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Original Research

Sewage Sludge Composting

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Abstract

Sewage sludge is formed during mechanical, biological and chemical sewage treatment. Composition of the sewage sludge is very complicated; it is rich in micro- and macroelements, but the sludge can contain toxic compounds and pathogenic organisms. There exist a large variety of methods of neutralization of the sewage sludge.

The present work describes the sewage sludge treatment methods and pays special attention to non-industrial methods of neutralization of the sewage sludge.

Keywords: sewage sludge, compost, composting.

Introduction

Sewage sludge is formed during mechanical, biological and chemical sewage treatment. Most often sludge content does not exceed 2% of the effluent sewage volume; however, we observed tendencies to build new sewage treatment plants or to develop those already existing. This causes the generation of large amounts of sewage sludge and the problem of its management becomes a growing problem.

Sewage sludge obtained as a by-product reflects the chemical composition of the treated sewage, but the composition of sewage itself is determined by the industrial wastewater inflow to the treatment catchment. Quantitative and qualitative composition of the sewage sludge is very complicated. It is rich in organic matter, nitrogen, phosphorus, calcium, magnesium, sulphur and other microelements necessary for plants and soil fauna to live. So it is characterized by the large manurial and soil-forming value. Except the indispensable elements to live, sludge can contain toxic compounds (heavy metals, pesticides) and pathogenic organisms (bacteria, eggs of parasites) [1-14].

In accordance with the above-mentioned composition sludge is qualified by law (State Journal, No 96, item. 592, 27.06.1997) as a waste material. This law simultaneously qualifies the rules of prevention of formation of waste material or minimize their quantities, removing the waste material from the formation place, and also utilizations or neutralization of waste material in such a way that assures the protection of life and health of people and protection of the environment. The manufacturer is obliged by law to utilize, remove and neutralize waste material [15]. So it is very important to predict the method of neutralization in the early steps of the project. Simultaneously it is necessary to guarantee financial support to perform all investment intentions. This practice shows that costs of neutralizing the sewage sludge carried through years of exploitation are greater than the cost of the investment (building of sewage plant). This is the next important argument, to develop new and cheap methods of utilization of sewage sludge in practice.

Figure 1 presents the selection of sludge treatment methods. The figure shows that composting and environmental utilization are two most preferred ways of sludge management and simultaneously these two groups of processes vary from the economical point of view. The composting is more expensive and environmental utilization is one of the cheapest methods of neutralization of sewage sludge [16].

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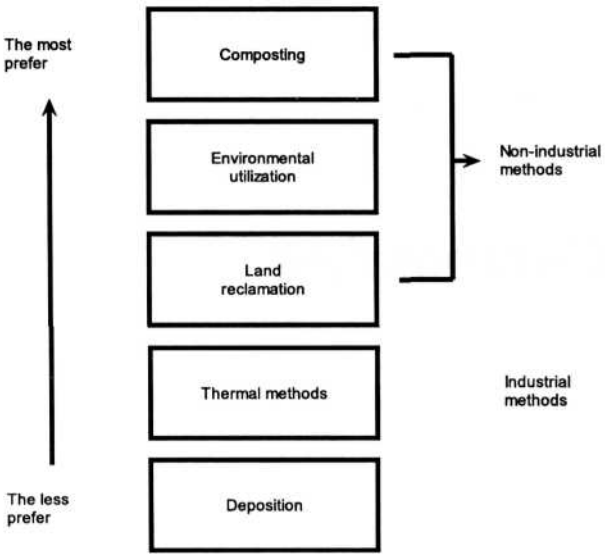

Fig. 1. Management of sewage sludge.

In the present work, sewage sludge treatment methods are described, with special attention for non-industrial methods of neutralization of the sewage sludge.

Quantitative and Qualitative Composition of Sewage Sludge and Compost

As presented in the introduction, sludge includes organic matter, nutrients and microelements. Inclusion of those compounds in the food chain is advantageous from an ecological point of view [7, 11, 17]. Non-industrial methods are applied in the sludge treatment to perform the above task.

In Figure 2 the divide of analytical methods utilized in compost analysis is presented. These techniques give the possibility for determination of qualitative and quantitative inorganic and organic compost compounds. In many cases determination of individual compounds at the trace level requires the application of suitable sample preparation techniques in *off-line* and *on-line* systems. Transparently, complied techniques as automated methods are recommended for these determinations [18].

The average mineral composition of the sludge is represented in Table 1 in comparison with limits for compost classes according to BN-89/9103-09 **[19-22].**

Sludge intended for non-industrial utilization should meet many requirements. One of them is the content of heavy metals. The maximum acceptable amounts of heavy metals in sewage sludge are represented in Table 2 [1, 12, 24].

Table 2. Acceptable contents of heavy metals in sewage sludge [1,12,24].

Metal	Soil fertilization, land reclamation		Agrotechnical composting Drainage and reclamation
	Agricultural exploitation	Non-agricultural exploitation	
	mg/kg d.m.		
Lead (Pb)	500	1000	1500
Cadmium (Cd)	10	25	50
Chromium (Cr)	500	1000	2500
Copper (Cu)	800	1200	2000
Nickel (Ni)	100	200	500
Mercury (Hg)	5	10	25
Zinc (Zn)	2500	3500	5000

Except for heavy metal contents, the other important factor that restricts the environmental utilization of sludge is the presence of pathogenic organisms (Table 3) and hydration (optimal 18-25% dry matter) [24-26].

Table 3. Biological-sanitary quality of sludge [24-25],

Determination	Admissible value of factor	
	Soil fertilization	Land reclamation
Pathogenic bacteria	Undetectable	Undetectable
Coliform index	Not lees than 0.01	–
ATT	< 10 in kg d.m.	< 300 in kg d.m.

where: ATT – eggs of helminth factor.

Table 1. Physico-chemical and manurial parameters of sewage sludges and composts [19, 23-24].

Determination	Unit	Sludge	Classes of composts according to BN		
			I	II	III
Total solids	% d.m.	45	–	–	–
Content of mineral matter	% d.m.	50	–	–	–
Content of organic matter	% d.m.	50	> 40	> 30	> 20
Hydration	% d.m.	55	25 – 40	25 – 40	50
Total nitrogen	% d.m.	< 2.0	> 0.8	> 0.6	> 0.3
Total phosphorus (P_2O_5)	% d.m.	< 1.5	–	–	–

where: d.m. – dry matter.

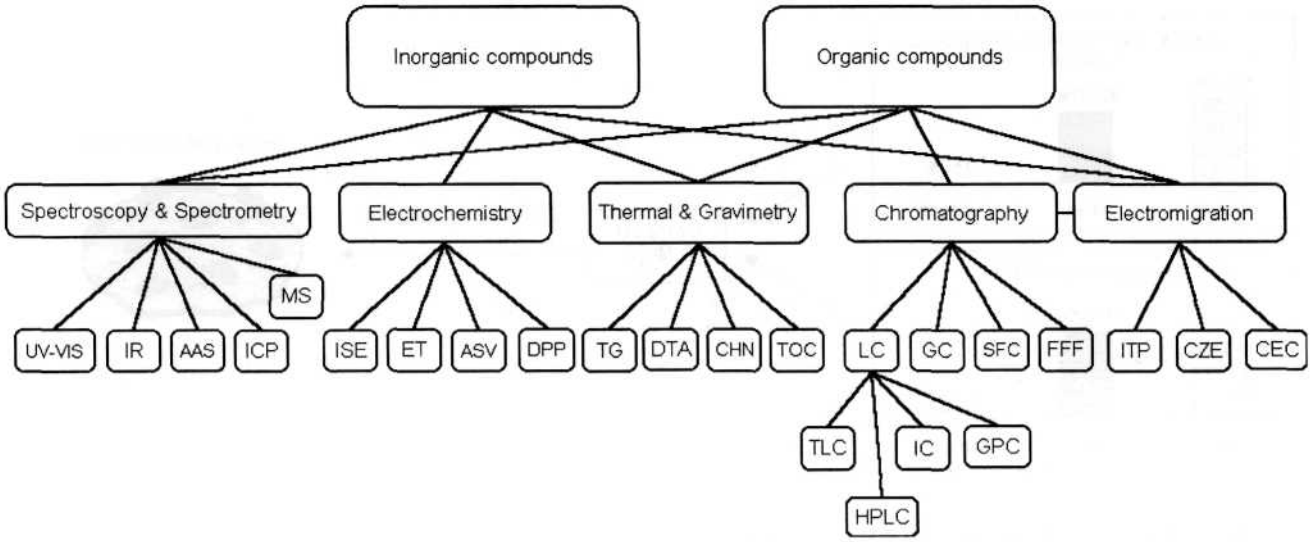

Fig. 2. Divide of analytical methods used in compost analysis [18].
where: AAS - Atomic Absorption Spectrometry, ICP - Induced Coupled Plasma, MS - Mass Spectrometry, ISE - Ion Selective Electrode, ET - Electrotitration, ASV - Anodic Stripping Voltamperometry, DPP - Derivative Pulse Polarography, TG - Thermogravimetry, DTA - Differential Thermal Analysis, CHN - Elemental Analysis, TOC - Total Organic Carbon, LC - Liquid Chromatography, TLC - Thin Layer Chromatography, HPLC - High Performance Liquid Chromatography, GPC - Gel Permeation Chromatography, GC - Gas Chromatography, SFC - Supercritical Fluid Chromatography, FFF - Field Flow Fractionation, **ITP** - Isotachophoresis, CZE - Capillary Zone Electrophoresis, CEC - Capillary Electrochromatography.

The improvement of biological-sanitary quality of the sludge can be performed by means of e.g. lime process. Keeping the pH value on the level of 10-12 warrants the sufficient sanitation of the sludge and the decrease of the coefficients to the values given in Table 3. However, one of the serious disadvantages of the lime process is non-persistent bonding of toxic heavy metal ions [11,27].

Composting with Structural Materials

The most preferred method of neutralization of sewage sludge is composting. It is a complicated process aimed at:

- destruction of pathogenic organisms;
- stabilization of organic matter - ripening;
- drying of the sludge;
- production of material which can be environment ally used or sold [28].

To reach the above aims the sludge has be mixed with structural materials in suitable proportion to obtain a C:N ratio of about 30:1 in the compost (Fig. 3).

In practice the most often used structural materials contain cellulose (i.e. wooden shavings, sawdust, bark, straw, leaf litter). The transformation occurring during the composting of materials containing cellulose with the sludge have enzymatic character [28-29]. Municipal waste materials and, e.g., shavings from elastic tyres are also used in composting [5, 28, 31, 33-37].

Many parameters influence the composting process. The most important factors are listed in Table 4:

Table 4. Parameters have influence on composting process [28, 32].

Determination	Unit	Value
Temperature of composting	°C	55 – 60
Moisture (W%) composting masses	%	40% < W < 60%
Aeration	$m^3/t \cdot h$	90 – 160
Time of composting	weeks	< 4
Time of ripening	months	< 6

The process of composting can be performed in several ways:

1. Pile method - heaping up the sludge piles mixed with structural materials and periodically turning these piles to aerate [28, 37];
2. Aeration's heap method - similarly as in the pile method, but the heap is arranged on a porous layer, which is periodically aerated by a blower [28];
3. Oxygenic composting in reactors [28]:

- vertical reactor (silo) - most often such reactors work in parrel rows. In the first the reactor most intensive processes of decay of organic matter occur. The second reactor can be used for ripening;
- horizontal reactor (tunnel reactor) - devices work in a single-stage arrangement. A big piston pushes the com posting mixture thorough the tunnel to its outlet;
- with mixing - rectangular or round arrangement, in which the aeration and mixing system are placed in dif ferent positions.

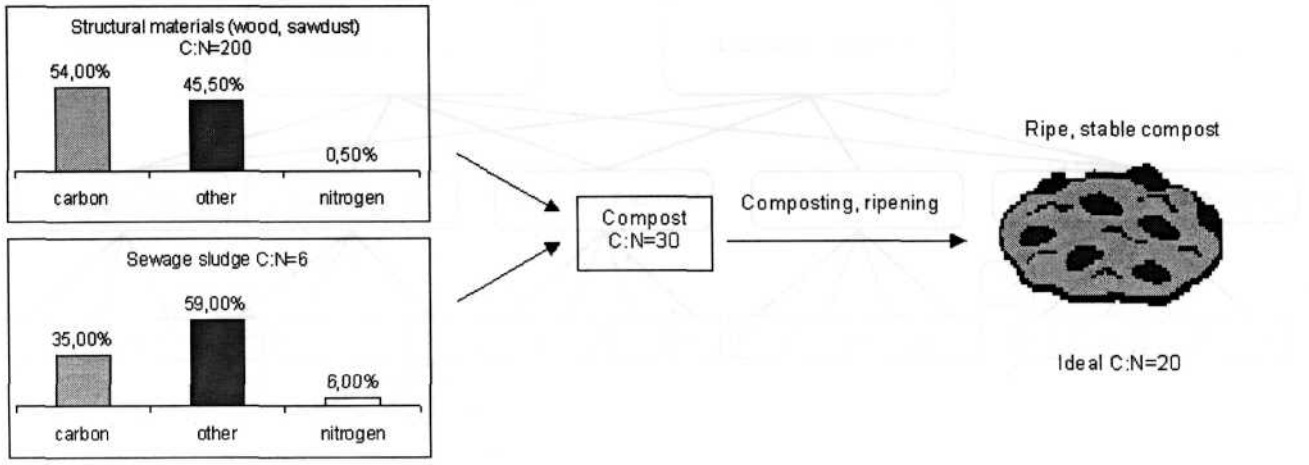

Fig. 3. Dependence C:N ratio in structural materials, sewage sludge and compost [28].

4. Composting in anaerobic reactors - the mixture of the sludge and the structural material is closed in reactors, where processes of fermentation occur [28].

The composting process transforms clammy consistence of the sludge to a sallow form of cloddish structure. Thanks to its structure it is easy to use it in field applications [1, 38-39].

The potential use of the obtained product of composting is agricultural use - fertilization of soils, planting of trees and shrubs [2, 9, 40, 46-47].

Agrotechnical Composting

Except for the composting of the sewage sludge with structural materials, in practice, agrotechnical composting is also used. Sludge supports the intensive growth of plants thanks to many nutrient components and water [1-2, 5-7, 10, 11, 17, 41]. Gradual draining and aeration transforms clammy consistency of the sludge to a sallow form. Annual putting of following layers of clammy sludge and sowing of plants (grass, charlock, reed, osier) causes the formation of the bed of several dozen sediments thickness being the product of sludge and plant fermentation [2, 41-45, 48].

Agrotechnical transformation of the sludge into the compost can be carried out in several manners:

- in lagoons filled with the sludge;
- in lagoons intended for drainage and temporary storage of the sludge;
- on sludge draining plots;
- in special beds used for sludge-vegetable compost production [2, 5, 49-50].

Non-Conventional Methods

Except for the methods of obtaining compost mentioned above, in practice several non-conventional techniques are applied. They are, for example vermiculture, i.e. farming of worms *(Eisenia fetida, Dendrobaena venetd)* at very high population [51-53].

Environmental use of the sewage sludge is connected with drainage and wasteland reclamation.

Drainage

Use of the sludge should increase the soil resources e.g. nutrients, humus, improve air-water conditions. The content of heavy metals in the sludge can be higher (Table 2), because the plants are not intended to be food of fodder [1-2, 5-7, 54].

Reclamation

The grounds of naturally degraded vegetable-soil cover, mining excavations, embankments and dumping sites of geological origin masses, dumping sites of waste industrial and municipal material is suitable to reclamation use of the sludge. The sludge in a suitable dose is introduced to the surface layer of depleted ground, and thanks to it the ground obtains proprieties of soil [1-2, 5, 11, 36, 38, 39, 54].

Surfaces threatened with water erosion and dependent on the erosive activity of wind can be fixed by means of the sewage sludge and plants (greening) [1-2, 5, 54].

Dose of Sludge or Compost

An important criterion of the utilization of sewage sludge is the dose of the sludge per area unit. The determination of suitable doses is difficult and the following factors must be taken into account:

- quantity of nutrients (especially nitrogen);
- quantity of soil - forming organic matter (humus);
- admissible contents of heavy metals in brought, fer tilized or reclaimed soils;
- contents of heavy metals in the sludge intended for fertilization or reclamation [1, 5, 55].

Composting and environmental use of sewage sludge is classified as waste-free technology.

Torun Experiences

Torun has possessed a modern sewage treatment plant for several years. The Municipal Sewage Treatment Plant (MOS) in Torun takes daily ca. 60,000 m^3 of sewage to treat, producing simultaneously ca. 80 tons of sewage sludge daily. Assuming a waste-free technology it was decided to compost the sludge and to carry out further environmental applications. The grounds existing around MOS (ca. 130 hectare) were divided into fields where the sludge, nutrients and compost are applied. During composting the colza straw and sawdust are used together with the sludge at a ratio of 1: 1 [16].

Conclusions

There exists a large variety of methods of neutralization of sewage sludge; however, their cost is a serious limitation in practice. Further development of the methods of waste material removal is necessary to limit the investment and exploitation costs. Sludge management should be developed towards great environmental utilization and this is possible with a gradual decrease of the storage on municipal dumping sites.

Acknowledgments

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