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AGRICULTURAL AND OTHER WASTES USED IN THE CONSTRUCTION INDUSTRY

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Abstract: The problem of sludge management in wastewater treatment plants remains a current issue. The characteristics of the sludge depend on the degree of pollution and the nature of the pollutants in the wastewater undergoing purification and on the sludge treatment methods. Before utilization or disposal, the sludge must be treated, with the aim of reducing the water content, fermentation properties and the presence of pathogens. Treated sludge can be used or disposed of, most commonly, in three ways: agricultural use, incineration or landfilling, depending on the properties of the sludge, as well as the option of the treatment plant operator. Other disposal and recovery methods exists, but they are less used.Researchers are looking for new ways to utilize this type of waste in order to minimize the negative impact both on the environment and on the operators of treatment plants. The article presents a way of handling for this waste – the use of sludge for the manufacture of construction materials. Agricultural waste can also be incorporated into building materials.
Keywords: waste, brick, agriculture, wastewater treatment, sludge

1. INTRODUCTION

Sludges from urban wastewater treatment plants come from various stages of treatment processes and are subject to waste regulations (*Nabaterega, R., Kumar, V., Khoei, S., & Eskicioglu, C., 2021; Hoang, S. A., Bolan, N., Madhubashani, A. M. P., Vithanage, M., Perera, V., Wijesekara, H., ... & Siddique, K. H., 2022*). They contain both compounds with agricultural value (organic matter, nutrients – nitrogen and phosphorus, potassium and small amounts of calcium, sulfur and magnesium), as well as pollutants such as: heavy metals, toxic organic substances, microplastics and pathogens (*Koyuncuoğlu, P., & Erden, G., 2021; Shi, W., Healy, M. G., Ashekuzzaman, S. M., Daly, K., Leahy, J. J., & Fenton, O., 2021; Nunes, N., Ragonezi, C., Gouveia, C. S., & Pinheiro de Carvalho, M. Â., 2021*). The characteristics of the sludge depend on the degree of pollution and the nature of the pollutants in the wastewater undergoing purification and on the sludge treatment methods. Before utilization or disposal, the sludge must be treated, with the aim of reducing the water content, fermentation properties and the presence of pathogens. Treated sludge can be used or disposed of, most commonly, in three ways: agricultural use, incineration or landfilling, depending on the properties of the sludge, as well as the option of the treatment plant operator. Other disposal and recovery methods exists, but they are less used.

The measures to reduce the negative impact in the recovery of sludge from sewage treatment plants can be classified according to three research directions:

- primary measures – applied before purification, within the pre–purification stations;
- secondary measures, i.e. measures along the technological flow of purification;
- final measures for disposal / recovery of sludge: biogas, agriculture, degraded lands, forestry, nurseries, tailings dumps, decantation ponds, incineration, construction materials, underground spaces, in ecological deposits intended for purified sludge.

The primary, secondary and final measures are dependent on other measures (legislative, institutional, technical, administrative, economic, logistical, financial, etc.).

In practice, there are no standard solutions for the elimination and valorization of sludge from sewage treatment plants, all sludge valorization options imply additional costs and cooperation with third parties, while the quality of the sludge must meet the regulations in force.

For example, sludge can be used in agriculture regardless of the moisture content, but must comply with Order 344/2004 and related restrictions. Composting cannot be considered a final way of capitalizing or eliminating sludge, but only represents a process through which the sludge becomes more viable, in order to use it for the production of natural fertilizers for agriculture, however, there are difficulties encountered by users in completing the necessary formalities for sludge transport. The use of sludge in agriculture is limited to a maximum of two times per year based on a use permit, based on agrochemical studies and a

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fertilization plan. Land quality rehabilitation and forestry can periodically offer opportunities to use sludge, but they cannot ensure the uptake of large quantities of sludge.

Punctually, the use of sludge for land conversion or for closing waste deposits is a medium–term solution. The approval of the environmental authorities is required when the sludge is used in quantities greater than those accepted from an agronomic point of view. The impact on the environmental components in the application of this solution must be carefully studied, as well as the risk analysis for the environment and the health of the population.

As can be seen, currently recourse is made to the application of auxiliary methods through various alternatives for managing / storing / valorizing the sludge for each region, respectively each sewage treatment plant operator; there being no universally valid solution for sludge recovery.

Starting from the need to capitalize on the resulting sludge in industrial wastewater treatment plants, it was pursued through the experiments presented in this article, its transformation into an inert waste, which can have various uses in the field of constructions (bricks, material for making plasters). Until now, in construction, the most common types of bricks are those made of burnt clay or autoclaved cellular concrete.

2. MATERIALS AND METHODS

The results obtained as a result of the use of sludge in the manufacture of construction materials are presented below. 12 experiments were carried out, the results of which are presented in the following section. In the sludge valorization process, an extremely important role was played by the treatment and preliminary characterization of the sludge, but also the characterization of the waste water that was subjected to purification.

The preparation of the sludge samples, starting from the characteristics of the treated wastewater up to the dewatering process, has a double purpose: the relevance and success of the experiment, i.e. the access to a positive result regarding the initial objective in compliance with the waste recovery legislation.

Each stage of the sludge recovery process is influenced by the previous ones, the links between the initial conditions and the results being affected by a complexity of factors.

Stages of the sludge valorization and inertization process:

a) Obtaining sludge by treating waste water;

b) Dehydration of the sludge by filtration on filter bags and/or centrifugation on a laboratory centrifuge;

c) Utilization of sludge by inertization with cement.

- Obtaining sludge by treating waste water. Physico–chemical analyzes were performed for the 12 experimental tests (pH, total organic carbon, dissolved organic carbon, humidity, organic substances, inorganic substances, chlorides, sulfates, fluorides, phenol index, total dissolved substances, metals – arsenic, cadmium , copper, total chromium, molybdenum, nickel, lead, zinc, mercury). The technological process from which the tested sludge originates is a physico–chemical industrial wastewater treatment process, a process in which the physico–chemical characteristics of the wastewater vary. For this reason, during the experiments, we worked with homogeneous samples. According to the working procedure of these standards, for a maximum amount of 2 tons of sludge, 10 samples of 200 grams each were taken, thus constituting homogeneous samples of 2 kg. 10 such samples of 2 kg were constituted. These were then homogenized again and the sample used for the experimental part was constituted. The transport and preservation of sludge samples was carried out at a temperature of 2 – 5°C and in safe conditions to avoid damage or destruction of the container and contamination or loss of the contents/sample. The part of the sample separated for physico–chemical determinations was preserved in glass vessels. The sludge samples taken were homogenized to constitute a single representative sample. The constituted sludge sample was codified and sampled in 3 sub–samples for the experimental tests.
- Sludge dehydration. Dehydration of the sludge was achieved by filtering on filter bags and then by centrifugation. This activity aims to obtain a sludge with a humidity lower than 80%, according to the requirements of the proposed technology.
- Utilization of sludge by inerting it with cement. Following the research carried out, 2 options were proposed for the valorization of industrial sludge: the production of bricks and the production of material for plasters.

≡ Obtaining bricks. Centrifuged sludge is mixed in an approximate ratio of: 45% cement + 55% sludge. The mixture is homogenized for 15 minutes, until a homogeneous paste is obtained, which is poured into

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metal or wooden molds. It is left to dry for 24 h, it is removed from the molds, leaving it in the open air for 3 – 4 days, in order for the lime from the sludge to come in contact with CO2 from the air, which helps to increase the resistance.

≡ Obtaining the material for plasters. The centrifuged sludge is mixed in the approximate ratio: 25% cement + 75% sludge. The mud is mixed with the cement, over which 20% water is added. The mixture is homogenized for 15 minutes. These mixtures dry freely. In order to control the quality of the sludge both at the entrance and exit of the process, physico–chemical analyzes were carried out on the characteristics of the sludge by a specialized laboratory.

During this period, wastewater with variable physico–chemical characteristics presented in Table 1 was treated in the treatment plant.

Table 1. The physico–chemical characteristics of the waste water from which the raw sludge for experiments is obtained

Parameter	Unit	Values
pH	pH unit	9,36 – 9,48
Suspended matter	mg/L	634,00 – 704,00
Biological Oxygen Demand BOD_5	mg O_2/L	360,12 – 420,12
Chemical Oxygen Demand CODCr	mg O_2/L	676,12 –742,18
Detergents	mg/L	2,31 – 3,22
Total Phosphorus	mg/L	2,22 – 2,64
Sulfates	mg/L	382,38 – 416,68
Ammonium	mg/L	1,72 – 2,38
Extractable substances	mg/L	29,90 – 30,00

In developing the experiments, the following standards in force (related to Romanian legislation) were respected, as a methodology:

- SR CEN/TR 15310–1:2009. Waste characterization. Waste sampling. Part 2: Guidance for the selection and application of sampling criteria under different conditions;
- SR CEN/TR 15310–2:2009. Waste characterization. Waste sampling. Part 2: Guidance for sampling techniques;
- SR CEN/TR 15310–3:2009. Waste characterization. Waste sampling. Part 3: Guidance on procedures for sub–sampling in the field;
- SR CEN/TR 15473:2009. Sludge characterization. Good practice for sludge drying;
- SR EN 12457–1/2003. Waste characterization. Leaching. Compliance verification test for granular waste and sludge leaching. Part 1: One–step batch test at a liquid–solid ratio of 2 l/kg for materials with high solid content and particle size below 4 mm;
- SR EN 12457–2/2003. Waste characterization. Leaching. Compliance verification test for granular waste and sludge leaching. Part 1: One–stage batch test at a liquid–to–solids ratio of 10 l/kg for materials with high solids content and particle size below 4 mm.

3. RESULTS

12 experiments were carried out, finally obtaining 2 types of construction materials: bricks and material for plasters. The main product is considered the brick.

As a result of following the above–mentioned methodology, experiment number 1 is presented with detailed description and pictures and the conclusions present the results obtained from the comparison of the 12 sets of experiments.

Experiment 1 – Working method for the preparation of the final brick product. The amount of mud used to obtain the final product, brick, was 2.75 kg. The amount of cement used to obtain the final product, brick, was 2.25 kg. The raw water sample was treated with aluminum sulfate, dose 0.5 g/l, for precipitation and coagulation of organic and inorganic substances. The resulting sludge after settling for 24 hours was filtered on filter bags and was later centrifuged in a laboratory centrifuge. Dewatered sludge was mixed in the ratio: 45% cement + 55% sludge. The mixture was homogenized for 15 minutes, until a homogeneous paste was obtained, which was poured into wooden molds. It was left to dry for 24 hours, removed from the molds, leaving it in the open air for 3 – 4 days, to allow the lime in the mud to come into contact with the CO2 in the air, which helped to increase the strength of the brick.

Figures 1–10 show the stages of making a brick. Table 2 shows the main stages in the sludge recovery process, with its main characteristics, and table 3 shows the main characteristics of the produced bricks. Characteristics of the final obtained product – sample code 1.1: stable shape, with high hardness to mechanical shocks.

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Figure 1 – Preserved sludge sample for physico–chemical analysis – sample code N1

Figure 2 – Raw sludge used in experiment 1.1

Figure 3 – Appearance of the sludge sample used in experiment 1.1

Figure 4 – Determination of the moisture content of the sludge sample before filtration and centrifugation

Figure 5 – Filtration on a bag filter to obtain sludge

Figure 6 – Sludge centrifugation, on a laboratory centrifuge

Figure 7 – Centrifugation on a laboratory centrifuge

Figure 8 – The resulting sludge after centrifugation

Figure 9 – Determination of the humidity of the sludge sample after filtration and centrifugation

Figure 10 – Final brick product – sample code 1.1

Table 2. Followed stages and parameters

Stage	Sludge	
	Appearance	Humidity [%]
Wastewater treatment	Semi–liquid, dark blue–grey	90,27
Sludge filtration and centrifugation	Solid, pasty, dark blue	64,76
Sludge inerting	Solid, stable non–crumbling, hard, gray product	–

Table 3. The physical behavior over time of the final brick product sample code 1.1

Drying time	24 h	1 day	2 days	3 days
Appearance	Wet, it keeps its shape	The hardening process begins	The hardening process is finalized	The product is dry and hard to mechanical stress (hitting with a hammer)

Table 4. Comparative results obtained after performing the 12 experiments

N°.	Test	Sludge moisture [%]		Composition [%]		Final product code	Final product description
		Undehydrated	Dehydrated	cement	sludge		
1	1.1	90,27	64,76	45	55	Brick 1.1	The product is dry and hard to mechanical stress (hitting with a hammer)
2	1.2	90,27	64,76	40	60	Brick 1.2	The product is dry, but porous and brittle when subjected to mechanical stress (hitting with a hammer)
3	1.3	90,27	64,76	50	50	Brick 1.3	The product is dry, very hard, resistant to mechanical shocks
4	1.4	92,01	78,19	25	75	Plaster material 1.4	The product is dry, adheres to the plastered surface, stable after 3 days of drying
5	1.5	92,01	78,19	20	80	Plaster material 1.5	The product is dry, brittle, crumbly, with reduced adhesion to the plastered surface
6	1.6	92,01	78,19	30	70	Plaster material 1.6	Solid product, with adhesion to the plastered surface, with slight cracks
7	1.7	98,63	74,30	45	55	Brick 1.7	The product is dry, very hard, resistant to mechanical shocks
8	1.8	98,63	74,30	40	60	Brick 1.8	The product is dry, but porous and brittle when subjected to mechanical stress (hitting with a hammer)
9	1.9	98,63	74,30	50	50	Brick 1.9	The product is dry, hard, resistant to mechanical shocks
10	1.10	96,55	82,55	45	55	Brick 1.10	Dry, stable product, with a slight tendency to crumble under mechanical stress
11	1.11	96,55	82,55	40	60	Brick 1.11	The product is brittle, crumbly
12	1.12	96,55	82,55	50	50	Brick 1.12	Stable product with slight tendency to crumble under mechanical stress

Table 4 shows the comparative results of the 12 experiments performed. Bricks were the main product made. In the experiments, the previously described methodology was followed, variating the composition/recipe of the construction materials, with the variation of the amount of sludge used.

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The recipe for making bricks can be further improved. Other types of waste can also be incorporated into the final manufacturing material. The team of authors will test new recipes for making bricks. The main components from which the bricks will be made are: sludge from industrial waastewater treatment plants, agricultural waste (from different crops such as corn, wheat, rape straw, elephant grass, energy plants), cement, sand and fiberglass waste. At least 5 recipes will be conceived, in which the composition of the materials will vary. Table 5 presents the variation limits for each component of the bricks.

Table 5. The variation limits of the different materials and waste that will enter in the composition of the bricks

Recipe	Industrial sludge [%]	Agricultural waste [%]	Cement [%]	Sand [%]	Fiberglass waste [%]
Variation of the composition of the components in the recipe	20–50	15–40	10–20	15–30	2–5

4. CONCLUSIONS

The proposed technology for obtaining bricks, dealt with in this article, is a technology for depollution and recovery of waste, eliminating the potential impact on environmental factors (water, air, soil). The solution can be improved by using several types of waste. The research team will continue the series of experiments looking for new solutions in order to ensure the most efficient management of the sewage treatment plants.

The experiments carried out by the research team led to the validation of recipes for the production of construction materials. Thus, a new solution is provided for those who manage wastewater treatment plants. The waste valorization solution leads to obtaining some essential advantages, among which: the reduction of the costs of transporting and storing the sludge generated by the sewage treatment plant; environment protection; reducing the pressure on municipal waste deposits; conferring possible income for the sewage treatment plant through the recovery of waste.

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