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POTENTIAL EFFECTS OF HEAVY METALS IN MUNICIPAL SOLID WASTE COMPOSTS ON PLANTS AND THE ENVIRONMENT

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While considerable attention has been paid to the land application of sewage sludges and composted sewage sludges in the U.S. during the last twenty years, land application of municipal solid waste (MSW) composts has received comparatively little attention. However, there has been a recent resurgence of interest in this topic as other options for solid waste disposal such as landfilling and incineration become less publicly acceptable and increasingly costly.

As interest in MSW composting increases, one of the concerns that must be addressed is the extent to which the low concentrations of heavy metals and metalloids (metal-like elements) present in MSW compost may adversely affect plant growth, soil organisms, water quality and animal and human health.

This fact sheet focuses primarily on how these elements are taken up by plants growing in soil to which MSW composts have been added. A brief discussion of the effects of these elements on soil organisms and water quality is also included.

The information is drawn from a review of long-term field experiments in which plants were grown in soil with high doses of MSW composts (i.e., realistic "worst case" situations). Few field studies with MSW composts have investigated the long-term cumulative effects of MSW compost application to agricultural land. To supplement the information available from MSW compost studies, studies of sewage sludge and yard waste compost have also been considered. Since MSW composts are similar to sewage sludge composts in many respects, much of what has been learned about the latter can be extrapolated to MSW composts.

New regulations for sewage sludge application to land were recently established by the U.S. Environmental Protection Agency. These regulations define Alternative Pollutant Limits (APL) for metals in sewage sludge.

Trace Elements and MSW Compost

Many metals and metalloids are present in minute ("trace") amounts in the soil and water. These trace elements occur naturally as a result of the weathering of rocks. They can be leached into surface water or groundwater, taken up by plants, released as gases into the atmosphere, or bound semi-permanently by soil components such as clay or organic matter.

Metals appear in the municipal solid waste stream from a variety of sources. Batteries, consumer electronics, ceramics, light bulbs, house

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dust and paint chips, lead foils such as wine bottle closures, used motor oils, plastics, and some inks and glass can all introduce metal contaminants into the solid waste stream. Composts made from the organic material in solid waste will inevitably contain these elements, although at low concentrations after most contaminants have been removed (Fact Sheet 3).

In small amounts, many of these trace elements (e.g., boron, zinc, copper, and nickel) are essential for plant growth. However, in higher amounts they may decrease plant growth. Other trace elements (e.g., arsenic, cadmium, lead, and mercury) are of concern primarily because of their potential to harm soil organisms and animals and humans who may eat contaminated plants or soil. The impact of metals on plants grown in compost amended soils depends not only on the concentration of metals, but also on soil properties such as pH, organic content and cation exchange capacity. Different types of plants also react very differently to metals which may be present.

Elements of Concern for Plant Health

Boron — Boron can decrease plant growth and excess boron in MSW composts may be an occasional problem for the agricultural application of MSW composts. However, like other trace elements, boron is more likely to be deficient in soils than to cause toxicity. Most boron in MSW compost is water soluble and sufficient leaching of the compost prior to application may eliminate the problem of toxicity. In addition, greenhouse experiments have found that the addition of mineral fertilizers will decrease the uptake of boron by plants. Thus, fertilization could also be used to reduce toxicity to plants.

Elements of Concern for Animal and Human Health

Cadmium, lead, and mercury can be harmful to animals and humans at relatively low concentrations and thus, should receive close scrutiny in relation to the application of MSW composts to agricultural soil.

Cadmium — While most long-term studies of MSW compost application to cropland have shown a decrease or little change in the cadmium content of crops, these experiments have not used the species that accumulate cadmium most readily, notably tobacco, mushrooms, spinach and other leafy vegetables.

Tobacco is of particular concern. When tobacco is burned and inhaled, much more of the cadmium is taken up by the human body than would be if eaten. For this reason, MSW composts containing more cadmium than is found in average soils should probably not be applied to land on which tobacco is grown.

Based on the limited data available, MSW composts should also probably be avoided in mushroom cultivation. In addition, uptake of cadmium by spinach and other leafy crops should be investigated further, since they are known to accumulate cadmium.

The National Research Council has recommended that the cadmium content of forage crops (those destined for animal consumption) be 0.5 mg/kg or less. Studies have shown that MSW compost applications may result in crop tissue concentrations that exceed this value. Occasionally, plants grown without compost may have tissue concentrations higher than 0.5mg/kg. However, a risk assessment performed on behalf of the U.S. EPA to establish Alternative Pollutant Limits for sewage sludge suggests that this value is overly conservative.

Lead — Plants take up only a small proportion of the lead from most soils, and long-term field studies suggest that very little increase in the lead content of crops will occur even with substantial additions of MSW compost. In fact, there is some evidence that MSW composts can actually decrease the uptake of lead by crops, presumably because the organic matter in the compost binds the lead and decreases its availability to plants. The application of MSW composts will, however, increase the lead content of uncontaminated soils. This may pose a risk to animals or children in the area who ingest the composted soil directly. The new APL limit for lead in sewage sludge was intended to be protective of human health; this issue is discussed further in Fact Sheet 5.

Mercury — The concentration of mercury in MSW composts is usually very low and thus there is little likelihood of significant uptake by plants. However, some mushroom species can accumulate heavy metals such as mercury, so MSW composts containing levels of mercury much higher than the background levels found in uncontaminated soils may not be suitable for mushroom production.

Metals of Minor Concern

Studies suggest that arsenic, chromium, copper, nickel and zinc are unlikely to cause problems for plant, animal, or human health, primarily because they are not found in high concentrations in MSW compost and/or are not readily taken up by plants.

Arsenic — Arsenic, while toxic to animals and humans, is not readily taken up by plants and thus, is unlikely to pose a problem.

Chromium — Chromium occurs only in trace amounts in MSW composts. In addition, most of the chromium in MSW composts occurs in a form not readily taken up by plants.

Copper — Long-term field studies show very little increase in the copper content of crops even with substantial additions of MSW compost. The organic material in the compost binds the copper and reduces its availability to plants.

Nickel — Nickel concentrations are generally low in MSW composts. Thus nickel, although toxic to plants, is unlikely to decrease plant growth when compost is applied.

Zinc — Although applications of sewage sludge have caused toxicity to plants due to zinc, MSW composts contain much lower concentrations of zinc than does sludge. Zinc in MSW compost is unlikely to injure crops and may, in fact, be beneficial in regions deficient in zinc.

Effects on Water Quality

In addition to affecting plant and animal health, trace elements contained in MSW composts may be leached (carried by water) from the soil and enter either ground or surface water. As with plant uptake, soil pH, organic matter content, and other soil characteristics affect the amount of leaching.

Little research has been conducted to determine the effect of MSW composts on water quality and aquatic ecosystems. One European study found the initial leachate concentrations of all the metals studied exceeded E.E.C. drinking water standards, but after one and a half years of leaching, only nickel still exceeded the limit. The study used extremely high compost application rates and experimental soil columns with very shallow soils and thus probably overestimates the leaching potential.

While other data on leaching from MSW composts is scarce, the evidence from long-term applications of sewage sludge suggests that the rate of leaching is low. Leaching of metals into groundwater is only likely to occur with heavy, repeated applications of MSW composts over many years in areas with sandy soils or other conditions that limit the opportunity for adsorption of metals by soil.

Effects on Soil Organisms

Little is known about the effect of trace elements in MSW composts on soil organisms such as invertebrates (e.g., earthworms) and microorganisms (e.g., nitrogen-fixing bacteria). When sewage sludge is applied to land, the concentration of some trace metals (e.g., cadmium) in earthworms is increased, but this increase does not pose a significant risk to the worms or to wildlife that consumes them based on the risk assessment performed to establish the new APL values for sewage sludge. The average values of lead, copper, and zinc in MSW composts exceed soil limits proposed by a group of European researchers to protect soil invertebrates. Those limits may be conservative, however, since metals are often less biologically available in composts than in mineral soils.

There is contradictory evidence as to whether metals in MSW composts may harm soil microorganisms, including nitrogen-fixing bacteria.

Long-term Concerns

As organic matter decomposes, the concentration of metals in compost—and thus, in the soil to which it has been applied—may increase. The available data suggest that if large amounts of MSW composts are applied to agricultural soils, half of the organic matter may decompose within one or two decades. Metal concentrations in soil are unlikely to exceed the concentration present in the original compost, unless very large amounts of compost high in organic matter are applied. Over time, metals generally become less available to plants and other organisms unless soil pH decreases greatly or the soil is flooded for a long period of time.

Potential Benefits of Trace Elements in MSW Compost

While this fact sheet focuses on potential adverse effects of heavy metals and metalloids in MSW compost, there are also potential beneficial effects for agriculture and horticulture. Soils that have been cropped for many years may be deficient in nutrients such as boron, zinc and copper, and MSW compost could mitigate such deficiencies. Other benefits include improved soil physical characteristics such as increased water-holding capacity, improved chemical characteristics such as nutrient retention capacity, and stimulation of microbial activity that can improve plant growth and decrease the leaching of pollutants into water supplies. MSW compost may also limit harm to plants by tying up trace pollutants and toxic organic compounds.

Related Regulatory Issues

For most heavy metals and metalloids, the levels in MSW compost are low relative to proposed standards for sewage sludges, such as the newly established APL values for sewage sludge. With the significant exception of lead, MSW composts can usually meet these lim-

its. However, it is essential to remember that these values, developed for sewage sludge, may need to be adjusted for MSW compost. In addition, some toxicologists and policy makers are concerned that the risk assessment methodology used to develop such standards is based on incomplete knowledge and are advocating a more conservative approach (Fact Sheet 6).

References

See the fully referenced article in a special issue of *Biomass & Bioenergy* (Vol. 3, Nos 3-4, pp. 239-259, 1992), from which this fact sheet is extracted. A copy of that journal containing 11 articles on MSW composting can be obtained through the Composting Council, 114 S. Pitt St., Alexandria, VA 22314, for $30.

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