cd and Hg are already toxic even in very low concentrations.

Trace Metals: This includes elements including Zn, Fe, Cu, Cr Mg, Li, Ni, V, Mn, Se and Co which are necessary part of physiology and nutrition for metabolic function of living things. Trace metals are present in animal and plant cells and tissue though in extremely small quantities. However ingestion of excess quantities of trace metals is toxic to human health.

They are a necessary part of nutrition and physiology [6].

Lead: Lead occurs naturally in minute amounts within the Earth's crust. Itis a soft, malleable poor metal with atomic number of 82. Ionic lead (Pb^{2+}), lead oxides and hydroxides and lead-metal oxyanion complexes are the general forms of lead that are released into the soil, groundwater and surface waters. The most common form of lead isPb^{2+} and it isvery reactive [7]. The predominant insoluble lead compounds are lead phosphates, lead carbonates (formed when the pH is above 6) and lead hydroxides. Lead sulphide is the most stable solid form within the soil matrix and forms under reducing conditions. Under anaerobic conditions (tetramethyl lead) can be formed due to microbial alkylation [8].Many industrial processes result to lead contamination such as lead mining, smelting, manufacture of pesticides and fertilizers, dumping of municipal sewage and the burning of fossil fuels that contain a lead additive. Products containing lead include paints, ceramic glazes, television glass, ammunition, atteries, medical equipment (i.e. X-ray shields, foetal monitors), and electrical equipment. The uses of lead for roofing and the production of ammunition have increased from previous years. Lead pipe, lead battery recycling sites [9].

Lead in the Environment: Lead is the main contaminant of plants in Enyigba, Lead is found in all food at varying amounts as it enters food chain via plant uptake. Lead accumulates in the body organs especially the brain, which may lead to poisoning (plumbism) or even death [10].Lead poisoning of children and youths in Zamfara State, resulted to the death of 163 people between March and June 2010 [11].Lead poisoning was caused by the illegal extraction of ore by villagers. Victims were poisoned through hand-to-mouth process and by contact with contaminated tools and water [12]

Pathways of Exposure to Lead: Humans are often exposed to lead via inhalation of lead-containing car exhausts, industrial emission, ingestion of lead-based paints, ingestion of contaminated soil or dust from hand-to-mouth activities of those living in lead polluted environment. In more recent time, humans are exposed to lead via food chain by consumption of plants grown in lead environment or animal that grazed on grasses around lead mines [13].

Toxicity of Lead: Little is known about the excretion of lead, once it has been absorbed in human body. The gastrointestinal tract, kidneys, and central nervous system are adversely affected by lead. Children exposed to lead are at risk of mental deterioration, lower Intelligent Quotient, shortened attention span, hyperactivity, and impaired development while adults usually experience decreased reaction time, loss of memory, nausea, insomnia, anorexia, and weakness of the joints [14]. Lead toxicity affects the central nervous system (CNS). Common serious symptoms of CNS symptoms include tremors, mood changes, aggression, seizures, coma, and learning disabilities and mental retardation in children. Peripheral nervous system symptoms can include reduced coordination and loss of muscular control. Other lead symptoms include renal failure or kidney failure in which the kidneys fail to function properly.

METHODS OF CLEANING UP HEAVY METALS IN SOILS

There are many methods used in cleaning up heavy metals in the soil and they include

Physical Methods: the summary of physical methods include

(i) *Excavation* (physical removal of the contaminated material from a site. It is rapid and there is a complete removal of the contaminants in a contaminated site, however this method merely transfers the pollutants from one place to another);

(ii) *Mechanical separation* (where the contaminated parts of soil are separated);

(iii) *Gravitational separation* (which is based on differences in density between fractions);

(iv) *Sieve analysis* (based difference in the grain size of elements);

(v) *Magnetic separation* (based on magnetic induction). There is need to neutralize or clean the separated fraction containing the pollutants in another process [15].

Chemical Methods

(i) *Oxidation and reduction,*

(ii) *Extraction,*

(*iii)* *Precipitation* of sparingly soluble chemical compounds

(iii) *pH stabilization* [16].

(iv) *Stabilization of the metals in the Soil:*this involves adding chemicals to the soil that cause the formation of minerals that contain the heavy metals in a form that is not easily absorbed by plants and animals [17].

(v) *Diluting the heavy metal content to safe level* by importing the clean soil and mixing with the contaminated soil as an on-site management [18].

(vi) *On-site containment and barriers* by covering the soil with inert material [19].

(vii) *Immobilization of inorganic contaminant* used as a remedial method for heavy metal contaminated soils [20].

(vii) *Complexing the contaminants,* or

(viii) *Liming* toincrease the soil pH [21]

Biological methods

(i) *Bioremediation* based majorly on the use of microorganisms to reclaim especially organic polluted soils.In the recent times, it is used for detoxication of soil polluted by inorganic substances (e.g. heavy metals).

(ii) *Phytoremediation* involved the use of higher plants to stop the spread of contamination, to extract from the soi,ldegrade and remove metals, organic and inorganic contaminants [22]

PHYTOREMEDIATION

Phytoremediation is the engineered use of green plants, including grasses, forbs, and woody species, to remove, contain, or render harmless such environmental contaminants as heavy metals, trace elements, organic compounds, and radioactive compounds in soil or water [9]. It takes advantage of the unique and selective uptake capabilities of plant root systems, together with the translocation, bioaccumulation, and contaminant storage/degradation abilities of the entire plant body. Phytoremediation includes all plant-influenced biological, chemical, and physical processes that aid in the uptake, sequestration (biological processes in which an organism accumulates a compound or tissue), degradation, and metabolism of contaminants by plants [23].

History of phytoremediation

The concept has actually been implemented for the past 300 years.However, using metal accumulating plants to remove heavy metals and other compounds was first formally introduced in 1983 [22].

Various Phytoremediation Processes: There are many phytoremediation processes such as

(i) *Phytoextraction* – The uptake and concentration of substances from the environment into the plant biomass [24].

(ii) *Phytostabilization*–The demobilization of substances in the environment, for example by limiting the leaching of substances from the soil [8].

(iii) *Phytotransformation*– The chemical modification of toxic substances due toplant metabolism which makes them inactive or immobile [25].

(iv) *Phytostimulation (rhizosphere degradation)*– The enhancement of soil microbial activity for the degradation of contaminants [6].

(v) *Phytovolatilization*–The phytotransformation of pollutants into more volatile substancein the soil or water and its release into the air as a less polluting substance [25].

(vi) *Rhizofiltration*- The filtering of water through a mass of roots to remove toxic substances while the pollutants remain absorbed in or adsorbed to the roots [8].

ADVANTAGES OF PHYTOREMEDIATION

(i) It is environmentally friendly

(ii) It uses the unique and selective uptake capabilities of plant root,

(iii) It is cost-effective,

(iv) It is aesthetically pleasing,

(v) Plants can be easily monitored,

(vi) Absorbed metals can be extracted from harvested plant biomass via phytomining [26].

Disadvantage of Phytoremediation

(i) It is limited to the surface area and depth occupied by the roots.

(ii) It relies on natural cycle of plants,

(iii) It takes time- require a long-term commitment.

(iv) The survival of the plants is affected by the toxicity of land

Two Versions of Phytoremediation

(i) *Natural hyper-accumulation***.** Plants, without assistance, naturally take up the contaminants in soil.

(ii) *Induced or assisted hyper-accumulation.* A chemical agent such as chelator is added to soil to increase metal solubility or mobilization so that the plants can easily absorb them.

Translocation Factor(TF)- Translocation factor is the plant's ability to translocate heavy metal from root to harvestable aerial part. Translocation factor >1 indicates a preferential partitioning of metals to shoot [27]. Mathematically, it is expressed as

$$TF = C_{shoot} / C_{root}$$

Where is C_{shoot} the concentration of metal in plant's shoot and C_{root} is the concentration of the metal in the root. TF is an index that shows the ability of a metal to move from one part of the plant to another [28].

Bioaccumulation factor (BAF)-also known as Bioconcentration factor (BCF), is the progressive increase in the amount of substance in a plant because the rate of intake exceeds the plant's ability to remove the substance from the body (Branquinho*et al.,* 2007). BAF provides an index of the ability of the plant to accumulate the heavy metals with respect to the metal concentration in the ecosystem. Mathematically, BAF is expressed as

$$BAF = C_{plant\ tissue} / C_{soil}$$

Where $C_{plant\ tissue}$ is the concentration of metal in plant tissue and C_{soil} is the concentration of the metal in the soil. [29]

Hyperaccumulator- A plant is classified as a hyperaccumulator for heavy metal (s) when it meets one of these three criteria;

(i) TF> 1 which is shoot/root quotient (level of heavy metal in the shoot divide by level of heavy metal in the root is greater than one).

(ii) BAF> 1 (extraction coefficient) (level of heavy metal in the shoot divide by total level of heavy metal in the soil is greater than one); extraction coefficient gives the proportion of total heavy metal in the soil which is taken up by the plant shoot/aerial part of the plant [30],

(iii) Higher levels of heavy metals of 10 – 500 times the levels in normal plants (uncontaminated plants). According to [31] hyperaccumulators are known to concentrate the pollutants in a minimum percentage which varies according to the pollutant involved (for example: more than 1000 mg/kg of dry weight for nickel, copper, cobalt, chromium or lead; or more than 10,000 mg/kg for zinc or manganese [32].

CONCLUSION

From the results of many researches such as [3] and [33], the soils of Enyigba are already polluted by Pb and other toxic metals. Phytoremediation pilot researches have been identified some plants as hyperaccumulator of lead and other toxic metals. For example in the investigating of Phytoremediation Potentials of Common Nigerian weeds for the purpose of cleaning up a Lead-zinc Derelict,it was reported that, based on high TF and BAF values, *Chromoleaeceaeodarata*has a greater potential to clean up Pb and Ni while *Imperata cylindrical* and *Helianthus annus*have the potential to clean up Mn and Cr contaminated soil [3]. Some of these non edible plants were hyperaccumulator of lead and they grow naturally in enyigba and have adapted to lead environment. This capacity for accumulation is due to hypertolerance, or*phytotolerance:* the result of adaptative evolution from the plants to hostile environments along multiple generations [29].More importantly phytoremediation can be applied to both organic and inorganic pollutants present in soil (solid substrate), water (liquid substrate) or the air [33]. The conventional methods of remediation may cost from $10 (about N3000) to 1000 per cubic meter at 1$ per N300. Phytoextraction costs are estimated to be as low as $ 0.05 (N165) per cubic meter [20].

ACKNOWLEDGEMENT

The author is grateful to Ebonyi State Univeristy for TETFund seed grant aimed at conducting Pilot Study on Phytoremediation of Enyigba lead-zinc derelict.

REFERENCES

1. Clark, R. B. (1992). Marine Pollution(pp. 61-79). Oxford, UK: Cleavendo Press.
2. Ademoroti, C.M,A. (1996) Environmental Chemistry and Toxicology Foludex press Ltd Ibadan, pp 162-181
3. Oti W.J.O. (2015) Investigation of Phytoremediation Potentials of Common Nigerian weeds for the purpose of cleaning up a Lead-zinc Derelict Mine. *American Chemical Science Journal,* Vol. 6, Issue.: 3 pp 158-163
4. Becker, W., Kumplainen J (1991). Contents of essential and toxic mineral Elements in Swedish Market-Baskets diets in 1987. *British Journal of Nutrition* 66 pp 151 -160
5. CODEX Alimentarius Commission: CX/FAC 95/18. Nov. 1994. Discussion Paper on Lead. 22. Sess. March 1995
6. Hogan M., (2010) The Encyclopaedia of Earth. www.eoearth.org/article/Heavy_metal
7. Weast, R.C.(1988) (ed.) Silvery Metals Handbook of Chemistry and Physics, 68th ed. Boca Raton, Florida: CRC Press Inc., p. 10
8. Raskin, I. and B. D. Ensley (2000). Phytoremediation of Toxic Metals: Using Plants to Clean Up the Environment. John Wiley & Sons, Inc., New York, pp 100-112
9. Meagher, R.B. (2000). Phytoremediation of toxic elemental and organic pollutants, Current Opinion In Plant Biology *3(2):* 153--162
10. Agency for Toxic Substances and Disease Registry (ATSDR).(1999). Toxicological Profile for Lead.Agency for Toxic Substances and Disease Registry, US Department of Health and Human Services, Public Health Service.205-93-0606.
11. OscarlineOnwuemenyi Federal Government commitment to eradication of lead poisoning Vanguard 1st May 2012 p 117 www.vanguardngr.com
12. LeislieAdogame, Zamfara Lead Poison: Preventing another Diasater Independence news, 4th June, 2010 www.dailyindependentnig.com
13. Berti, W.; and Cunningham, S. (1994) Remediating soil lead with green plants. Trace Substances. Environment, and Health: Science Reviews, Northwood. pp 43-50.
14. Agency for Toxic Substances and Disease Registry.(ATSDR).(1992). Case Studies in Environmental Medicine, Lead Toxicity.U.S. Public Health Service, U.S. Department of Health and Human Services, Atlanta. GA. pp 13-32
15. Brady, N.C., and Wiel R.R. (1999) The nature and properties of soils. 12th ed. Prentice Hall. Upper Saddle River, NJ. pp 23-26
16. Robb, G., and J. Robinson (1995).Acid mine drainage prediction and remediation. Mining *Environ. Manage.* 3(3): 19-21
17. Williams, G.M. (1988): Land Disposal of Hazardous waste. – Engineering and Environmental issues. pp 37-48.
18. Musgrove, S. (1991): – In, Proceedings of the International Conference on Land Reclamation, University of Wales. Elsevier Science Publication, Essex, U. K
19. Body, P.E., Inglis, G.R. and Mulcahy, I. (1988): Lead Contamination in Port Pirie, South Australia. – Report No.101 Adelaide, SA.
20. Mench, M.J., Didier, V.L., Loffler, M., Gomez, A. and Masson, P. (1994): – J. Environ. Qual. 23; 785-792.

21. Alloway, B.J. and Jackson, A.P. (1991): The behavior of heavy metals in sewagesludge amended soils. – Sci. Total Environ. 100: 151-176.
22. Cunningham, S.D., Shann, J.R., Crowley, D., Anderson, T.A., (1997): In Phytoremediation of Soil and Water Contaminants. (ed. Krueger, E.L., Anderson, T.A. and Coats, J.P) – American Chemical Society, Washington, DC.
23. Cluis C. (2004) Junk-greedy greens: phytoremediation as a new option for soil decontamination. *Biotech J* 2: 60–67
24. Ghosh M. and Singh S. (2005). A comparative study of cadmium phytoextraction by accumulator and weed species. *Environ. Pollut.*5 (12) 67-71
25. William J. (2008) The Use of Phytoremediation Technology for Abatement Soil and Groundwater Pollution in Tanzania: Opportunities and Challenges Journal of Sustainable Development in Africa (Vol.10, No.l) pp15-17
26. Baker, A.J. and Whiting S.N. (2002). In Search of Holy Grail: A Further Step in Understanding Metal Hyperaccumulation, *NewPyhtoremediation Journal,* (155), 1-7
27. Yanqun, Z., Yuan. L..Jiajun, C.. Haiyan.C. Li. Q. and Schvartz.C. (2005) Hyperaccumulationof Pb, Zn and Cd in herbaceous grown on lead-zinc mining in Yunnan.*China Em-iron.Int.* 31.755-762
28. Baker, A.J.M. and Whiting S.N. (2002). In search of holy grail-a further step in understanding metal hyperaccumulation. *New Pyhtol.*155, 1-7
29. Reeves, R. and Baker, A. (2000). Metal- Accumulating Plants, Phytoremediation of toxicmetals: Using plants to clean up the environment. Raskin, I. and Ensley, B. D. (ed.) New York: John Wiley & Sons, Inc., pp 193-229
30. Ma L.Q., Komar K.M., Tu C., Zhang W., Cai Y. and Kenelly E.D. (2001) A fern that hyper accumulates arsenic. Nature 409: 579-582
31. Vassil, A.D., Kapulnik, Y., Raskin, I., and Salt, D.E. (1998): The role of EDTA in lead transport and accumulation by Indian mustard. – Plant Physiology 117; 447-491.
32. Nweke, F. N, Okaka, N.C and Offor, E. C (2008). Lead, zinc and pH concentrations of Enyigba soil in Abakaliki Local Government Area of Ebonyi State. Nigeria. *African Journal of Biotechnology* 7(14), 2441-2443
33. Salt D. E, Smith R, Dand I, Raskin I. (1998). Phytoremediation.Annu. Rev. Plant Physiol.*Plant Mol.Biol.*,Vol 49: pp 643-668