

## Comprehensive utilization of urban sewage sludge

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### Abstract

Sewage sludge compost can be utilized as an agricultural fertilizer from secondary raw materials and as a soil filler in gardening, landscaping, and land reclamation. The composting technology is tested and available; moreover, the use of low-pollution compost is crucial. To ensure and guarantee quality, as well as for product sale, quality assurance systems similar to those for bio-waste compost should be applied. Voluntary quality confirmation of products made from sewage sludge can achieve important goals.

**Keywords:** Stabilization, compost, quality, bulking agent, organic matter, sanitation, sewage sludge

### Introduction

Throughout history, human settlements and industrial sites have been established near freshwater bodies used for drinking, hygiene, agriculture, and industrial purposes. Water usage by humans alters its natural properties, sometimes making it sanitary hazardous. With the development of urban and industrial engineering, organized systems for discharging polluted water through special hydraulic structures became necessary. Freshwater's importance as a natural resource is continuously increasing. Domestic and industrial use pollutes water with mineral and organic substances, turning it into wastewater.

Industrial growth necessitates preventing the adverse effects of industrial wastewater on water bodies [1]. Many modern technological processes involve discharging wastewater into water bodies. The diverse composition, properties, and flow rates of industrial wastewater require specific methods and structures for local, preliminary, and complete treatment. Each industrial enterprise's engineering communications include a complex of sewer networks and facilities for discharging wastewater (which is technically or economically unfeasible to reuse) and facilities for preliminary wastewater treatment and valuable substance extraction [2].

Since these residues are sources of nutrients and organic matter, it is logical to return them to the soil under optimal conditions to enhance fertility and continue the natural nutrient cycle. These organic wastes can undergo biodegradation processes, breaking down complex components into simpler compounds by living organisms. Composting is a type of biological treatment that can stabilize municipal sewage sludge. There are four phases of composting [3].

**Phase 1 (lag phase):** It starts immediately after fresh waste is added to the compost pile. Microorganisms adapt to the waste type and living conditions in the compost pile during this phase. Although decomposition begins, the microbial population is still small, and the temperature is low.

**Phase 2 (mesophilic phase):** The substrate decomposition process intensifies. The microbial population increases, mainly due to mesophilic organisms adapting to low and

moderate temperatures. These organisms quickly break down soluble, easily degradable components like simple sugars and carbohydrates. Once these substances are depleted, microbes start decomposing more complex molecules like cellulose, hemicellulose, and proteins. After consuming these substances, microbes release complex organic acids, which serve as food for other microorganisms. However, not all formed organic acids are absorbed, leading to their excessive accumulation and resulting in a pH decrease, indicating the end of the second composting stage. This phenomenon is temporary as the excess acids lead to the death of microorganisms.

**Phase 3 (thermophilic phase):** Microbial growth and metabolism cause the temperature to rise. When the temperature exceeds 40°C, mesophilic microorganisms are replaced by thermophiles, which are more resistant to high temperatures. At 55°C, most human and plant pathogens die. If the temperature exceeds 65°C, aerobic thermophiles in the compost pile die. The high temperature accelerates the breakdown of proteins, fats, and complex carbohydrates like cellulose and hemicellulose, the main structural components of plants. As food resources deplete, metabolic processes slow down, and the temperature gradually decreases.

**Phase 4 (final phase):** As the temperature falls to the mesophilic range, mesophilic microorganisms dominate the compost pile again. Temperature is the best indicator of the maturation stage. In this phase, remaining organic substances form complexes known as humic acids or humus, resistant to further decomposition.

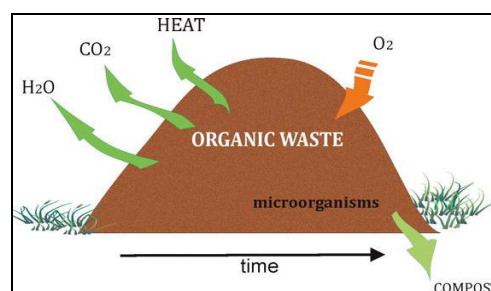


Fig 1: Simple diagram of the composting process

Compost made from sewage sludge used as a soil filler has several advantages over untreated sludge. It has higher moisture retention, improves soil water supply, increases pore volume, enhances aeration, stabilizes structure, and protects against erosion. During decomposition, harmful components are neutralized, resulting in a hygienically safe product.

**Composting process:** Compost is obtained from the aerobic treatment of a special mixture of sewage sludge and other materials, usually wood waste, bark, garden trimmings, and green branches. Compost is classified as fresh or mature depending on the degree of decomposition. Soil obtained from prolonged sewage sludge composting, such as soil formed over years in reed filters (biological-soil systems for small-scale sewage treatment in rural areas), is one example. For necessary aerobic conditions, moisture levels (over 50% during intensive decomposition) and air pore volume in the material should be sufficiently high. Since sewage sludge structure is unstable, unlike bio-waste, some additional ingredients are needed:

- Shredded shrub trimmings
- Long-fiber plant waste
- Chopped straw and wood
- Tree bark
- Sawdust and wood chips
- Paper and cardboard trimming.

The amount of additional materials depends on the dry substance content in the sludge: as moisture content increases, so does the fraction of additives and the total volume of sludge to be treated. Dehydrating the initial material is recommended to reduce the volume of decaying material.

**1. Composting systems:** Six hygienically tested systems are used for sewage sludge composting:

- Containers
- Tunnels
- Open piles
- Covered piles
- Piles with membrane covers (semi-permeable)
- Reactors.

Stack composting systems using turning machines and reactors are widespread. In stack composting, fresh compost from closed systems must go through a maturation stage to reach the IV or V decomposition degree. Composting sewage sludge costs in Germany range from €100 to €200 per ton of dry substance for stack composting and €150–300 per ton for reactor use.

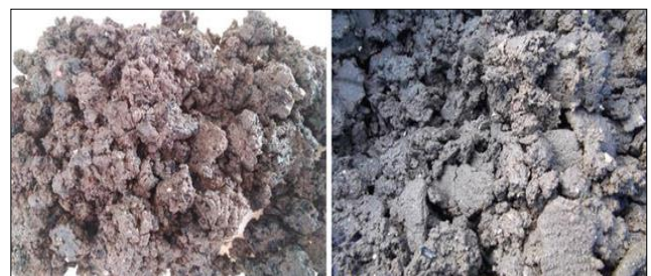
**2. Heavy metal content in sewage sludge:** Besides essential biogenic elements like phosphorus and other organic substances, sewage sludge contains significant concentrations of anthropogenic heavy metals. Protecting the environment from pollution under intense anthropogenic pressure is a global ecological problem [4]. The level of environmental heavy metal pollution increases with urbanization and industrialization. The chemical impact on plants, animals, and humans occurs through food chains that connect the plant and animal worlds of specific communities into a unified migration system. In acidic soils, heavy metal mobility and availability to plants are

significantly higher compared to neutral and slightly alkaline soils [5]. With city growth and industrial production increase, sewage volumes have risen, leading to widespread sewage treatment plant construction in the past two decades. However, wastewater treatment inevitably creates sludge disposal problems. Urban sewage sludge (USS) has a complex elemental composition, containing significant amounts of organic matter, nitrogen, and ash elements, primarily phosphorus. This makes its extensive use as unconventional organic fertilizers in agriculture and urban greening feasible [6, 7, 8].

A crucial condition for maintaining ecosystem sustainability is using waste as a raw material resource and reducing its negative environmental impact [9, 10]. One method of USS disposal is its use as fertilizer in its original state or in compost with organic fillers [11]. It is known that USS effectiveness is comparable to traditional organic and mineral fertilizers. In the 1970s-80s, the environmental aspects of using urban waste organic fractions in agriculture attracted increasing attention in the European Economic Community, Japan, and the USA [12, 13]. However, using USS may lead to soil contamination with heavy metals. USS contains several metals, which, though not functionally significant for plants, can adversely affect plant growth and development [14]. The primary factor determining the ecological significance of studies on using USS as fertilizer is the heavy metal content. All elements in USS can be classified into three subgroups based on potential agroecosystem hazards:

- Toxic: Cd, Ni, Pb, Zn, Cu, Cr<sup>3+</sup>
- Moderately toxic: Ag, Sn, Sr, Zr, Se
- Non-toxic: B, Co, Mo, Mn [15, 16].

To improve the initial physical and physicochemical properties of USS and reduce the overall concentration of macro- and microelements, organo-vegetal compost (OVC) is produced based on USS. This improves ecological indicators related to heavy metal dynamics and plant availability [17]. The main indicators characterizing soil pollution when using USS and OVC are concentration coefficients and the total elemental contamination index. Figure 2 shows various aspects of the collected sewage sludge.



**Fig 2:** Sewage sludge from two treatment plants

**3. Comprehensive Utilization of Urban Sewage Sludge:**

To obtain a sanitary-epidemiologically safe product containing urban sewage sludge, an aerobic fermentation technology (passive composting) of dewatered sludge organic matter was chosen, included in the best available technologies list [19, 20]. According to studies and regulations, effective composting of organic waste requires:

- Optimal compost material moisture content should be 60%, but the process can occur within a 40-70% range.

Higher moisture content slows organic decomposition, creates anaerobic conditions, and produces foul odors.

- The C/N ratio of compost material should be 25:1 to 35:1. Higher ratios slow the process, while lower ratios cause nitrogen loss.
- The optimal pH level for compost material is 7-8, but composting can occur in a wider pH range (6.5-9).

Composting organic waste results in a fermented mixture that is stabilized biocompost with high nutrient content [21, 22]. During organic decomposition, self-heating of compost material (over 60°C) occurs, killing most human and plant pathogens and weed seeds [23, 24]. Optimal parameter ranges were maintained by selecting compost mixture components. The classic approach to obtaining fermented sewage sludge involves adding carbon-rich components (sawdust, straw, peat) to balance the high nitrogen content in the sludge and achieve the optimal C/N [25, 26, 27].

**Conclusion:** Based on the analysis, it is possible to jointly utilize urban wastewater sludge with clean wood sawdust, feed waste, peat, and soil waste. The resulting beneficial product in the form of biocompost is characterized by a high content of organic matter, nitrogen, phosphorus, and potassium in forms accessible to plants. When biocompost is mixed with sand, optimal ratios were identified, providing the most favorable conditions for the growth of herbaceous plants, exemplified by ryegrass. Increasing the options for urban wastewater sludge utilization will reduce the number of sludge fields, thereby decreasing the negative impact on environmental components. However, it is crucial to ensure that each batch of produced biocompost or the resulting technogenic soil is controlled for sanitary-hygienic, bacteriological, and parasitological indicators to confirm their safety for various uses according to current regulatory documents.

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