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Potential Effects of Sewage Sludge on Soil, Plant and Environment in Agricultural Use

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***Abstract*:** *Sewage sludge is an inevitable end product of wastewater treatment and contains many pollutants left over from wastewater treatment. Sewage sludge is a concentrated solids suspension, which is mostly composed of organic matter and nutrient-loaded organic solids, and whose consistency can vary in slurry or dry form depending on the treatment technique. Disposal of sludge has become a major problem as the amount of sewage sludge is gradually increasing and the variety of chemicals used today is gradually increasing. Sludge disposal always constitutes a significant part of the wastewater management cost. Since this problem could not be solved with current methods, it became necessary to conduct new researches on this subject. Many countries have imposed legal restrictions on certain sludge disposal practices (e.g. sea discharges and landfills) over the past 50 years, leading to widespread agricultural use of sewage sludge as an economical alternative disposal method. The common finding of the studies carried out to date is that there is no doubt that sludge has an economic value in terms of growing plants. In various countries around the world, sewage sludge is applied to the land for the improvement of agricultural areas, grass growing areas and mining areas due to its beneficial effects. Increasing interest and incentives for the use of sewage sludge, which contains many pathogens and pollutants, is creating a growing social concern over the environmental consequences and potential health hazards of these recycling practices. The production of large quantities of sewage sludge, which contains relatively high levels of heavy metals and toxic substances, increases the need for solutions for safe disposal of this material without causing new ecological and environmental pollution problems.*

Keywords: *sewage sludge, soil, plant, environment*

1. Characteristics of Sewage Sludge

The composition of the treatment sludge can be very variable depending on the source of the wastewater, the treatment technique of the wastewater, the quality of the wastewater and seasonal effects [1, 2]. Sewage sludge is composed of mostly organic solids, toxic organic chemicals, plant nutrients and inorganic chemicals including heavy metals and some exotic compounds and has a rich salt content. The determination of the hormonal effect (IAA content and cytokinin-like activity) of sewage sludge on the rooting of plants [3] reveals the surprising diversity and richness of the sludge content. Sewage sludge can also contain pathogenic bacteria, viruses and parasite eggs, which are a health concern. The amount and composition of these substances can be completely different according to different countries or settlements.

Table 1 shows the composition of a typical domestic raw sewage sludge and traditional barn manure. In domestic sewage sludge, most of the dry matter is composed of organic matter as in barn manure, nitrogen and phosphorus contents are higher and potassium content is lower in terms of plant nutrients compared to barn manure. It appears to contain heavy metals in higher concentrations than barnyard manure. Since raw sewage sludge is not biologically stable, it may cause appearance, odor and hygienic problems; It is stated that anaerobically digested sludge will not cause such problems since it is biologically stable. In addition, large

amounts of polycyclic aromatic carbohydrates (3,4-Benzpyrene; 3,4-Benzfluoranthen; etc.) can be found in sewage sludge and these are carcinogenic compounds.

TABLE I. Typical Composition of Raw Sewage Sludge and Digested Sludge [4].

Parameters	Raw sewage sludge	Manure
pH	6,0	7,96
Organic matter, %	65	73,8
Total Nitrogen, %	4,0	2,12
Total P_2O_5, %	2,0	1,77
Total K_2O, %	0,4	1,56
Total Zn, mg kg^{-1}	1660	180
Total Cu, mg kg^{-1}	236	46
Total Ni, mg kg^{-1}	54	15
Total Pb, mg kg^{-1}	443	21
Total Cd, mg kg^{-1}	2,8	*

*: Below detection limit (< 0.01 mg kg-1)

Heavy metal content of sewage sludge varies considerably depending on its source. In this respect, there are significant differences between domestic wastewater treatment sludge and industrial wastewater treatment sludge, and it is reported that the sludge remaining after the treatment of domestic wastewater has a lower mineral substance density, and zinc is the dominant substance among heavy metals. Since industrial wastewater and the treatment sludge precipitated from them contain toxic and harmful substances to plants, their use in agriculture is considered quite problematic.

2. Potential Role of Sewage Sludge in Agricultural Use

The agricultural use of sewage sludge has been attempted since approximately 150 years ago, when modern wastewater management began. The characteristics of the domestic sewage sludge resemble organic fertilizer and compost and may contain nutrients in different proportions compared to an ideal fertilizer. Although the proportion of sewage sludge in agricultural use is very low in general, the regional proximity of agricultural lands to the treatment plants significantly affects the potential of sewage sludge in agricultural use locally. In terms of producers, some factors limit the agricultural use of sewage sludge. The use of sewage sludge is generally more difficult than the use of chemical fertilizers. The reason for this is that the physical and chemical properties (different water, nutrient and trace element contents) of the sludge formed as a result of the differences in the settlements and treatment processes, which are the source of the wastewater, are variable.

An alternative disposal is provided by the use of sewage sludge in agricultural areas and the use of recycled elements in the sludge in plant production. Sewage sludge contains essential plant nutrients for plant growth. The use of sludge as a soil conditioner improves soil physical properties similar to other organic-based soil applications. However, in most field applications since the initial production of sewage sludge, little attention has been paid to its adverse effects on soil, vegetation and groundwater. Low concentrations of toxic chemicals enter the wastewater and most of these toxic chemicals are taken from the wastewater by wastewater treatment processes and concentrated in the sewage sludge. Sewage sludge also contains human pathogens. Although the number of pathogens present in wastewater can be significantly reduced by treatment, pathogens and toxic chemical pollutants can enter sludge-treated soil. Today, producers and food industries in many countries are expressing their concerns that the agricultural use of sewage sludge will affect the safety of food products and sustainability in agricultural areas, potentially posing economic and liability risks [5].

3. Plant Nutritional Properties of Sewage Sludge

The plant nutrient value of the sewage sludge is similar to the organic waste-based soil conditioners routinely applied to agricultural fields such as barnyard manure and compost; It has been reported that sewage sludge applications increase the amount of product in cultivated plants and forest plantations [6].

Sewage sludge contains all the essential elements for the growth of higher plants. Nitrogen and phosphorus are the most abundant essential plant nutrients in sludge. It is stated that most of the total nitrogen in the treatment sludge is protein nitrogen, and the nitrogen utilization coefficient in the sludge varies between 10% and 30% depending on the soil type and plant type. Whereas the plants benefit from the phosphorus in the sludge relatively better, and it has an effect like Thomas phosphate and Superphosphate [7]. Sewage sludge applications provide a general increase in nitrogen content in soil and plant tissues [8] and sometimes yield higher yields than NPK fertilizers equivalent to nutrient content [9].

However, plant nutrients in sewage sludge are out of control, unlike commercial fertilizers whose nutritional properties are produced to meet plant needs. For this reason, the treatment sludge applied at agronomic rates to meet a selected nutrient requirement may cause the levels of other nutrients to be insufficient or excessive. Sewage sludge contains approximately 1-6% organic and/or inorganic nitrogen in dry matter. While soluble inorganic nitrogen forms are directly available to the plant, organic forms must be mineralized in order for them to be converted into plant available forms. In addition to nitrogen and phosphorus, sewage sludge also contains other essential nutrients for plant growth such as calcium, potassium, magnesium, sodium, iron, manganese and zinc. It has been reported that when sewage sludge is applied in agronomic amounts for nitrogen and phosphorus nutrients, it will generally provide most of the other essential nutrients with the possible exception of potassium [10].

4. Effects of Sewage Sludge on Soil, Plant and Groundwater

As in the application of other organic materials such as sewage sludge, compost and barnyard manure, which are rich in organic matter, to the soil, when applied in sufficient quantities, it improves the physical conditions of the soil and creates a more suitable environment for nutrient and water regulation. Thus, it has a positive effect on water penetration, porosity, bulk weight, structural strength and aggregate stability in the soil.

In the use of sewage sludge as a nitrogen source, mineralization of organic nitrogen should be considered to avoid over-fertilization, nitrate accumulation in the plant and the potential danger of leaching of excess nitrate into groundwater. As with all agricultural practices, proper management is necessary to avoid excess nitrate application.) It is determined nitrate as the dominant anion in the soil solution after the application of aerobically treated urban sludge to the soil [11]. Many types of sludge provide phosphorus in excess of plant requirements when applied as a nitrogen source. In certain soils, the amount of available phosphorus can be high, particularly where barnyard manure is plentiful and its impact on surface water quality is of concern.

The accumulation of metals in sewage sludge treated soils can inhibit the activity of Rhizobium and Cyanobacter species and cause decreases in microbial biomass. Studies on microbial contamination of plant fruit by sludge treatments have shown that contamination complies with microbiological standards [12]. The risk of transfer of viruses, bacteria and protozoa to groundwater due to sludge applications due to predictable pathogen death on sewage sludge and soil particles and immobilization of microorganisms can be ignored within certain limits if the sewage sludge is properly treated and applied to unsaturated soils.

Concentrations of potentially harmful trace elements in sewage sludge are, with very few exceptions, higher than typical concentrations in soil. Potentially harmful chemicals (largely trace elements and stable organics) are concentrated in the sludge during the wastewater treatment process. Sewage sludge applications generally increase the concentrations of trace elements in the soil and the metal contents in plants increase with increasing sludge loading on the soil [12,13, 14]. It is stated that heavy metals added with the treatment sludge applied to the soil 16 years ago are still in the form that can be taken by the plant [15].

Bioavailability of heavy metals in sewage sludge with metal content within acceptable limits is quite high [16, 17]. In repetitive field applications, trace elements other than boron accumulate at or slightly below the depth where the sludge is applied. Resistant organic chemicals decompose in the soil over time, depending on their chemical properties and soil properties.

Certain elements in sludge (eg salts, Cd, Cu, Ni and Zn) can be phytotoxic when applied to soil above critical levels. Trace elements and trace organics in the sludge may cause serious health problems if they are taken up by the product at a level that will be harmful to consumers or if they reach them by other means. When the elements from the sludge application are not immobilized in the surface soil, they will be able to reach the root zone and drained into the groundwater. The transport and fate of such potentially harmful elements is also an environmental concern. It is highly probable that heavy metals accumulating in the plant can act in the plant-animal-human chain and have a toxic effect on humans. It has been reported that the Cd content of most plants grown in highly sludge-treated soil is well above the level suitable for animal consumption [13].

On the other hand, contrary findings are that the use of sewage sludge does not cause dangerous increase in heavy metal contents (Zn, Cu, Ni, Pb, Cd and Cr) in the tested plants and the levels are in the acceptable range [12], the current practice in agricultural use of sewage sludge. There is also local and limited research evidence that it will not have a negative impact on acid or potentially acid soils when regulations are followed.

5. Conclusion

According to the results obtained from the researches made with sewage sludge, there are values indicating that the productivity of the treated sludge increases and some soil physical properties are positively affected. However, it is seen that unwanted harmful organic substances and heavy metal accumulation occur, and potential threats on agriculture and environmental values with the increasing bioavailability of metals in the medium and long term. When using sludge in plant production for human consumption, the criteria in the legal regulations and the guideline information are complied with; It is stated that crop production carries a manageable risk for the environment and consumers. On the other hand, in recent years, there has been an increase in research findings suggesting that processed sewage sludge can be an alternative substrate for the cultivation of ornamental plants. By making regulations in the physical and chemical structure of the sewage sludge, it can be converted into commercial value in first class compost and/or substrate quality.

In the agricultural use of sewage sludge, due to the potential health, environmental and sustainability risks it carries, the discipline of the sewage sludge application regulation should be strictly followed in terms of a protective approach within the scope of our current knowledge and technological possibilities in sludge production. On agricultural soils where treatment sludge is applied; In order to determine the long-term potential effects of sludge on the sustainability of groundwater and soil plant production, detailed information is needed in terms of sewage sludge-soil relationships, without approaching the buffering limit of pollutants.

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