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Potential Impacts of the Use of Composted Wastes on Soil and Water Resources and Food Security

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Abstract— **Due to the increasing need for organic fertilizers in agriculture in recent years, there has been an intense demand for alternative organic fertilizer sources. Municipal solid wastes and treatment sludges generated in urban settlements can be used as an organic fertilizer after composting. Many of results demonstrated that sewage sludge (SS) and municipal solid waste compost (MSWC) could be successfully used as a agricultural fertilizer and presents no significant hazards to agricultural soils, crops, or the environment if it is applied in quantities commensurate with crop needs. Nevertheless, there have been increased concerns that agricultural use of SS and MSWC over longer time periods may affect the safety of food products and sustainability of agricultural land, and may carry potential economic and liability risks. The accumulation of pollutants such as various undesirable salts, harmful organic substances and heavy metals can be seen in the soils where organic waste composts are applied, which pose risks on plant production, environment and consumers and sustainable soil management. Differences in research findings are largely due to the time and spatial variability of waste sources, the diversity of anthropogenic factors, and the locality of most studies**.

***Keywords*—Composted wastes, soil and water pollution, food safety**

I. INTRODUCTION

SS is an inevitable end product of municipal wastewater treatment and contains many of the pollutants that are removed from the influent wastewater during treatment. SS is a concentrated suspension of solids, largely composed of organic matter and nutrient-laden organic solids, and its consistency can range in form from slurry to dry solids, depending on the type of sludge treatment. The quantity of SS is expected to increase as a greater percentage of the population is served by sewers and as advanced wastewater treatment processes are brought on-line. Sludge disposal has always represented a substantial portion of the cost of wastewater management. Over the past 50 years, restrictions have been placed on certain sludge disposal practices (e.g., ocean dumping, incineration and landfill disposal), causing public wastewater treatment utilities to view the agricultural use of sludge as an increasingly cost-effective alternative. In addition to its use on agricultural land, SS can be marketed and distributed for home gardening and landscaping purposes. Currently, 36 percent of SS is applied to the land for several beneficial purposes, such as agriculture, turfgrass production, and reclamation of surface mining areas, 38 percent is landfilled, 16 percent is incinerated, and the remainder is surface disposed by other methods [1].

Urban or municipal wastes can contain paper, plastic, glass, metal and other wastes apart from organic matter to a significant extent. Due to the excess of pollutants in the solid wastes coming from the mixed storage source, the composting efficiency of organic materials decreases and the MSWC quality produced is also low. Compostable organic materials can be successfully used as a source of organic fertilizer in solid wastes that are classified at the source and classified separately. However, many pollutants can be found in MSWC, similar to sewage sludge, even under optimum production conditions.

In this review, the risks and beneficial effects of SS and MSWC in agricultural use are discussed based on the study findings so far.

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II. POTENTIAL ROLE OF COMPOSTED WASTES IN AGRICULTURE

Raw SS is a substance containing pollutants remaining from the treatment of wastewater, containing approximately 50% organic matter and significant plant nutrients, various inorganic substances and various pathogens. Toxic chemicals in low concentrations are introduced into municipal wastewater. Many of these toxic chemicals are removed from the wastewater and concentrated into the SS by the wastewater treatment process. SS also contains human pathogens. Although it can be treated to significantly reduce the number of pathogens present, pathogens and toxic chemical pollutants may be introduced into sludge-amended soil. Municipal solid wastes include material wastes used in daily public life and various organic and inorganic wastes that are out of use. After the organic elements in these wastes are separated, they can be converted into organic fertilizers by composting processes. However, the composition of this fertilizer produced is qualitatively different from traditional organic fertilizers. Raw SS and MSWC cannot be used in agricultural areas without composting.

Using composted organic wastes on agricultural land also provides an alternative to disposal by using the recyclable constituents of these wastes in the production of crops. Disposal of SS, which is a by-product of treatment plants and contains pollutants in wastewater, is an important technical and financial problem of municipality administrations. Similarly, the limitation of solid waste landfill areas and the environmental effects of these areas necessitate the recycling of solid wastes. The composting of organic materials in the wastes and their usage in agricultural production will not only ensure optimum resource use, but also reduce the pressure on natural resources and significantly help to protect environmental pollution and natural life.

It is necessary to apply enough organic matter to the soil in order to ensure soil fertility, protect soil quality and health in cultural soils. Applications of organic matter to the soil make physical, chemical and biological multidimensional and long-term positive changes in the soil and make soil fertility sustainable. In recent years, the importance of applying organic matter to soils in terms of sustainable soil use and preservation of soil quality has been well understood by many farmers. The inadequacy of organic matter sources in the face of increasing demand leads producers to use alternative organic fertilizer sources.

Agricultural use of organic wastes has been practiced since it was first produced. Composted organic wastes resemble manure and traditional organic compost. They may contain fertilizer elements in different proportions than an ideal fertilizer. Organic wastes are composed of largely organic solids, inorganic chemicals including heavy metals and plant nutrients, sometimes toxic organic chemicals, and some exotic compounds. Determination of hormonal effect (IAA contents and cytokinin-like activity) of SS [2] also shows an amazing diversity of sludge content. High organic matter and plant nutrient contents of SS and MSWC are important factors that support plant growth and soil fertility. The use of organic wastes as a soil conditioner also serves to improve soil physical properties in a manner similar to other organic-based soil amendments. However, the high salt content and the presence of possibly toxic organic and inorganic substances in these materials limit plant growth and sustainable use of soils. While SS has been land applied since it was first produced, most of early operations were carried out with little regard for possible adverse impacts to soil, crops, or ground water. With the increased interest in reclaimed water and the promotion of agricultural use for SS, there has been increased public scrutiny of the potential health and environmental consequences of these reuse practices. Today, in many countries, it is obligatory to biologically stabilise the treatment sludge for disposal by using it in agriculture.

The contents of organic waste composts vary greatly depending on the place and time of production and composting methods. Consumption habits, nutrition culture and waste management practices of the public living in a region determine the content of the raw waste obtained. The common finding of the studies on SS and MSWC to date is that these materials can be used as a valuable organic fertilizer in field and garden cultures. However, the time and spatial variability of the properties of these materials, and more importantly, the participation of pollutants from various emissions to these materials can be limited their usage.

III. Composted Wastes as a Source of Plant Nutrients

The plant nutrient value of composted SS has been evaluated by many investigators and the nutrient composition is considered to be similar to other organic-waste based soil amendments that are routinely applied on cropland, such as animal manure and other organic composts. SS applications improve yield in crop plants; and in forest plantations [3,4,5]. SS contains all the elements essential for the growth of higher plants. Nitrogen and phosphorus are the most abundant major plant nutrients in sludge, its agricultural usage is almost exclusively as a supplemental source of nitrogen and/or phosphorus fertilizer [6]. SS applications produce a general increment of nitrogen both in soil and plant tissue [7] and produces higher yield than NPK fertilizers at equivalent rates [4].

In addition to nitrogen and phosphorus, SS contain all other nutrients essential for the growth of crops, including calcium, iron, magnesium, manganese, potassium, sodium, and zinc [8]. Agricultural soils which have been tilled for decades are often deficient in certain trace elements, such as zinc and copper [9] and land applications of municipal sludge can help to remedy these trace metal deficiencies [10]. Where treated sludges are applied according to agronomic rates for nitrogen and phosphorus, many of these essential nutrients, with the possible exception of potassium, are usually present in amounts adequate to meet the needs of the crop [11].

Although SS can provide all essential plant nutrients, unlike manufactured chemical fertilizers whose nutrient properties can be formulated to suit the crop requirements, plant nutrients in composted wastes are uncontrolled. For this reason applying SS or MSWC at agronomic rates to satisfy the requirement for one nutrient may cause the levels of other nutrients to be excessive or remain deficient. The soluble inorganic forms are immediately available to plants, but the organic forms must first be mineralized to plant-available forms. For sludge to be efficiently used as a source of available nitrogen, the mineralization of organic nitrogen must be taken into account to avoid over fertilization, nitrate accumulation in plant and potential leaching of excess NO_3-N into ground water. It is reported that after surface application of an aerobically digested MSWC, nitrate was to be determined as a dominant anion in soil solution [12].

Most SS supply more than enough phosphorus to satisfy crop needs when applied as a source of nitrogen. In certain soils, available phosphorus may be excessive, particularly where animal manure is plentiful and where impacts to surface water quality are of concern. In these situations, soil phosphorus levels should be monitored and SS application rates be adjusted to correspond to crop phosphorus rather than nitrogen needs.

IV. Soil, Plant, and Ground Water Effects of Composted Wastes

Organic wastes, is rich in organic matter, which, if added in sufficient quantities, will improve the physical condition of soil and render it a more favorable environment to manage the nutrients and water. As with the addition to soils of other organic materials, such as hay and animal manure, the addition of organic matter accompanying successive organic wastes additions can improve the physical properties of soil. This, in turn, exerts a positive influence on water penetration, porosity, bulk density, strength, and aggregate stability. However, high salt content and possible high levels of elements such as Na, Cl and B can cause plant toxicity and soil structure dispersion.

The accumulation of metals in sludge-amended soils may inhibit the activity of certain strains of clover rhizobia and cyanobacteria, and cause reductions in microbial biomass. This may be of concern to the sustainability of certain negative legume species, but should not impact commercial food crop production. Studies on the microbiological contamination of plant fruit by SS applications showed that contamination was in accordance with the microbiological standard rules [13]. If stabilized SS is applied correctly in unsaturated soil conditions, the risk of transfer of viruses, bacteria and protozoa to groundwater can be negligible due to predictable pathogen death and immobilization of microorganisms on sludge and soil particles. Concentrations of potentially harmful trace elements in SS are, almost without exception, greater than their concentrations in typical soil. Potentially harmful chemicals (largely, trace elements and persistent organics) become concentrated in the SS during the wastewater treatment process. The persistent organic chemicals degrade over time in soils. Degradation rates are dependent on the chemical in question and on soil properties. Organic wastes applications usually increase the concentrations of trace elements in soils and metal contents in plants increased with increasing composted waste loading [13, 14].

Metal ion uptake by the vegetables was determined to be different among the different plant species [14]. Certain source constituents in SS (e.g., salts, cadmium, copper, nickel, and zinc) could be phytotoxic if added to soil in excess of critical levels. Trace elements and trace organics in SS are of concern if they are taken up by crops in amounts harmful to consumers or through other pathways. It is reported that most plants grown on soil amended with the higher SS rates were too high in Cd to be suitable for animal consumption [15].

Most of heavy metals are generally not mobile in soils. However their transport to ground water as a result of composted waste application at agronomic rates can vary depending on the soil and climate conditions and agricultural technics. Mobility and bioavailability of heavy metals increase under conditions of acidic soil reaction, light texture, low clay and organic matter, and low cation exchange capacity. Due to most trace elements are immobile, the added sludge-borne trace elements tend to concentrate in the surface to the depth of incorporation. The fate and transport of potentially harmful constituents in the environment are also of concern. If the constituents from the sludge application are not immobilized in the surface soil, they may escape the root zone and leach to ground water. As long as agricultural use of SS follows current regulations, no adverse effects on acid soils or potentially acid soils, are anticipated [16]. However, accumulation of large quantities of SS, containing relatively high levels of heavy metal, has increased the need for solution for safe disposal of this material without causing new ecological problems [17].

A few toxic organic compounds and detergents have been found in SS. Some trace organics may be absorbed by the aerial part of the plant through volatilization of the compounds from the soil surface. Plant tissues may absorb volatile toxic organic chemicals from the vapour phase of volatile compounds. It is postulated that, this pathway does not seem important, particularly where sludge are incorporated into the soil. Because the concentrations of toxic organic compounds in sludge are low and they are either biodegradable in soils or strongly sorbed by soil particles, they do not represent a risk to ground water contamination. On the other hand, the aeration that occurs during treatment of wastewater and during many sludge treatment processes removes most of the volatile organic chemicals at the treatment plant.

The findings obtained from the studies carried out to date are that SS and MSWC may be in different compositions and their effects may differ according to soil and climate conditions. It is known that as a result of repeated applications of these materials in agricultural soils for many years, pollutants easily accumulated in soil and plants at a significant level and cause many environmental problems [18, 19, 20, 21]. All of these are notable examples of the safe reuse concerns of these wastes and require strict compliance with relevant legal norms in the safe recovery of this type of wastes.

V. Conclusion and Recommendations

Based on more than 50 years of research and experience on various organic wastes, including SS and MSWC, agricultural practice guidelines and regulatory standards for the use of these materials have been developed by various international environmental research organizations. Today, norms for the use of SS and MSWC in agriculture have been developed in many countries and are under strict control. According to EPA, the use of SS in the production of crops for human consumption presents a manageable risk. In SS rule of European Union, it is stated that limits of the annual and cumulative loading of trace elements are adequate to protect against phytotoxicity and to prevent the accumulation of these elements in crops at levels harmful to consumers if it is applied in quantities commensurate with crop needs. Nevertheless, continued monitoring of trace elements in soils over longer time periods is also suggested. It is mostly recommended that application of composted sewage sludge in areas except for food crop production such as forest plantations and forest reclamation areas may be more safely alternative disposal.

Variation of organic waste composition in a great range and its heavy metal and toxic compound contents due to differences of waste origin (municipalities and their industrial contributors), treatment and conditioning processes could be seen a determining factors in agricultural usage. Due to the time and spatial variability of waste sources and waste content, it is important to standardize the composition of composted wastes as well as complying with the relevant norms in agricultural use of wastes. This application will enable to obtain a better quality compost with content arrangement as well as the supply of waste source in accordance with the standards and safe.

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