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*Zinc in Soils: A review of its Distribution and Impacts

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Abstract

Zinc is one of the most common naturally occurring essential trace elements in the soil. However, most zinc enters the soil as a result of human activities; soils being an ultimate sink for contaminants and a natural buffer controlling the environmental cycling of chemical elements to the atmosphere, biota and hydrosphere. Concern for zinc levels arises principally because too little zinc is as important a health problem as too much zinc. Hence, zinc contents in soil constitute a major issue in environmental monitoring because maintenance of agricultural and ecological functions of soils is important for existence.

Key- words: Trace metal, environment, human activities, soils.

Introdution

Zinc was discovered in prehistoric times and was named from German, zink which means of obscure origin. It is the 23rd most abundant element in the Earth's crust with average concentration of 70ppm, ranging from 10- 300ppm (Malle, 1992). Its most important ore is zinc blende or sphalerite (Zn, Fe) S which contains roughly 10% Fe and 40-50% Zn. It also occurs in calamine, $Zn_4(Si_2O_7)(OH)_2.H_2O$; smithsonite,$ZnCO_3$; willemite,Zn_2SiO_4 and zincite, ZnO(Garrett,1982). Generally, zinc metal is produced from ores and from recycled zinc products which contributes about 30% of the world zinc supply (IZA, 1997). European Zinc Institute (1990) also reported that some two million tones of zinc are recycled every year.

Physical and Chemical properties

Zinc is a transition metal of atomic number 30 with standard atomic weight 65.409(4). It exhibits a valence state of 2 and forms stable covalent complexes. Zinc is a lustrous metal, grayish-white with a bluish tint, brittle at ordinary temperature when cast, but becomes malleable and ductile between 100^{0}C and 210^{0}C. It is a fair conductor of electricity, tarnishes quickly in moist air, and burns in air with a bright bluish-green flame, giving off fumes of ZnO. Pure zinc reacts slowly with acids, alkalis and other non-metals, but small quantity of small impurities hasten the reaction with dilute acids to release hydrogen. It has a melting point of 419.4^{0}C and boiling point of 907^{0}C with a density of 7.133gcm^3 at 20^{0}C. Zinc also form numerous soluble salts and sparingly soluble compounds as well as a range of insoluble and soluble organic complexes (Barak and Helmke, 1993; Lindsay, 1979).

Uses

The oldest use of zinc is in alloy brass. Its other forms of alloys include bronze, soft solder, typewriter metal, and pennies are made from a copper- zinc alloy. Zinc is also

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used in making casings and anodes for dry cell batteries, in plates for printing and engraving, in roofing and galvanized iron to prevent corrosion. Zinc compounds of chlorine, sulfur and particularly oxygen are very useful material to modern civilization. They are widely used in the manufacture of ceramics, dyes, fertilizers, rubber including tyres, white paints, as well as in both domestic(such as baby creams and shampoos) and industrial products(Garrett,1982; Wild, 1994; Alloway and Ayres,1997; Chemical Fact Sheet,1998; Human Health Fact Sheet,2005).

Zinc contents and inputs in soils

Zinc is found in all natural soils at varying concentrations depending on the chemical and physical weathering of the parent rocks (Broadley et al., 2007). However, secondary natural inputs of zinc into soils arise principally from atmospheric and biotic processes (Friedland, 1990). Average soil zinc contents of 50 and 66ppm are reported to be typical for mineral and organic soils respectively, with most agricultural soils having a range of 10-300ppm (Alloway, 1995; Barber, 1995). Kabata- Pendias and Pendias (1992) have also estimated the grand mean of zinc in worldwide soils to be 64ppm. Furthermore, the natural content of zinc in surface soils has been given to range from 17-125ppm, with a mean value of 60ppm (Ward, 1995). Values representing the maximum allowable limits (MAL) of zinc concentrations have also been established for many countries such as Germany (50ppm), Austria, Canada, Great Britain, and Poland (100ppm), as well as Japan at 125ppm (Kabata- Pendias, 1995).

Human activities have long influenced zinc inputs to soils whose pollution is often associated with mining and smelting. Hence, zinc level of as high as 11,700ppm has been encountered from a site where mining wastes were dumped directly for more than a century (Ebbs and Kochian, 1997). Nriagu(1990), also noted that the anthropogenic emissions of zinc have exceeded the fluxes from natural sources and Friedland(1990) estimated the ratio of zinc emissions arising from anthropogenic and natural inputs to be >20:1. Other sources of anthropogenic zinc inputs into soils include agrochemicals, particles from galvanized surfaces and rubber mulches, as well as fossil fuel combustion, mine waste, phosphatic fertilizer (50-1450ppm), limestone (10-450ppm), manure (15-450ppm) and sewage sludge at a range of 91-49,000ppm (Chaney, 1993; Alloway, 1995).

Zinc distribution in soils

Zinc distribution in soils has been identified with pH, organic matter content and free oxides of Fe and Mn (MacLean and Langille, 1976; Udo and Fagbami, 1979). However, Broadly et al.(2007) have identified pH as the major factor determining soil zinc distribution and Kabata- Pendias and Pendias (1992), observed that organic complexing and precipitation of zinc appear to be of much lesser importance as factors controlling zinc solubility in soils than clay minerals, hydrous oxides and pH. Zinc becomes much less available as the soil pH increases, and this usually occurs at pH greater than 7.4 but may also happen at a pH of 6.5 (Agronomy Fact Sheet Series, 2007).

Generally, zinc usually remain in the upper layers bound to soil particles, hence insoluble zinc constitutes greater than 90% of soil zinc (Human Health Fact Sheet, 2005; Broadly et al.,2007). Several authors have reported accumulation of zinc in the surface horizons, indicating that zinc is only relatively mobile in soils (Karim and Sedberry,1976; Williams et al.,1987; McBride et al.,1997). Dowdy et al.,(1991) observed only a small movement of zinc down the soil profile after more than a decade of sludge applications. Moreover, increase in zinc concentration with depth has been shown to coincide with corresponding increase in clay in most soil profiles studied (Rhandhawa and Kanwar, 1964; Fagbami et al., 1985). The concentrations of zinc in both loam and clay soils have been estimated to be over 1000 times higher than in the water between the soil particles(Human Health Fact Sheet,2005).

Transmission through the food chain.

Zinc is an essential micronutrient for all organisms, including plants, animals and humans, but at high levels in soil, zinc can be phototoxic (Khan et al., 1981; Wild, 1994; Wallace and Wallace, 1994), or transferred to the food chain, where it may have relatively toxicity effects on the health of animals and humans (Alloway and Ayres, 1997; Sinaj et al., 1999).

Zinc in plants

The fact that zinc is a micronutrient has limited the success in predicting plant tissue concentration from soil content. However, in the case of excessive intake, zinc phytotoxicity occurs when tissue zinc reaches 200- 300ppm (Tambasco et al. 1999). Furthermore, Wild (1994), observed that plants that retain zinc in their roots are more adapted to high concentrations in the soil, since translocation of zinc from roots to shoots is species dependent. Zinc is not readily translocated within the plant, hence, deficiency usually appear first on younger leaves and less than 20ppm is recommended as deficient level in mature leaf tissue (Vitosh et al., 1997). Several authors have also reported severe zinc deficiency symptoms for many crops (Marschner, 1995; Sharma, 2006). Ward (1995), moreover, suggested a range of 12-60ppm and an average of 30ppm as the natural zinc concentrations in plants. However, for plant foodstuffs mean concentration of 25ppm and a range of 1.2-45ppm have been recommended (Ward, 2000).

Zinc in animals and humans.

Zinc primarily enters the body through the food intake, water or by little soil or dust particles, but is less commonly absorbed through the skin (EHLR 295, 2004). However, the major route of exposure to zinc in soil is via incidental ingestion from dirt or dust on fingers through hand- to-mouth habits of young children. Too little zinc in a diet is as important a health problem as too much zinc. Lack of enough dietary intake of zinc in humans may result in loss of appetite, decrease in sense of smell and taste, as well as in immune function, slow wound healing and skin sores. Too little zinc in the diet may also give rise to poorly developed sex organs and retarded growth in young men and in babies in pregnant women (ATSDR, 1994).

The risk and health implication of large doses of zinc consumption depend on the individual, the circumstances and the amount of the zinc ingested. Levels 10-15times higher than the recommended dietary allowances of 5, 12, and 15 mg per day for infants, women, and men respectively taken orally (by mouth) even for a short period can cause stomach cramps, nausea, and vomiting. Consuming high doses over an extended period can also cause anemia, damage the pancreas and decrease the good form of cholesterol (EHLR 295, 2004; Human Health Fact Sheet, 2005).

In field collections of animals, zinc contents are extremely variable, thus difficult to interpret; for individual species, zinc content varies with age, organ or tissue, season, sex, and other possible factors. However, concentrations are usually less than 210ppm in dry weight tissues of birds and mammals, and less than 700ppm in fish tissue (Eisler, 1993). In animals clinical manifestation of zinc deficiency include growth retardation, loss of appetite, skin changes, testicular atrophy and decreased immunity (Prasad, 1979; Droke, 1993). Symptoms of acute poisoning that include anorexia, depression, decreased milk yield, diarrhea, enteritis, excessive eating and drinking, as well as convulsions and death in severe cases have been documented in animals and birds (Ogden et al. 1988; Lu and Combs, 1988a; Binnerts, 1989). Furthermore, in aquatic environment the gills of fish are usually damaged physically by high zinc contents (NAS, 1979).

Conclusion

Specific soil extractable zinc levels, which might indicate toxicity, have not yet been established, since plant species differ in the extent to which they translocate zinc from root to shoot and subsequently to fruits and grains that generally contain lower concentration than in leaves. However, elevated soil zinc contents may occur on extremely acid soils that may lead to high plant uptake that may result in zinc toxicity which may consequently affect the food chain; soil- plant-animal/man or soil- plant-animal-man. Furthermore, as a nutritive trace element, zinc deficiency occurrence is also of great concern because it has adverse effects on all the stages of reproduction, development, growth and survival of animals, humans and plants.

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