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Review

Risk and health implications of polluted soils for crop production

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Studies of polluted soils have shown heavy metals contamination of the soils as well the uptake of these toxic elements by plants. Consequently, there are reasons for concern over elevated concentration levels of heavy metal/toxic elements in polluted soils. This can ultimately result in high human and animal exposure to these toxic elements through food-chain transfer, ingestion of wind blown dust or direct ingestion of soils. The toxic effects caused by excess concentrations of heavy metals in living organisms include competition for sites with essential metabolites, replacement of essential ions, reactions with –SH groups, damage to cell membranes and reactions with the phosphate groups.

Key words: Polluted soils, toxic/heavy metals, plant uptake, health.

INTRODUCTION

It has been the interest of the public to know whether vegetables, fruits and food crops cultivated in polluted soils are safe for human consumption especially now the environmental quality of food production are of major concern (Chiroma et al., 2003). The understanding of the behaviour of heavy metal in soil-plant system seems to be particularly significant. The sources of heavy metal in plants is their growth media (air, soil, nutrients) from which heavy metals are taken up by roots or foliage. Although some heavy metals such as Cu, Zn, Mn, and Fe are essential in plant nutrition, many heavy metals do not play any significant role in the plants physiology. Plants growing in a polluted environment can accumulate the toxic metals at high concentration causing serious risk to human health when consumed (Vousta et al., 1996; Alloway, 1990; Kabata-Pendias, 1984).

There is considerable variability in actual uptake by plants of these elements from soil depending on such properties as pH and organic matter content, cationic exchange capacity, binding to different soils components and the plant species involved (Nyles and Ray, 1999; Kabata-Pendias and Pendias, 1984). Heavy metals have been reported in crops grown in abandoned polluted areas (Okoronkwo et al., 2005a; Jeanne and Sidle, 1991; Ihenyen, 1991; Ndiokwere, 1984) and also in soils irrigated with sewage water (Chiroma et al., 2003).

The uncontrolled input of heavy metals in soils is undesirable because once accumulated in the soil, the metals are generally very difficult to remove (Smith et al., 1996). Subsequent problems may be toxicity to the plant growing on the contaminated soil and uptake by the plants resulting in high metals levels in plant tissues. Since one of the main sources of these heavy metals contamination includes discharge of metal polluted wastewater to land, attempts have been made by various researches to find more effective means of eliminating, controlling or managing these heavy metal discharges from industrial effluent, sewage water, etc. However, since most industries still do not obey the regulations on treatment and management of effluents before discharge, these heavy metals still find their way to soil. An

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improvement on the conventional methods of treatment (coagulation, precipitation, reverse-osmosis, etc) (Faust and Aly, 1987; Ali et al., 1998; Hsisheng and Chien,1998) have been applied, which includes the use of maize cob and husk (Igwe and Abia, 2003; Igwe and Abia, 2005, Igwe et al., 2005) cassava waste (Abia et al., 2003) banana pith (Low et al., 1995), sunflower stalks (Gang and Weixing, 1998) caladium bicolor (Wild cocoyam) (Horsfall and Spiff, 2004a, b), and coconut fiber and sawdust (Igwe et al., 2005b).

It is, therefore, the main objective of this paper to review the studies on the plant-uptake of heavy metals in polluted environment: abandoned waste dump sites, abandoned battery factory sites and soils irrigated with sewage water and point out the risk and health implications posed to living organisms on consumption of plants cultivated on such soils.

HEAVY METAL UPTAKE BY PLANTS

The accumulation of heavy metals by plants; roots, steam and leaves grown in polluted soil have been reported. Okoronkwo et al. (2005a, b) reported the levels of Pb, Ni, Cr, Cd and As present in the soils and also the uptake of Pb, Ni and Cd in the roots and leaves of cocoyam (*Colocesia esculents*) and Cassava (*Mannihot esculent* Cranz) harvested from an abandoned waste dump soils in Umuahia, South-Easten part of Nigeria. The average mean concentration of Pb was 111.75±17.78 and 76.63±19.94 mg/kg, respectively, in leaves and roots of cassava. The concentrations of Ni and Cd in both roots and leaves were 24.47±1.88 and 4.10 mg/kg, respectively. For cocoyam, the concentrations of Pb were 83.02±27.84 and 105.37±45.37 mg/kg in the root and leaf, respectively, while the root and leaves had similar values of 22.59 and 4.10 for Ni and Cd, respectively.

Anikwe and Nwobodo (2002) also reported high level of heavy metals (Pb, Fe, Cu and Zn) in their study on long term effect of municipal waste disposal on soil properties and productivity of sites used for urban agriculture in Abakaliki, South eastern part of Nigeria. Amusan et al. (1999) studied plant uptake of heavy metal on a similar site at University of Ife garbage dump and found out that Pb uptake by water leaf (*Talinum triangulare*) and okra (*Albennucus esculentus*) increased in leaves and roots of waterleaf and in the fruit of okra relative to those grown in non-dump sites. These investigators recorded 83.92 mg/kg Pb content of waterleaf (leaves) in the dump site soil against 3.99 mg/kg from a non-dump site soil. Similar work by Ademoronti (1995) showed that vegetable accumulate considerable amount of heavy metal (Pb, Cr, Cu, Zn) in roots and leaves. Arsenic (As) has been detected in roots of cassava (Okoronkwo NE, unpublished data). Furthermore, Alloway and Ayres (1997) reported that Cd, although present in quite low concentration (<10 mg/kg), is relatively taken up by food crops especially leaf vegetables and enters the human diets.

Nwoko and Egunojobi (2002) studied lead contamination of soils and vegetation in an abandoned battery factory site in Ibadan, Nigeria, and reported the presence of Pb in the tissues of plants, with roots containing higher residual Pb than shoots in most cases. Jeanne and Sidle (1991) reported the presence of heavy metals in vegetables grown on abandoned Pb-Zn tailings pond. Also Pb was reported on vegetables grown near busy traffic highways (Ihenyen, 1991; Ndiokwere, 1984)

Chiroma et al. (2003) studied heavy metal contamination of vegetable and soils irrigated with sewage water in Yola, Nigeria and reported high concentration of the metals (Fe, Zn, Cu, Mg, Mn and Pb) suggesting heavy metal contamination of the soil irrigated with sewage water and their accumulation in different parts of plants cultivated in the soil. They also showed that the metal concentration vary in the different parts of the plants. Moreover, the result indicated that Fe tends to accumulate in roots and leaves but Zn accumulates in roots and translocates gradually to the leaves while Mn and Mg shows greater accumulation in unwashed leaves. There was also the tendency of high metal concentration on the unwashed plants compared to the washed plants. Similar work by Sonuhmacher (1993) who studied on the levels of Cr, Cu and Zn in washed edible vegetable reported the same range of level present in the crops.

Furthermore, studies have revealed that Pb does not readily accumulate in the fruiting part of vegetable and fruit crops (e.g. corn, beans, squash, tomatoes, straw, berries, apples); higher concentrations are most likely to be found in leafy vegetables (e.g. lettuce) and on the surface of root crops (Rosen, 2002). Also Spitter and Feder (1979) reported lead contamination in vegetables grown on contaminated soils.

HEALTH IMPLICATIONS OF HEAVY METAL ACCUMULATION

An important part of estimating the risks of health effects from exposure to toxicants involves extrapolation from experimentally observation data, and identification of the hazard source is also very important. Many metals act as biological poisons even at parts of per billion (ppb) levels. The toxic elements accumulated in organic matter in soils are taken up by growing plants (Dara, 1993). The metals are not toxic as the condensed free elements but are dangerous in the form of cations and when bonded to short chains of carbon atoms (Bairds, 1995). Many metals with important commercial uses are toxic and hence undesirable for indiscriminate release into the environment (Bunce, 1990).

Chaney (1980) and Smith et al. (1996) cautioned on the use of wastes in crop production since it may be possible for heavy metal from the waste to accumulate in soils and thereby enter the food chain, contaminate surface and underground water thus cause health hazard. Lead contamination of biota is well documented (Boon and Soltanpour, 1992; Odukoya and Ajayi, 1987; Bearington, 1975). Lead is usually ingested through food, water and cigarettes (Krenkel, 1974; Sax and Sax, 1975). Lead is very toxic and has very chronic health implications even at very low concentration (Meittinien, 1975; Bryan, 1976). Ingestion of Pb could cause metal retardation in children (Huges et al., 1980), colic anemia and renal diseases (Fisherhbein, 1992). Lead replaces Ca in the bone (Mills, 1971; Bryce-Smith, 1971). Its effect is cumulative and long term exposure has been noted to cause serious health hazard (Essien, 1992) which include inhibition of the synthesis of haemoglobin and also adversely affect the central and peripheral nervous system as well as the kidney (Bhata, 2002). Human being may be exposed to nickel by eating contaminated food containing nickel. Foods naturally high in nickel include soya-beans, nuts and oat meals. Miller and Miller (2002) noted that Zn and Cu are toxic to plants before they accumulate in sufficient concentrations to affect animals or human. Consequently, high concentration of Zn and Cu kill or stunt plants growth.

Cadmium adversely affects several important enzymes. It can also cause painful osteomalacia (bone disease), destruction of red blood cell and kidney damage. Cadmium is chemically very similar to zinc and are found in the +2 oxidation state. It is believed that much of the physiological action of cadmium arises from its chemical similarity to zinc. Specifically, Cd may replace Zn in some enzymes thereby altering the stereochemistry of the enzyme and impairing its catalytic activity. Disease symptoms ultimately results. Arsenic forms a number of toxic compounds. The toxic As_2O_3 is absorbed through the lungs and intestine. Biochemically, arsenic acts to coagulate proteins, and inhibits the production of adenosin triphosphate (ATP) in essential metabolic processes.

Generally, at the biochemical levels, the toxic effects caused by excess concentrations of heavy metals include competition for sites with essential metabolites, replacement of essential ions, reactions with –SH groups, damage to cell membranes and reactions with the phosphates groups (Alloway and Ayres, 1997).

CONCLUSION

The high risk of exposure to heavy metal due to plant uptake of these toxic elements makes the use of polluted soils; abandoned waste dump site, irrigated soils with sewage water or any other form of polluted soils, environmentally risky for agricultural purposes. However, a clean-up procedure could be embarked on to reduce the heavy metal concentration in the soil either by use of bioremediation, particularly phytoremediation which involves the use of plants in the detoxification of the soil to reduce the concentration levels of heavy metals in the soil or the land can be reclaimed by top soiling with uncontaminated soils from offsite to a depth that would minimize uptake of heavy metal by vegetations.

REFERENCES

Abia AA, Horsfall M Jr, Didi O (2003). The use of chemically modified and unmodified cassava waste for the removal of Cd, Cu, and Zn ions from aqueous solution. Bioresource Tech. 90: 345-348.

Ademoronti CMA (1995) Bioaccumulation of Heavy Metals in some Mangrove fauna and flora In: Environmental Chemistry and Toxicology March Prints and Consutancy, Benin. pp.180-182.

Ali A, Bradley AK, Duong DD (1998). Comparison of Equilibra and kinetics of High surface Area activated carbon produced from different precursors and by different chemical treatments. Ind. Eng. Chem. Res. 37, 1329-1334.

Alloway BJ (1990) Heavy Metal in soils Blackie Glasgow UK.

Alloway BJ and Ayres DC (1997). Chemical principals for environmental pollution Blackie Academic and Professional pp 190-220.

Mills A (1971). Lead in the environment. Chem in Britain 7(4): 160-162.

Amusan AA, Ige PV, Olawala R (1999), Preliminary investigation on the use of Municipal waste dump for farming paper presented at the 25th annual conference of soil science society of Nig held November 21 – 25, 1999, Benin City Nig

Anikwe MAN, Nwobodo KCA (2002) Long term effect of Municipal waste disposal on soil properties and productivity of sites used for urban agriculture in Abakaliki Nigeria. Bioresources Technol 83: 241-251.

Bairds C (1995). Environmental Chemistry. Printed in United State of America pp 387 – 387.

Bearington F (1975). Heavy Metal contamination of vegetables and in domestic gardens around a smelting complex. Environmental Pollution 9: 211-217.

Bhata SC (2002). Environmental Chemistry. CBS Publishes and Distributors, New Delhi pp 442

Boon DY Soltanpour PN (1992). Lead, Cadmium and Zinc contamination of aspen garden soil and vegetation. Journal of environmental quality 21: 82-86.

Bryan GW (1976). Heavy Metal contamination in sea, in: Matius Pollution Johnson, Academic Press. Pp 185 – 302.

Bryce-Smith D (1971). Lead pollution, a growing hazard to public health Chemistry in Britain, 7(2) 54 – 56.

Bunce NJ (1990). Environmental Chemistry Winners Publishing Ltd. Winnipeg Canada, pp 206 – 247.

Chaney Rl (1980). Health risk associated with toxic metals in municipal sludge in: Bilton G et al (ed) Sluge-Health-Risk of land application. Ann Arbor Scie. Publi MI pp 59 – 83

Chiroma TM, Hymore FK, Ebawele RO (2003). Heavy Metal contamination of vegetables and soils irrigated with sewage water in Yola. NJERD, Vol., 2 No. 3.

Dara SS (1993). A Text book of Environmental Chemistry and pollution control. Printed at Rjendra Rarindra Printers (PVT) Ltd Ram Niger, New Delhi 10055, 167 – 206.

Essian EU (1992). Differential accumulation of lead on selected edible vegetables associated with roadside gardening in Nig. Trop. J. Applied Sciences 1(2): 83-86.

Faust SD, Aly OM (1987). Adsorption processes for water treatment, Butterwort publishers, Boston. pp. 108-132.

Fischbein A (1992). Occupational and environmental lead exposure In: environment and occupational medicine. Ron WN (ed) Little brown

publication Boston pp. 735 – 736.
Gang S, Weixing S (1998). Sunflower stalks as adsorbents for the removal of metal ions from waste water. Ind. Eng. Chem. Res. 37(4), 1324-1328.
Horsfall M Jr, Spiff AI (2004b.) Studies on the effect of pH on the sorption of Pb2+ and Cd2+ from aqueous solutions by caladium bicolor (wild cocoyam) biomass. Elect J. Biotechnol (online). 15 December, vol. 7, No. 3. Available from internet: http://www.ejbiotechnology.info/content/vol.7/issure3/full/8/index.html. ISSN 0717 3458.
Hsisheng T, Chien-Ts H (1998). Influence of surface characteristics on liquid – phase Adsorption of phenol by Activated carbon prepared from Bituminous coal. Ind. Engr. Chem. Res. 37 (9), 3618-3624.
Huges Mk, Lepp Nw, Phipps DA (1980). Arial heavy metal pollution and terrestrial ecosystem. Advance Ecol. Research 11: 217 - 227
Igwe JC,Abia AA (2003). Maize Cob and Husk as adsorbents for removal of cadmium, lead and zinc ions, from wastewater the physical scientist 2, 83-94.
Igwe JC, Abia AA (2005). Sorption kinetics and intraparticulate diffusivities of Cd, Pb and Zn ions on maize cob, Afr. J. Biotech. 4(6) 509-512.
Igwe JC, Nwokennaya EC, Abia AA (2005b). The role of pH in heavy metal detoxification by biosorption from aqueous solutions containing chelatng agents Afr. J. Biotechnol. 4 (10): 1109-1112.
Igwe JC, Ogunewe DN, Abia AA (2005a) Competitive adsorption of Zn(II), Cd(II) and Pb(II) ions from aqueous and non-aqueous solution by maize cob and husk. Afr. J. Biotechnol. 4 (10): 1113-1116.
Ihenyen A (1991). A Comparative study of Pb, Cu and Zn in roadsides sediments in Metropolitan Lagos and Benin, Nig. Environ. Int. 18(1): 103 – 105.
Jeanne CC, Sidle RC (1991). Fate of heavy metals in an abandoned Zinc tailing pond. J. Environ. Qual. 20: 745 – 751.
Kabat Pendias A, Pendias H (1984). Changing metal cycles and human health Nnagu, JO (ed), Springer, Verling Berlin.
Krankel JSC (1989). Sources and classification of water pollutants In: Industrial pollution: Sax NJ (ed) Van Nostrand Reinhold Co. New York. pp. 177 – 219.
Low KS, Lee CK, Leo AC (1995). Removal of metals from electroplating wastes using banana pith. Bioresour. Techonol. 51(2-3): 227-231.
Miettinen JK (1975). The accumulation and excretion of heavy metals in aquatic environment. Peter A (ed) Krenkal Perganon Press. p. 155.
Miller DM, Miller WP (2000). Land application of wastes. Summer ME (ed) Handbook of soil science CRC Books New York.
Ndiokwere CL (1984). A Study of Heavy metal pollution from motor vehicle emission and its effect on road side vegetation and crop in Nigeria. Environ. Pollut. Series 8(7): 35 – 42.
Nwoko CO, Egunobi Jk (2002). Lead contamination of soil and vegetation in an abandoned battery factory site in Ibadan, Nig. J. Sustain Agric. Environ. 4(1): 91 – 96
Nyles CB, Ray RN (1999). The nature and properties of soils. 12th Edition United States of America. Pp 743 – 785.
Odukoya OO, Ajayi SO (1987). Trace metals in Nigeria fish – Nigerian Journal of Nutrition Science 3(2): 105 – 113.
Okoronkwo NE, Ano AO, Odoemenam (2005a). Environment, health and risk assessment with the use of an abandoned municipal waste dump site for food crop production. Paper accepted for presentation by division of Agric and food chem.. at the 230th American. Chem. society Aug. 28 – Sept. 1
Okoronkwo NE, Ano AO, Igwe JC, Onwuchekwa EC, Nnorom I (2005b). Levels of toxic elements in soils of abandoned waste dump site. Paper accepted bv division of chemical toxicology for at the 230th American chemical society Aug. 28 – Sept. 1
Rose CJ (2002). Lead in the home garden and urban soil environment. http://www.extension.umn.edu/distribution.horticulture/DG2543html.
Sax NI, Sax PH (1975). Encyclopedia index in industrial pollution. Sax NJ (ed) Van Nostrand Reinhold, New York pp. 577 – 683.
Smith CJ, Hopmans P, Cook FJ (1996). Accumulation of Cr, Pb, Cu, Ni Zn and Cd in soil following irrigation with untreated urban effluents in Aust. Environ Pollut. 94(3): 317 – 323.
Sonuhmache M, Domingo JL, Liobet JM, Conbella IJ (1993). Chromium, Copper and Zinc concentration in edible vegetables grown in Terragon Province Spain, J. Bull. Environ. Contamination and Toxicol. 58: 515-521.
Vousta D, Grimanins A, Sammara C (1996). Trace elements in vegetable grown in an industrial areas in relation to soil and air particulate matter. Environ. Pollut. 94(3): 325 – 335.