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INNOVATIVE SOLUTIONS FOR THE PRODUCTION OF BRICKS FROM WASTEWATER TREATMENT SLUDGE

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Abstract

Based on the need to recover various wastes such as waste from wastewater treatment plants, it is proposed to use sludge in the manufacture of various building materials as bricks. So far, bricks made of different materials and combinations of classical materials as burnt clay, cement, sand, but also of other unconventional materials, most of them coming from different wastes, are used in construction. To use the sludge for bricks fabrication, it is necessary to inert it and to obtain a moisture content below 80%. Also, the physico-chemical and ecological parameters must be suitable for sludge utilization and their values must be situated within the limits imposed by legislation. So, the sludge is centrifuged in order to reduce the moisture content from (90-95)% to a maximum of 80%, treated, then the sludge batches are characterized and finally the sludge is recovered by inert cement.

Key words: *bricks, sludge, construction, waste, wastewater treatment*

JEL Classification: Q25

Introduction

The wastewater treatment process produces sludge with a variable physico-chemical composition, depending on the composition of the treated wastewater and the nature of the chemicals used for treatment. This treated sludge can be used in the manufacture of bricks together with other component materials. Sludge must be classified according to its physico-chemical characteristics and according to the environmental legislation in force (in Romania: Law 211/2011, Regulation

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1272/2008, HG 856/2002) in hazardous, non-hazardous or inert waste classes. According to this classification, the waste is transported, inertised and deposited in specialised landfills per waste class. The costs of transport, inerting and storage are high and have a final effect on the total wastewater treatment costs. By using sludge in the construction materials, wastewater treatment plants considerably reduce their operating costs.

The idea of the authors resulted from an existing need on the Romanian market (and not only), where there is an urgent need for sludge treatment solutions, storage or/and reuse and due to the restrictions imposed by the environmental legislation regarding the way of construction, operation and waste management. [Korhonen et al., 2018]

The current worldwide trend is to move in the direction of addressing the problem of waste from wastewater treatment plants towards reuse or recovery in agriculture (as N, P, K, Mg, Ca supplement) or use as a holding material for oil products, after composting, followed by briquetting (determination of heat capacity). Based on the need to recover the sludge from the industrial wastewater treatment plant, the authors aim to transform it into an inert waste (by including it in a matrix that does not allow the leaching of chemical elements) and use it in the production of building materials: bricks and mortar for plaster. The process has been patented, and the novelty is the sludge from industrial wastewater treatment utilization in combination with cement to produce construction materials.

According to Eurostat data, the sludge generated by the WWTPs has increased in Romania, both in volume and in kg per capita, so that the sludge per inhabitant evolved from 3.84 kg of sludge / capita in 2008 to 12.69 kg / capita in 2018, Romania registered the highest growth of 19 of the EU28 states in 2018 (only these have reported statistical data). The treatment processes of wastewater generate the sludge which negatively impacts the health and the economy.

Referring to the quantities of sludge generated by the wastewater treatment plants in Romania (Fig. 1), but also those at European or world level, they have an increasing tendency, mainly caused by the population growth.

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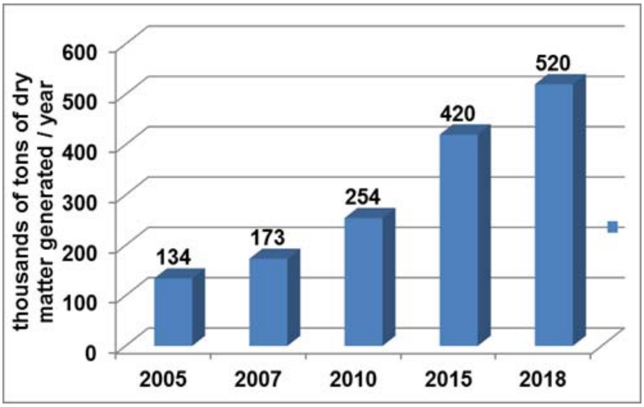

Figure no. 1. Evolution of the amount of the sludge generated by the wastewater treatment plants in Romania

In respect of the waste management, there are known, numerous processes of use / storage / disposal of the sludge from wastewater treatment plants, presented in Table 1. As can be seen each process has both advantages and disadvantages. The process of obtaining bricks from sludge does not present any disadvantage and makes this a viable solution both from economic point of view and from environmental protection point of view.

Table no. 1. Options available for the use and disposal of sludge, and their practical benefits and constraints

Options	Benefits	Constraints
Sludge use options – land based		
• Agriculture • Reclamation • Silviculture • Forestry • Amenity • Horticulture	• Policy • Nutrients • Organic matter • Low cost/low technology	• Voluntary • Vulnerable • Variable demand • Quality • Impacts • Competition
Sludge use options – fuel based		
• Incineration • Supplementary fuel for power and processes • Gasification	• "Green" energy • Transport costs (if on site) • Continuous process	• Public perception • Planning controls • Costs • Emissions • Ash disposal

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Options	Benefits	Constraints
Sludge disposal options – land based		
• Landfill - Mono - Co-disposal	• Low cost • Low technology • Fill and forget • Enhanced CH4 recovery	• Gas emissions • Leachate • Legacy • Resource loss • Void loss
Sludge disposal options – water based		
• Surface waters	• Low cost • Low technology • Biological productivity • CO2 fixation	• Contaminants • Nutrients • Perception

Although sludges represent only 2% of the total wastewater, the costs related to sludge management vary between (20-60)% from the total operating costs of the treatment plant (Foladori et al., 2010). Considering these figures, even though there are many recipes for making bricks from the market, research in the field must continue to reduce pollution and reduce resource depletion, problems that contribute to the intensification of climate change.

Literature Review

One of the most important problems facing society today is the large amount of waste generated by agriculture, industry and constructions in the context of accelerated consumption, until depletion of natural resources. Thus, at a worldwide level, there are intense concerns for managing waste in an environmentally sound manner and making use of the secondary materials they contain. In the scientific literature are mentioned studies regarding the utilization of agricultural waste such as coconut shell [Sujatha & Balakrishnan, 2021; Hamada *et al.*, 2020], rice bark [Ketov *et al.*, 2021; Jittin *et al.*, 2020], peanut husk [Zúñiga-Torres *et al.*, 2021; Maraveas, 2020], spent coffee ground [Saberian *et al.*, 2021; Lachheb *et al.*, 2019], olives pomace [Lopez-Garcia *et al.*, 2021; El Boukili *et al.*, 2021; José & Castro, 2018], grain straw [Calatan *et al.*, 2020; Olacia *et al.*, 2020; Xing *et al.*, 2018], hemp [Nováková., 2018], foam from vines [Taurino *et al.*, 2019], berries sugar cane [Ricciardi *et al.*, 2020; Daheriya & Singh, 2018], waste from industrial sludge [Gomez *et al.*, 2019; Daheriya & Singh, 2018], fiber waste glass [Munir *et al.*, 2021; Xin *et al.*, 2021] and even the reuse of waste to make a similar product (expensive clay mites) [Huarachi *et al.*, 2020] in different combinations and proportions. Attempts have also been made to obtain bricks products from plant fibers (chopped stems, seed husks, sawdust) clay, construction waste, industrial waste [Priyadarshini *et al*., 2021; Ganesh *et al*., 2020; Daheriya & Singh, 2018].

Theoretical Background

The preparation of the sludge sample from the characteristics of the treated wastewater to the dewatering process, has a dual purpose: relevance and success of the experiment, i.e. access to a positive result with respect to the initial objective. [Gomes et al., 2019]

Each step of the process will be influenced by the previous ones, the links between initial conditions and results are affected by a complexity of factors.

Stages of the sludge recovery and inerting process:

a) obtaining sludge by wastewater treatment;
b) dewatering of sludge by filtration on bag filters and/or centrifugation on a laboratory centrifuge;
c) sludge recovery by cement inerting.

Structure of the production process of sludge bricks from wastewater treatment plants

a) Obtaining sludge from wastewater treatment.

- Sampling Plan elaboration which takes into account the sampling objectives. The objective of sludge sampling is to provide representative samples for the sludge batch for which the experimental tests are being carried out. The aim is to obtain representative and valid (real) samples for the full characterisation of the constituent/constituents of the environmental component under examination. This means that the samples must be collected and preserved (kept under specific preservation conditions - by refrigeration or chemical treatment) so that the quality indicators measured in the sample itself have the same value as the entire composition of the generated sludge.
- Analyses required for the sampled samples. Physico-chemical analyses (pH, total organic carbon, dissolved organic carbon, moisture, organic substances, inorganic substances, chlorides, sulphates, fluorides, phenol index, total dissolved substances, metals - arsenic, cadmium, copper, total chromium, molybdenum, nickel, lead, zinc, mercury) will be carried out. Characteristics of the technological process from which the sludge to be tested originates: the technological process from which the sludge to be tested originates is a

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physico-chemical process for the treatment of technological wastewater. The physico-chemical characteristics of these waters may vary. These characteristics will be mentioned for each experimental test performed. Depending on these characteristics, the dose of coagulant added (10% aluminium sulphate solution) will also vary.

- Sampling methodology. Sampling involves the collection of samples from different points of the charge under investigation. According to the working procedure of these standards, for a maximum quantity of 2 tons of sludge, 10 samples of 200 grams are taken, constituting a homogeneous sample of 2 kg. Ten such 2 kg samples were taken. These were then homogenised and the sample was formed for the experiments to be carried out. Samples are taken in plastic or borosilicate glass containers of 2000 ml volume, washed and kept in 5% (v/v) nitric acid solution for 24 hours and rinsed 2-3 times with distilled water, then filled and acid added for preservation); finally, they are sealed. Transport and preservation of the sample is carried out at (2 – 5)ºC and under safe conditions to avoid damage or destruction of the container and contamination or loss of the sample.
- Sampling Frequency. Sampling is done at each sludge discharge from the treatment plant, generally weekly, in order to test each charge of sludge generated by the wastewater treatment process.
- Location and sampling points. The sampling location is at the discharge from the secondary clarifier.
- Sample coding. Sample coding must be clear, representative of the sample taken.

b) Sludge dewatering. Sludge dewatering is carried out by filtration on bag filters and/or centrifugation on a laboratory centrifuge. This aims to obtain a sludge with a moisture content of less than 80%, according to the requirements of the proposed patent technology.

c) Sludge recovery by cement inerting in order to obtain bricks. The centrifuged sludge is mixed in the ratio of: 45% cement + 55% sludge. The mixture is homogenised for 15 minutes until a homogeneous paste is obtained and poured into metal or wooden moulds. Leave to dry for 24 hours, then removed from the moulds and leave in the open air for 3-4 days to allow the lime in the sludge to come into contact with the CO_2 in the air, which helps increase strength.

Experimental tests of the process of obtaining bricks

Centrifuged sludge is mixed in the ratio of: 45% cement + 55% sludge. The mixture is homogenised for 15 minutes until a homogeneous paste is obtained and poured into metal or wooden moulds. Leave to dry for 24 hours, then remove from the moulds and leave in the open air for 3-4 days to allow the lime in the sludge to come into contact with the CO2 in the air, which helps increase strength.

Only 3 of the experimental results are shown in Table 2.

Table no. 2. Experimental tests

Experiment	Sludge sample code	Final product code	Sludge sampling date	Experiment date
2. 08.	N8	2.08	04.05.2020	04.05.2020
2. 09.	N8	2.09	04.05.2020	04.05.2020
2. 10.	N8	2.10	04.05.2020	04.05.2020

During the test period, wastewater with varying physico-chemical characteristics was treated in the treatment plant (Table 3).

Table no. 3. Physico-chemical characteristics of waste water from which raw sludge for experiments is obtained

Parameter	MU	Values
pH	Unit. pH	8,75-8,89
Suspended solids	mg/L	510,8- 625,0
Biochemical Oxygen Consumption	mg O_2/L	342,91-36,22
Chemical Oxygen Consumption	mg O_2/L	672,18-685,04
Detergents	mg/L	3,01-3,32
Total Phosphorus	mg/L	2,61-2,87
Sulphates	mg/L	376,78-396,37
Ammonium	mg/L	2,62-2,86
Extractable substances	mg/L	30-30,9

I. Aluminium sulphate: 0.5 g/l wastewater.

Sludge sampling from treatment plant. According to the working procedure for a maximum quantity of 2 tons of sludge, 10 samples of 200 grams each were taken

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to form a homogeneous sample of 2 kg, then all the indications mentioned in the Methodology chapter were followed. The constituted sludge sample was coded and sampled into 3 subsamples for the experimental tests that were carried out. The part of the sludge sample separated for physico-chemical determinations was preserved in jar glass (Fig. 2) and taken from the raw sludge (Fig. 3). The final product is shown in Fig. 4.

Figure no. 2. Preserved sludge sample for physico-chemical analysis sample code N8

Figure no. 3. Raw sludge used in experiments

Figure no. 4. Final brick product sample code 2.08

Description of the sludge sample, after wastewater treatment:
- Semi-liquid, dark blue appearance with grey iridescence.
- Sludge moisture before filtration and centrifugation: 97.05%.
- Sludge moisture after filtering on bag filter and centrifugation: 64.99%.
- Quantity of sludge used to obtain final product, brick: 2.75 kg.
- Quantity of cement used to obtain final product, brick: 2,25 kg.

Working method for the preparation of the final brick product:

The raw water sample is treated with aluminium sulphate, dose 0,5 gr/L, for precipitation and coagulation of organic and inorganic substances. The resulting sludge after settling for 24 h is filtered on filter bags and centrifuged on laboratory centrifuge. The dewatered sludge is mixed in the ratio of: 45% cement + 55% sludge. The mixture is homogenised for 15 minutes until a homogeneous paste is obtained and poured into metal or wooden moulds. Leave to dry for 24 hours, then remove from the moulds and leave in the open air for 3-4 days to allow the sludge cousin to come into contact with the CO_2 in the air, which helps increase strength.

Conclusion

Efficient and quality wastewater management ensures that sludge of appropriate quality is obtained for management and recovery according to the proposed technology (inertness and end product: bricks and plaster). The new 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). Wastewater treatment plants that implement such sludge recovery technologies can minimise their operating costs (transport, storage and waste disposal), and even more so, they can obtain additional income from the sale of the bricks.

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