

## WASTE MANAGEMENT IN AGRICULTURE AND WASTEWATER TREATMENT PLANTS

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### Abstract

*The paper presents a new type of bioreactor that capitalizes the wastewater sludge to be further used as fertilizer in agriculture. Wastewater sludge, soil and compost are mixed inside the bioreactor, finally resulting an agriculture fertilizer. The use of wastewater sludge in agriculture, as fertilizer, can significantly reduce the cost of sludge removal from wastewater treatment plants, as well as can assure the requirements for inorganic components (nitrogen, phosphorus) for many agricultural crops. Thus, sludge from wastewater treatment plants can be successfully used in agriculture to: reduce the use of other chemical fertilizers; sustainable development of the environment; improving the physical and organic properties of soils through the intake of nutrients, trace elements; improving microbial activity in the soil, etc.*

**Keywords:** bioreactor, wastewater sludge, soil, compost, fertilizer, agriculture

### 1. INTRODUCTION

During the last decades, due to the modern lifestyle, advances in industry and technology have led to a significant increase of waste amount and type. The problem of waste accumulation is valid all over the world. Among the industrial waste is the sludge from industrial wastewater treatment plants.

The alarming increase in the volume of waste and the accentuation of the dangerous characteristics that they manifest towards man and the environment, must be stopped by preventing the production and by stimulating their recycling to the maximum [1].

Depending on how they are managed, waste can have an impact on both human health and the environment through emissions to air, soil, surface water and groundwater. However, they can also lead to the loss of material resources (respectively metals and other recyclable materials), having at the same time a potential for reusable source. Rational waste management can protect public health and the environment, while promoting the conservation of natural resources.

The use of raw or treated industrial sludge in agriculture can significantly reduce the costs for sludge removal from wastewater treatment plants, as well as much of the requirements for inorganic components (nitrogen, phosphorus) in many crops [2].

Among the future trends and perspectives, based on the concept of the circular economy, regarding the recovery of sludge, is the reuse in agriculture, direct or after treatment, having as effects the reduction of costs and the protection of the environment [3].

The use of sludge from wastewater treatment is one of the most important challenges in their management [4]. Sludge from treatment plants can be used successfully to: reduce the use of agricultural fertilizers; sustainable development of the environment with benefits for both the sludge producer and the farmer; improving the physical and organic properties of soils by the supply of nutrients (nitrogen, phosphorus, sulfur), trace elements; water retention in the soil; improving microbial activity in the soil; rehabilitation of degraded lands by improving soil texture, etc.

Waste is a source of pollution, but at the same time it is a secondary source of raw materials. Sludge contains nutrients (especially N, P, K, Na, non-toxic metals) which are an agronomic benefit. The use of sludge in agriculture has become an alternative for the use of waste for economic and practical reasons.

Due to the large amounts of sludge resulting from wastewater treatment, high transport costs, lack of advanced technologies to ensure better sludge management, it has been found that a sustainable solution is their use in the rehabilitation of degraded and/or agricultural land.

## 2. MATERIALS AND METHODS

### 2.1. Materials

Within the subsidiary research project no. 248/2018, was design and realised a bioreactor for the recovery of sludge from textile wastewater treatment plants to be further used as fertilizer in agriculture.

The bioreactor for the recovery of sludge from textile wastewater treatment plants, proposed by researchers / authors, (Fig. 1) is a parallelepiped type and is realised from resistant material to mechanical and chemical stress.



**Fig. 1.** Bioreactor for the recovery of sludge with furter in agriculture

The bioreactor tank (fig. 2) is the main component of the equipment. Inside the tank, the agitation and uniformization of the components is performed with 2 coil-type agitators, each driven by a screw-type gear motor. The shaft axis is parallel to the length of the tank. Spiral-type stirrers rotate counterclockwise. The bioreactor is covered with a removable lid, made of metallic material, with spaces for the evacuation of possible gaseous emissions and seals to avoid throwing out the homogenized material.



**Fig. 2.** Bioreactor tank

Feeding is done at the top, and the mixture is discharged at the bottom. The material of the tank (stainless steel type AISI 304 / W1.4301) used for fabrication ensures the conditions of a good operation [5]:

- mechanical strength, corrosion resistance;
- relatively cheap material.

The main technical characteristics of the bioreactor designed and realized by the research team / authors: type of mixer: with two helical rotors; type of operation: discontinuous with helical working members arranged horizontally; agitation and uniformity of the components: with two concentric turns, but with opposite winding directions; by homogenizing the mixture: mud, compost, soil, no pressure is created; Fermentation reactions related to the organic matter in the compost can take place in the bioreactor, as a result of which small amounts of: CO<sub>2</sub>, H<sub>2</sub>O and O<sub>2</sub> can be released; overall dimensions: L x W x H: 1,060 mm x 710 mm x 980 mm; mass: 128 kg.

A mixture of sludge, compost and soil is introduced into the bioreactor in a certain proportion.

## 2.2. Methods

The components (fig. 3) used to perform the experiments are:

- sludge from the textile wastewater treatment plant;
- agricultural land;
- the compost.

The sludge is used in non-centrifuged form. The agricultural soil is cleaned by sieving any hard components (stones). The sludge is added first in the bioreactor and then, in portions, the agricultural soil and compost, continuing the mixing.



**Fig. 3.** Components of the agriculture fertilizer

In the experimental tests, attempts were made to determine the optimal variant of the mixture, varying the proportion of the components of the mixture, the time of their addition and mixing.

In this sense, two variants were tried:

- simultaneous addition of the components of the mixture and mixing. In this case, the process of homogenization of the mixture becomes more difficult.
- adding components one at a time, in portions, over a period of time.

## 3. RESULTS

During the laboratory experiments, a series of researches were performed, tests to establish the optimal proportions of materials that are introduced into the bioreactor as well as to establish the mixing times. The results are summarized in Table 1.

**Table 1.** Laboratory tests performed and the main results

| Test no  | Mixture ratio | Frequency (Hz) | Mixture time (min) | Mixed appearance                           |
|----------|---------------|----------------|--------------------|--------------------------------------------|
| <b>1</b> | Sludge: 12 kg | 30             | 10                 | Wet, gray paste with coarse agglomerations |
|          | Soil: 4 kg    | 40             | 10                 | Wet, gray paste with coarse agglomerations |
|          | Compost: 4 kg | 50             | 10                 | Wet, gray paste with coarse agglomerations |
| <b>2</b> | Sludge: 12 kg | 30             | 30                 | Wet, gray paste with coarse agglomerations |
|          | Soil: 4 kg    | 40             | 30                 | Wet, gray paste with coarse agglomerations |
|          | Compost: 4 kg | 50             | 30                 | Wet, gray paste with coarse agglomerations |
| <b>3</b> | Sludge: 12 kg | 30             | 60                 | Wet, gray paste with medium agglomerations |
|          | Soil: 4 kg    | 40             | 60                 | Wet, gray paste with medium agglomerations |
|          | Compost: 4 kg | 50             | 60                 | Wet, gray paste with fine agglomerations   |
| <b>4</b> | Sludge: 16 kg | 30             | 60                 | Wet, gray paste with medium agglomerations |
|          | Soil: 4 kg    | 40             | 60                 | Wet, gray paste with medium agglomerations |
|          | Compost: 4 kg | 50             | 60                 | Wet, gray paste with medium agglomerations |
| <b>5</b> | Sludge: 10 kg | 30             | 60                 | Wet, gray paste with fine agglomerations   |
|          | Soil: 5 kg    | 40             | 60                 | Wet, gray paste with fine agglomerations   |
|          | Compost: 5 kg | 50             | 60                 | Wet, gray paste with fine agglomerations   |

The main characteristics of the textile wastewater sludge, soil and compost are presented in tables 2-4.

**Table 2.** Physic-chemical characteristics of sludge

| Composition                 | Determined quantity in sludge |          |
|-----------------------------|-------------------------------|----------|
|                             | [mg/kg]                       | [%]      |
| <b>pH</b>                   | 7,40 unit pH                  |          |
| <b>Inorganic substances</b> | 967420                        | 96,74    |
| <b>Organic substances</b>   | 32580                         | 3,258    |
| <b>Total soluble salts</b>  | 8120                          | 0,8120   |
| <b>Humus</b>                | -                             | -        |
| <b>Total organic carbon</b> | 12124,0                       | 1,2124   |
| <b>Total nitrogen</b>       | 1,24                          | 0,000124 |
| <b>Ammoniacal nitrogen</b>  | 0,24                          | 0,000024 |
| <b>Nitrates</b>             | 0,6                           | 0,00006  |
| <b>Nitrites</b>             | <1,0                          | <0,0001  |
| <b>C/N ratio</b>            | 1712,9                        | -        |
| <b>Total phosphorus</b>     | 5,12                          | 0,000512 |

|                                                |       |          |
|------------------------------------------------|-------|----------|
| <b>Chloride</b>                                | 2982  | 0,2982   |
| <b>Tone</b>                                    | 2312  | 0,2312   |
| <b>Phenol index</b>                            | <5,0  | <0,0005  |
| <b>Fluoride</b>                                | <10   | <0,001   |
| <i><b>Alkali and alkaline-earth metals</b></i> |       |          |
| <b>Magnesium</b>                               | 30,2  | 0,00302  |
| <b>Potassium</b>                               | 52,8  | 0,00528  |
| <i><b>Heavy metals</b></i>                     |       |          |
| <b>Arsenic</b>                                 | <1,0  | <0,0001  |
| <b>Cadmium</b>                                 | <3,0  | <0,0003  |
| <b>Total chrome</b>                            | <50   | <0,005   |
| <b>Copper</b>                                  | 5,2   | 0,00052  |
| <b>Manganese</b>                               | <0,5  | -        |
| <b>Molybdenum</b>                              | <20   | <0,002   |
| <b>Mercury</b>                                 | <0,01 | <0,00001 |
| <b>Nickel</b>                                  | <10   | <0,001   |
| <b>Lead</b>                                    | 20,4  | 0,00204  |
| <b>Zinc</b>                                    | 26,4  | 0,00264  |

**Table 3.** Physic-chemical characteristics of the used soil

| <b>Composition</b>          | <b>Determined quantity in soil</b> |              |
|-----------------------------|------------------------------------|--------------|
|                             | <b>[mg/kg]</b>                     | <b>[%]</b>   |
| <b>pH</b>                   |                                    | 7,42 unit pH |
| <b>Inorganic substances</b> | 897400                             | 89,74        |
| <b>Organic substances</b>   | 102600                             | 10,26        |
| <b>Humus</b>                | 62330                              | 6,23         |
| <b>Total organic carbon</b> | 35617                              | 3,56         |
| <b>Total soluble salts</b>  | 1720                               | 0,172        |
| <b>Total nitrogen</b>       | 1452                               | 0,145        |
| <b>Ammoniacal nitrogen</b>  | 12,4                               | 0,00124      |
| <b>Nitrates</b>             | 25,2                               | 0,00252      |
| <b>Nitrites</b>             | 1,18                               | 0,000118     |
| <b>C/N ratio</b>            | 24,52                              | -            |
| <b>Total phosphorus</b>     | 46,4                               | 0,00464      |
| <b>Chloride</b>             | 18,6                               | -            |

|                                         |        |          |
|-----------------------------------------|--------|----------|
| <b>Tone</b>                             | 882    | 0,0882   |
| <b>Phenol index</b>                     | <5,0   | <0,0005  |
| <b>Fluoride</b>                         | <5,0   | <0,001   |
| <i>Alkali and alkaline-earth metals</i> |        |          |
| <b>Magnesium</b>                        | 140,2  | 0,01402  |
| <b>Potassium</b>                        | 186,4  | 0,0186   |
| <i>Heavy metals</i>                     |        |          |
| <b>Arsenic</b>                          | <1,0   | <0,0001  |
| <b>Cadmium</b>                          | 3,1    | 0,00031  |
| <b>Total chrome</b>                     | 52     | 0,0052   |
| <b>Copper</b>                           | 5,1    | 0,00051  |
| <b>Manganese</b>                        | 114,62 | 0,01146  |
| <b>Molybdenum</b>                       | <20    | <0,002   |
| <b>Mercury</b>                          | <0,01  | <0,00001 |
| <b>Nickel</b>                           | 18     | 0,0018   |
| <b>Lead</b>                             | 50,2   | 0,00502  |
| <b>Zinc</b>                             | 98,4   | 0,00984  |

**Table 4.** Physic-chemical characteristics of the used composed

| <b>Composition</b>          | <b>Determined quantity in compost</b> |            |
|-----------------------------|---------------------------------------|------------|
|                             | <b>[mg/kg]</b>                        | <b>[%]</b> |
| <b>pH</b>                   | 6,56 unit pH                          |            |
| <b>Inorganic substances</b> | 408810                                | 40,881     |
| <b>Organic substances</b>   | 591190                                | 59,119     |
| <b>Total soluble salts</b>  | 4240                                  | 0,424      |
| <b>Humus</b>                | 582640                                | 58,26      |
| <b>Total organic carbon</b> | 361210                                | 36,12      |
| <b>Total phosphorus</b>     | 14240                                 | 1,42       |
| <b>Ammoniacal nitrogen</b>  | 1920                                  | 0,192      |
| <b>Nitrates</b>             | 10244                                 | 1,02       |
| <b>Nitrites</b>             | 2076                                  | 0,207      |
| <b>C/N ratio</b>            | 25,43                                 | -          |
| <b>Total phosphorus</b>     | 55,4                                  | 0,00554    |
| <b>Chloride</b>             | 1264                                  | 0,126      |
| <b>Tone</b>                 | 4562                                  | 0,456      |

|                                         |       |          |
|-----------------------------------------|-------|----------|
| <b>Phenol index</b>                     | <5,0  | <0,0005  |
| <b>Fluoride</b>                         | <10   | <0,001   |
| <i>Alkali and alkaline-earth metals</i> |       |          |
| <b>Magnesium</b>                        | 104,2 | 0,01042  |
| <b>Potassium</b>                        | 85,0  | 0,0085   |
| <i>Heavy metals</i>                     |       |          |
| <b>Arsenic</b>                          | <1,0  | <0,0001  |
| <b>Cadmium</b>                          | <3,0  | <0,0002  |
| <b>Total chrome</b>                     | 42,0  | 0,0042   |
| <b>Copper</b>                           | 4,9   | 0,00049  |
| <b>Manganese</b>                        | 50,12 | 0,00501  |
| <b>Molybdenum</b>                       | <20   | <0,002   |
| <b>Mercury</b>                          | <0,01 | <0,00001 |
| <b>Nickel</b>                           | 8,98  | 0,000898 |
| <b>Lead</b>                             | 27,9  | 0,00279  |
| <b>Zinc</b>                             | 41,5  | 0,00855  |

From all the experimental tests performed on the bioreactor (Table 1), 3 tests provided good results in terms of homogeneity and physical appearance of the mixture, namely tests 3, 4 and 5. The final composition of the fertilizer was also determined by the authors and is presented in Table 5.

**Table 5.** Physic-chemical characteristics of the mixture obtained in the bioreactor

| Composition                 | Determined quantity in the mixture |         |
|-----------------------------|------------------------------------|---------|
|                             | [mg/kg]                            | [%]     |
| <b>pH</b>                   | 7,37 unit pH                       |         |
| <b>Inorganic substances</b> | 810262,0                           | 81,026  |
| <b>Organic substances</b>   | 189738,0                           | 18,973  |
| <b>Total soluble salts</b>  | 5550,0                             | 0,555   |
| <b>Humus</b>                | 161242,0                           | 16,124  |
| <b>Total organic carbon</b> | 105268,0                           | 10,226  |
| <b>Total phosphorus</b>     | 3923,0                             | 0,392   |
| <b>Ammoniacal nitrogen</b>  | 483,0                              | 0,0483  |
| <b>Nitrates</b>             | 2567,6                             | 0,0811  |
| <b>Nitrites</b>             | 519                                | 0,0519  |
| <b>C / N ratio</b>          | 26,83                              | -       |
| <b>Total phosphorus</b>     | 27,7                               | 0,00277 |

|                                                |        |          |
|------------------------------------------------|--------|----------|
| <b>Chloride</b>                                | 1566,0 | 0,1566   |
| <b>Tone</b>                                    | 2517,0 | 0,2517   |
| <b>Phenol index</b>                            | <5,0   | <0,0005  |
| <b>Fluoride</b>                                | <10    | <0,001   |
| <b><i>Alkali and alkaline-earth metals</i></b> |        |          |
| <b>Magnesium</b>                               | 76,0   | 0,0076   |
| <b>Potassium</b>                               | 94,0   | 0,0094   |
| <b><i>Heavy metals</i></b>                     |        |          |
| <b>Arsenic</b>                                 | <1,0   | <0,0001  |
| <b>Cadmium</b>                                 | <3,0   | <0,0002  |
| <b>Total chrome</b>                            | 23,5   | 0,00458  |
| <b>Copper</b>                                  | 5,1    | 0,00051  |
| <b>Manganese</b>                               | 41,1   | 0,00411  |
| <b>Molybdenum</b>                              | <20    | <0,002   |
| <b>Mercury</b>                                 | <0,01  | <0,00001 |
| <b>Nickel</b>                                  | 6,7    | 0,00067  |
| <b>Lead</b>                                    | 29,6   | 0,00296  |
| <b>Zinc</b>                                    | 48,2   | 0,00482  |

#### 4. DISCUSSION

As a result of performing the tests (briefly presented in Table 1), the following were found:

- the increase of the compost percentage in the composition introduced inside the bioreactor results in the increase of the values corresponding to the humus indicator;
- the increase of the sludge percentage in the composition introduced inside the bioreactor results in the decrease of the values corresponding to the humus indicator;
- the increase of the sludge percentage in the composition introduced inside the bioreactor results in the decrease of the values corresponding to the organic carbon indicator;
- the increase of the sludge percentage in the composition introduced inside the bioreactor results in the increase of the values corresponding to the humidity indicator.

At the Experimental test no. 4, the humidity of over 70% imprints a pasty appearance towards the liquid of the mixture, which implies, after application on the ground, a drying period of the applied layer;

- the increase of the sludge percentage introduced inside the bioreactor results in the increase of the values corresponding to heavy metals, without exceeding the limits imposed by environmental legislation and legislation on the use of sludge in agriculture;
- the increase of the mixing time favorably influences the texture of the fertilizer, this becoming with small agglomerations, similar to the soil texture.

At test no. 5, the highest values were recorded for humus and organic carbon, mineral substances assimilable by plants (phosphorus, total nitrogen, magnesium, potassium.)

Also, taking into account the Romanian legislation the maximum permissible concentrations of heavy metals in sludges intended for use in agriculture is presented in Table 6.

**Table 6.** Maximum permissible concentrations of heavy metals in sludges intended for use in agriculture

| Parameters                                                                                                                                                                                                                                 | Limit values of dry matter [mg/kg] |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------|
| <b>Cadmium</b>                                                                                                                                                                                                                             | 10                                 |
| <b>Copper</b>                                                                                                                                                                                                                              | 500                                |
| <b>Nickel</b>                                                                                                                                                                                                                              | 100                                |
| <b>Lead</b>                                                                                                                                                                                                                                | 300                                |
| <b>Zinc</b>                                                                                                                                                                                                                                | 2000                               |
| <b>Mercury</b>                                                                                                                                                                                                                             | 5                                  |
| <b>Chromium</b>                                                                                                                                                                                                                            | 500                                |
| <b>Cobalt</b>                                                                                                                                                                                                                              | 50                                 |
| <b>Arsenic</b>                                                                                                                                                                                                                             | 10                                 |
| <b>AOX</b> (sum of organohalogen compounds)                                                                                                                                                                                                | 500                                |
| <b>PAH</b> (Polycyclic Aromatic Hydrocarbons)                                                                                                                                                                                              | 5                                  |
| <b>Amount of the following substances:</b> anthracene, benzoanthracene, benzo-fluoranthene, benzoperylene, benzopyrene, chrysen, fluoranthrene, indeno (1, 2, 3) pyrene, naphthalene, phenanthrene, pyrene PCB (polychlorinated biphenyls) | 0,8                                |

## 5. CONCLUSIONS

The approach to the use of the textile wastewater sludge in agriculture is a novelty in this field, having economic effects and contributing to environmental protection. There are major concerns about the use of sludge in agriculture in the treatment of domestic wastewater. The team of authors developed and tested a new model of bioreactor that uses waste (sludge) for further use in agriculture. As a result of the tests for determining the values of the qualitative indicators (Table 6), it was found that they fall within the limits provided by the legislation in force. In conclusion, the new equipment is a viable solution for the capitalization of sludge obtained from agricultural treatment plants as fertilizer.

The application of sewage sludge on the ground progressively improves the fertility of the soil and in particular its physical properties. Cereals and industrial crops are the most suitable for the use of sludge.

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