Research on the possibilities of evaluation and recovery of sludge from sewage treatment plants from the perspective of circular economy

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Abstract

The characterization and recovery of sludge from sewage treatment plants involves understanding its composition and implementing strategies to extract valuable resources from this byproduct. Sludge characterization helps identify its properties, including organic and inorganic content, contaminants, and potential for resource recovery. Recovery processes focus on extracting energy, nutrients, and other valuable materials from sludge, contributing to sustainable waste management practices. Characterization of sludge involves assessing its physical, chemical, and biological properties. This includes determining the moisture content, organic matter content, nutrient levels, heavy metal concentrations, and presence of pathogens or other contaminants. Through detailed characterization, treatment plants can optimize their processes and implement suitable recovery techniques. Recovery of sludge offers several benefits. Energy recovery can be achieved through anaerobic digestion, where organic matter is decomposed by microorganisms to produce biogas, a renewable energy source. Alternatively, sludge incineration can produce heat or power. Nutrient recovery is another important aspect, as sludge can be a valuable source of phosphorus and other essential nutrients for agricultural use. Additionally, innovative techniques like pyrolysis and hydrothermal carbonization are being explored to recover resources such as biochar and carbon-based materials from sludge. The characterization and recovery of sludge from sewage treatment plants are essential for sustainable waste management. By understanding its composition and implementing recovery processes, valuable resources can be extracted, including energy, nutrients, and other valuable materials. These efforts contribute to minimizing waste, promoting resource efficiency, and mitigating environmental impacts associated with sludge disposal. This study provides an overview of the characteristics, management, and potential uses of sewage sludge.

Keywords: *sludge, management, valorization*

1. Introduction

Sludge from sewage treatment plants refers to the semi-solid residue that remains after the wastewater treatment process. It is commonly known as sewage sludge or biosolids. Sewage sludge is primarily composed of organic and inorganic materials that are present in the wastewater, along with bacteria and other microorganisms that play a role in the treatment process. During sewage treatment, solid particles and organic matter are separated from the wastewater through physical and biological processes. The resulting sludge is typically a combination of organic and inorganic solids, water, and microorganisms. It may also contain trace amounts of various pollutants, such as heavy metals and chemical contaminants, which can vary depending on the source of the wastewater. Once separated from the wastewater, sewage sludge undergoes further treatment to reduce its volume and stabilize its composition. This treatment can involve processes like thickening, dewatering, and digestion, which help remove excess water and break down organic matter. The treated sludge can then be recycled or disposed of in a safe and environmentally friendly manner. Recycling options for sewage sludge include land application, where it is used as a fertilizer or soil amendment, or it can be used as a source of energy through anaerobic digestion or incineration. Proper management and treatment of sewage sludge are essential to minimize environmental impacts and ensure public health and safety. It's worth noting that the specific composition and handling of sewage sludge may vary depending on local regulations, treatment methods, and the characteristics of the wastewater being treated.

2. Materials and methods

For this study six samples of sludge resulted from industrial wastewater treatment plant were tested. Certain factors are taken into consideration during test preparation. The sample needs to be 95% dry and have granulation less than 1 mm. Obtaining fine particles and separating the larger particles must be done if they do not match. Additionally, large material must be ground if its mass exceeds 5%. Other instances need removing and recording the kind and weight of the material since it cannot be ground. In order to determine the mass of the entire material, the sieved material and the material that could not be ground must be considered. The determination of the dry substance is another important factor because it will stick to the results. This test is run at a temperature of 105°C ± 5°C on a thermogravimetric balance. After the preparation of the samples follows their actual analysis. Different and complex techniques were used to obtain the most detailed results about the composition of the sludge. Gravimetric and electrochemical techniques were used and complex analyses such as combustion and inductively coupled plasma mass spectrometry. All samples were analyzed in the same way and also the samples comes from industrial wastewater treatment plant. A CHN elemental analyzer was used to determine carbon, nitrogen and hydrogen. Based on the modified Dumas method, elemental analyzer is highly flexible, offering modularity that allows more than 20 configurations in a single instrument. In addition to expanding analytical capabilities, this analyzer has powerful software that supports automation and accurate reporting, making the system easy to use from start to finish. Also was used a calorimeter IKA to determine the calorific value. A combustion calorimeter measures the heat that arises from burning. The sample is weighed into a digestion vessel and filled with oxygen (30 bar). The burning process is started by means of an ignition spark. The experiment ends when the sample is fully burned. By measuring the temperature increase, the sample's calorific value or heating value can be calculated. For metals was used an ICP mass spectrometer. The instrument features a helium mode collision cell and half mass correction that remove both polyatomic and doubly charged ion interferences, making method development simpler.

3. Results and discussions

In Table 1 are presented the results obtained for sludges. The calculation is performed according to the dry matter. From the results obtained it can be seen that there are no large variations in the results.

Table 1. Results

Analyses	Unit of measurement	1-S	2-S	3-S	4-S	5-S	6-S
Humidity	%	74.6	74.7	76.1	74.4	75.7	73.3
Dry Matter	%	25.4	25.3	23.9	25.6	24.3	26.7
Carbon	% d.m.	26.92	26.76	27.5	26.31	27.55	26.14
Hydrogen	% d.m.	3.15	3.99	4.03	4.05	4.06	3.84
Nitrogen	% d.m.	3.89	3.92	3.94	3.61	3.85	3.72
Ash	% d.m.	49.61	47.57	45.83	45.47	45.22	55.24
Phosphor	% d.m.	2.38	2.26	2.92	3.09	2.26	2.12
Higher Calorific Value	MJ/kg d.m.	11.36	11.9	12.01	11.89	12.01	11.43
Lower Calorific Value	MJ/kg d.m.	10.71	11.08	11.18	11.06	11.18	10.64
Loss On İgnition	% d.m.	48.03	48.97	51.6	51.37	49.91	46.41
Aluminium	mg/kg d.m.	9323	10824	9613	10824	10901	10403
Arsenic	mg/kg d.m.	<2.50	<2.50	<2.50	<2.50	<2.50	<2.50
Cadmium	mg/kg d.m.	1.5	1.6	1.7	1.7	0.77	0.81
Copper	mg/kg d.m.	178	204	199	208	196	195
Chromium	mg/kg d.m.	72.8	72.8	66.4	71.6	63.9	81
İron	mg/kg d.m.	15363	13703	13610	11627	50725	44866
Magnesium	mg/kg d.m.	4915	5422	5318	5659	5318	5284
Mercury	mg/kg d.m.	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Nickel	mg/kg d.m.	26.6	25	22.9	24.4	22	27.8
Lead	mg/kg d.m.	31.2	31.3	33.6	36.7	31	29.6
Selenium	mg/kg d.m.	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00
Zinc	mg/kg d.m.	778	852	828	878	765	790

4. Sludge recovery from the perspective of circular economy

Sludge management from a circular economy perspective follows recovery procedures: technological recovery (recovery of industrial products), energy recovery (secondary and renewable energy resources) and recovery in agriculture.

4.1 Valorification on agriculture

The condition for promoting sludge as a fertilizer in agriculture is that the soil is not adversely affected by its components. Mainly due to the content of heavy metals, nitrogen compounds etc. there is no valorization of sludge in agriculture. Sewage sludge can only be used in agriculture if it complies with the provisions of the law, i.e. the joint order of the Ministry of the Environment and Water Management and the Ministry of Agriculture No 344/2004 approving the technical rules on the protection of the environment and in particular of land when using sludge in agriculture.

Thus, according to the present decree, for sludge used in agriculture, the maximum permitted value of:

- the concentration of heavy metals in the soil through which the sludge is spread,
- the concentration of heavy metals in the sludge;
- the maximum annual quantity of heavy metals which may be put on agricultural land. If sludge from municipal water treatment contains toxic organic and/or inorganic compounds that do not allow agricultural recovery, energy recovery can be considered.

The permissible limits for sludge used in agriculture are given in the table below.

Table 1. Limits of sludge allowed in agriculture

Element	Limit	Unit of measurement	Element	Limit	Unit of measurement
Lead	900	mg/kg d.m.	Nickel	200	mg/kg d.m.
Cadmium	10	mg/kg d.m.	Mercury	8	mg/kg d.m.
Chrome	100	mg/kg d.m.	Zinc	2500	mg/kg d.m.
Copper	800	mg/kg d.m.	PCB	0.2	mg/kg d.m.

4.2. Energy recovery

If the quality of the sludge from the treatment plant is not suitable for agricultural use, the treatment plant will have to find other means of treating the sludge. Anaerobic fermentation is the most widely used energy recovery process in sludge treatment for methane separation (60-65%) generating heat (37-40°C) and energy in a relatively short time, about 6 hours . According to the principle of circular economy, fermentation sludge removed from the biogas tank can be recovered by: reuse on agricultural land, co-processing at cement plants or incineration/co-incineration at plants that meet energy efficiency requirements for energy recovery. This assumes that drying takes place in a separate plant or in combination with the kiln.

4.3. Technological valorization

Waste sludge management from a circular economy perspective follows the following recovery methods: technology valorization (valorization of industrial products), energy valorization (secondary and renewable energy sources) and valorization in agriculture and animal husbandry (fertilizers, feed, etc.).

Conclusions

According to the values obtained and comparing with the literature data and also with national and international legislation the following conclusions can be reached:

- comparing the results obtained with the permissible limit values in agriculture valorization, it can be concluded that industrial sludge from sewage treatment plants can be used as a fertilizer in agriculture.
- energy and technological valorization can also be considered

Future trends and perspectives based on the circular economy concept regarding sludge use are: reuse in agriculture, directly or after composting, incineration thanks to modern technologies for cost reduction and environmental protection.

- It is desirable to improve thermal treatment methods in terms of gas treatment costs, ash, dioxin and furan emissions and heavy metal emissions.
- Advanced technologies such as pyrolysis and recovery of phosphorus from sludge are trending countries that want to apply

However, a conventional economic alternative could be the application of solar sludge drying technologies to reduce transport costs and increase the calorific value of sludge.

- With regard to sludge reuse in agriculture, it should be noted that advanced sludge treatment technologies (thermal drying, composting, thermophilic anaerobic digestion, automated thermophilic aerobic digestion) and lime treatment) should be incorporated with technologies that remove odors and pathogens and remove harmful compounds.

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