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THE CONCEPT OF ALTERATION AND MANAGEMENT OF SEWAGE SLUDGE AT THE SEWAGE TREATMENT PLANT IN SZAMOTUŁY

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Abstract

Under applicable law (The Act on Fertilizers and Fertilization 2007) sewage sludge produced in wastewater treatment plants is treated as waste.

The article presents 5 variants of alteration and management of sewage sludge from the wastewater treatment plant in Szamotuły. Some of them include the use of green mass that can be obtained as a result of urban greenery maintenance works. For the purpose of this article there was carried out a quantitative balance of sludge, taking into account different degrees of its hydration. There were also discussed the results of an experiment conducted on the semi-technical scale. The drying process took place under a plastic tunnel with a length of 10 m. Two series of sludge drying at different outdoor temperatures were carried out. The sludge drying time in conditions of high ambient temperatures (24-36˚C) was 18 days. There was also determined the dependance between hydration and drying time at lower temperatures.

In the final analysis, there were employed two basic methods of sludge treatment: solar drying and composting. The introduction of new solutions removes numerous existing sludge disposal costs. The benefits will consist in the elimination of sludge disposal costs or sludge hygienisation costs.

Key words: sewage sludge, waste, solar drying, composting.

INTRODUCTION

Under applicable law (The Act on Fertilizers and Fertilization 2007) sewage sludge produced in wastewater treatment plants is treated as waste with catalog number 19 08 05 (Regulation of the Minister of Environment on the Waste Catalog, 2014). The literature describes various ways of sewage utilisation, and the choice depends on numerous factors i. a. ecological, technological, technical or economic aspects. The problem of proper management of sewage sludge has become the subject of intense research because of their chemical pollution and a large amount of dry matter. In the recent years significant changes in the approach to the problems associated with the development of sludge in wastewater treatment plants are observed (Antonkiewicz, Jasiewicz 2009). According to forecasts, in 2020 the most frequently used methods of sewage sludge management will be: thermal neutralisation as well as agricultural and natural use (National Waste Management Plan 2014). So far, particular emphasis has been put on the quality of wastewater discharged from wastewater treatment plants. Type of wastewater flowing into the wastewater treatment plant determines the physico-chemical composition of the sludge. Some of contaminants are not degraded in wastewater treatment processes but they are accumulated in the sewage sludge (Antonkiewicz, Jasiewicz 2009). Increase in requirements in this field has led to an increase in the amount of sludge produced in treatment processes. Costs related to sludge disposal or its hygienisation would incline sewage treatment managers to seek alternative solutions. The final stage of sludge treatment was its mechanical dehydration and storage at numerous wastewater treatment plants. Eventually, a municipal biodegradable waste landfill ban (since January 2016) (Bień *et al.* 2011) has been enforcing changes in alteration and management of sewage sludge.

The methods of alteration and management of sewage sludge are determined by legal acts in force. The most significant regulation is the Sewage Sludge Directive (86/278/EEC), which states that sludge may have properties useful in tillage, wherein it cannot deteriorate soil quality. The Sewage Sludge Directive imposes the requirement for sludge treatment and prohibits the use of sludge containing heavy metals. The quality of sludge and soils, where they are used, must be monitored. According to the regulation, it is required to keep up-to-date records on sludge (86/278/EEC). Agriculture sludge management is recommended for small and medium-sized treatment plants, however this path is virtually closed to large facilities. This is due to inappropriate physicochemical properties of sludge that results from, first and foremost, an excessive content of heavy metals (Bień *et al.* 2011). Sludge management is also regulated by:

1. National Waste Management Plan (2014)

2. Regulation of the Minister of Environment on Municipal Sewage Sludge (2015)
3. Regulation of the Minister of Agriculture and Rural Development on the implementation of certain provisions of the Act on Fertilizers and Fertilization (2008)
4. The Act on Fertilizers and Fertilization (2007)
5. The Act on Renewable Sources of Energy (2015)
6. The Act on Waste (2013)

According to the regulations, final sludge neutralisation may take place through R1 (combustion), R3 (composting) and R10 (agriculture or ecological improvement) recovery processes, provided for organic waste, including sewage sludge.

AIM AND SCOPE OF THE STUDY

The article presents methods of alteration and management of sewage sludge from a municipal wastewater treatment plants, simultaneously taking into account the tightening provisions in this regard. The proposed variants aim to reduce costs being incurred to date when implementing the methods complying with currently applicable regulations. The introduction of new solutions will remove numerous cost of sludge neutralisation. Exemplary benefits will consist in the elimination of sludge disposal costs, or the elimination of sludge hygienisation costs. Additionally, it is anticipated to undertake operations related to green waste management, resulting from the maintenance of urban greenery.

DESCRIPTION OF THE FACILITY

The wastewater treatment plant in Szamotuły purifies wastewater applying the technology of biological wastewater treatment with activated sludge. The wastewater treatment plant receives an average of 3600 m^3 of wastewater per day. It serves 25000 PE (Population Equivalents). The design flow is 6300 $m^3 \cdot d^{-1}$ (maximum 8000 $m^3 \cdot d^{-1}$). The content of organic compounds in raw wastewater is BOD_5 – 350 g $O_2 \cdot m^{-3}$, COD – 700 – 900 g $O_2 \cdot m^{-3}$.

Sludge that is a result of treatment processes is stabilised with oxygen. The amount of stabilised sludge of a hydration level of 98,8%, formed per day is approx. 90 m^3. At present, stabilised sludge is being stored, then dehydrated on a belt press having a capacity of 20 $m^3 \cdot h^{-1}$ (in three portions). The current average amount of sludge after dehydration on the press is 3000 – 4000 $t \cdot year^{-1}$, giving an average of 8 – 10 $t \cdot d^{-1}$. Sludge hydration level after the press is 85% (approx. 15% of dry mass).

Subsequently, dehydrated sludge is transported by means of a screw conveyor directly onto a trailer, in order to dispose it for further development. Sludge disposal cost is PLN $70 \cdot t^{-1}$, which gives up to PLN 300 000 per year. Sludge is periodically limed (slaked lime) for the purpose of its chemical stabilisation and conditioning.

RESEARCH METHODOLOGY

The article presents several variants of alteration and management of sewage sludge. In order to ensure that the proposed methods correspond to technological and practical considerations, there was carried out a quantitative sludge balance for the analysed facility. Raw sludge weight per day is calculated from the formula:

$$M_d = S_{98,8\%} \cdot V_d \tag{1}$$

where:
M_d – sludge weight per day, $kg_{d.m.} \cdot d^{-1}$

$$S_{98,8\%} = \frac{\rho_{98,8\%} \cdot (100 - W)}{100} \tag{2}$$

where:
$S_{98,8\%}$ – excess sludge concentration of a hydration level of 98,8%, $kg_{d.m.} \cdot m^{-3}$
$\varrho_{98,8\%}$ – sludge density of a hydration level of 98,8%, $kg \cdot m^{-3}$
W – sludge hydration, %

$$V_d = MR \cdot V_j \tag{3}$$

where:
V_d – sludge volume per day, $dm^3 \cdot year^{-1}$
PE – Population Equivalents
V_j – unit sludge volume – 4, $dm^3 \cdot (M \cdot d)^{-1}$

Sludge weight, density and volume of a hydration level of W% is calculated from the formula:

$$M_{W\%} = M_d \cdot \frac{100}{(100 - W)} \tag{4}$$

$M_{W\%}$ – sludge weight of a hydration level of W%

$$\rho_{W\%} = \frac{100 \cdot \rho_G \cdot \rho_W}{(100 - W) \cdot \rho_W + W \cdot \rho_G} \tag{5}$$

$\varrho_{W\%}$ – sludge density of a hydration level of W%, $kg \cdot m^{-3}$
ϱ_G – density of solids content in sludge, $kg \cdot m^{-3}$

ϱ_W – water density, kg·m^{-3}

$$V_{W\%} = \frac{M_{W\%}}{\rho_{W\%}} \tag{6}$$

$V_{W\%}$ – sludge volume of a hydration level of W%, m^3·year^{-1}
$M_{W\%}$ – dry sludge weight, t·year^{-1}

The proposed method of alteration requires different levels of sludge hydration, thus the above calculations are made for W = 25, 35, 50, 70 and 85%.

As one of the methods of alteration was going to be solar drying (Trojanowska 2013), dehydrated sludge from the wastewater treatment plant in Szamotuły was subject to this type of drying process under field conditions – on the semi-technical scale. The experiment was conducted under a foil tunnel with a length of 10 m (Figure 1).

Figure 1. The tunnel for sludge drying on the semi-technical scale

Single sludge drying batch was approx. 100 kg. Output hydration was 85%. The drying process was completed after achieving the hydration level of 26%. Two series of sludge drying at different outdoor temperatures were carried out. Sludge was shovelled several times a day. The conditions of the semi-technical scale were comparable to those found in unheated solar drying chambers (Trojanowska *et al.* 2012).

Theoretical demand for space for a solar drying chamber was calculated using the formula:

$$V_{85\%} = P_j \cdot V_{OS} \tag{7}$$

where:

$V_{85\%}$ – theoretical area for sludge drying, m^2

P_j – unit area of sludge dehydrated to W = 85% – 1,2 ÷ 1,5, $m^2 \cdot t^{-1}$

V_{OS} – amount of sludge after dehydration on the press, $t \cdot year^{-1}$

There were also carried out initial briquetting tests of partially hydrated sludge without additives and with the addition of grass and wood chips.

TEST RESULTS

1. Quantitative balance of sewage sludge

Raw sludge volume per day calculated according to the Formula 3 is 100 $m^3 \cdot d^{-1}$. Excess sludge concentration of a hydration level of 98,8% ($S_{98,8\%}$) calculated according to the Formula 2 is 12 $kg_{d.m.} \cdot m^{-3}$. Sludge weight per day M_d = 1200 $kg_{d.m.} \cdot d^{-1}$ (Formula 1). Table 1 include the balance results for sludge at different hydration levels.

Table 1. Parameters of sludge at different hydration levels

Hydration %	$M_{W\%}$ $t \cdot d^{-1}$	$\varrho_{W\%}$ $kg \cdot m^{-3}$	$V_{W\%}$ $m^3 \cdot d^{-1}$	M $t \cdot (3weeks)^{-1}$	V $m^3 \cdot (3weeks)^{-1}$	M $t \cdot (6weeks)^{-1}$	V $m^3 \cdot (6weeks)^{-1}$
85	8.00	1066	7.50	168.0	157.5	336.0	315.0
70	4.00	1141	3.50	84.0	73.5	168.0	147.0
55	2.70	1227	2.20	56.7	46.2	113.4	92.4
50	2.40	1259	1.91	50.4	40.1	100.8	80.2
35	1.85	1366	1.35	38.9	28.4	77.7	56.7
25	1.60	1447	1.10	33.6	23.1	67.2	46.2

Theoretical space demand for sludge drying at W = 85% to form granulate was calculated according to the formula (7). There were adopted the minimal unit space demand for sludge drying 1,2 $m^2 \cdot t^{-1}$, and its maximum value 1,5 $m^2 \cdot t^{-1}$. By taking into account the above, there was obtained the value of theoretical space demand for a solar drying chamber ranging from 3600 m^2 to 4500 m^2. For a drying chamber there will be used an existing shed with the floor surface of 1600 m^2. Actual space demand for sludge drying will depend on the adopted variant of sludge alteration and management and the correlated final moisture level required. The shed will be sufficient in each variant being discussed.

2. Sludge drying on the semi-technical scale

Figure 2 illustrates the course of a sludge drying process in time and at outdoor temperatures between 24-36˚C during the day. The temperature of sludge subject to drying was varied from 29 to 36˚C.

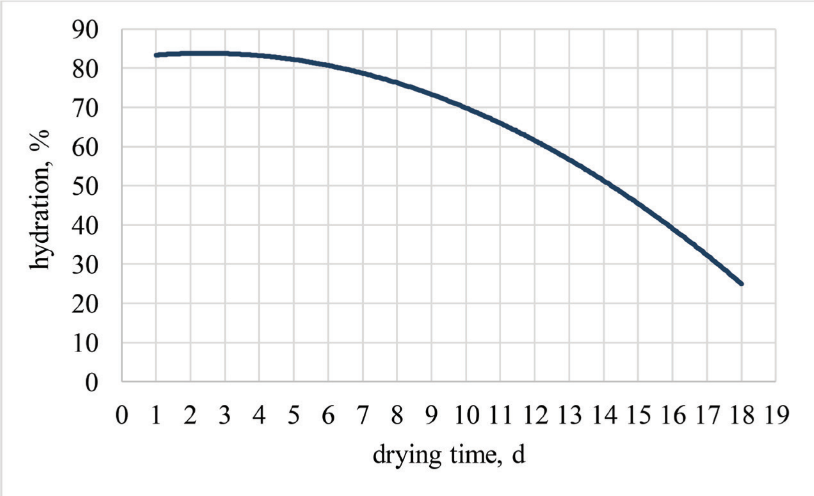

Figure 2. The course of a sludge drying process at outdoor temperatures between 24 – 36˚C

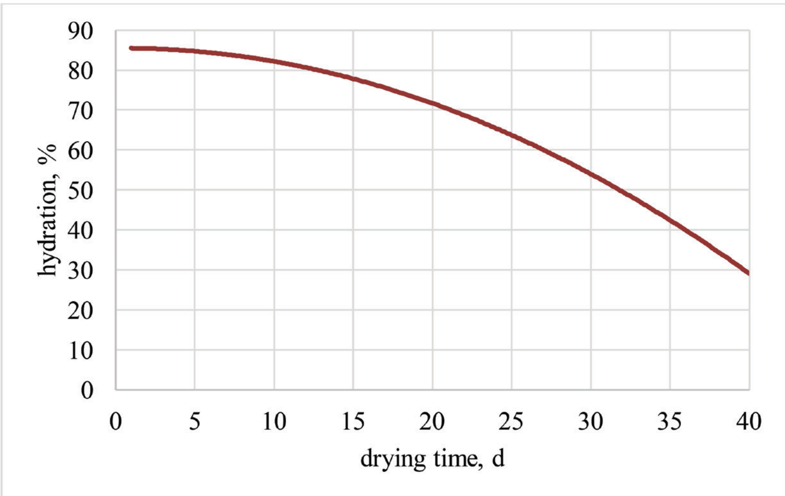

Figure 3. The course of a sludge drying process at outdoor temperatures between 16 – 23˚C

The sludge drying time in conditions of high ambient temperatures was 18 days.

Figure 3 shows the dependence between hydration and drying time at lower temperatures. Outdoor temperature fluctuated during the day from 16 to 23˚C, and sludge temperatures from 16 to 24˚C.

Actual sludge drying time on the semi-technical scale will also depend on the required final hydration level of sludge, in the selected variant of alteration.

3. Briquetting

Sludge will be dried from the following hydration levels: 85% to 25% (briquetting – sludge only), 35% (briquetting – sludge with dried green mass) or 50 – 55% (sludge composting). In case of compost briquetting, it must be dried from 50 or 55% to 25% of the moisture level.

There were carried out briquetting tests with partially dried sewage sludge from the treatment plant in Szamotuły and with its mixture including grass and wood chips. It was found that the maximum additive content can be up to 50%, whereby the content of wood chips should not be higher than 25%. Otherwise, briquette still can be made, however, the performance of a briquetting machine will be approx. 25% lower than anticipated by the producer, and the briquette will be of poorer quality. Briquetting of sludge material without additives is possible after subject it to partial drying to 20 to 30% of the moisture content level. Briquette's quality and durability will, however, be lower than in case of using additives. Briquetting material moisture should be between 20 – 30%.

PROPOSED METHODS OF ALTERATION AND MANAGEMENT OF SEWAGE SLUDGE

There are anticipated 5 variants of alteration and management of sewage sludge and green mass derived from the maintenance of urban greenery (Figure 4).

Variant 1.

Sewage sludge is dehydrated on the belt press to the moisture content of approx. 85%. Next, it is transported to the solar drying chamber, located at the wastewater treatment plant in Szamotuły. Sewage sludge is dried to the moisture content of 30-35%. Green mass is also subject to drying. Green mass moisture after drying is approx. 15%. The next stage is to mix partially dried sludge with green mass and to press the mix. The moisture of briquetting mix is approx. 25%. The final stage in variant 1 is to burn the briquette obtained as part of R1 recovery process (Trojanowska 2010).

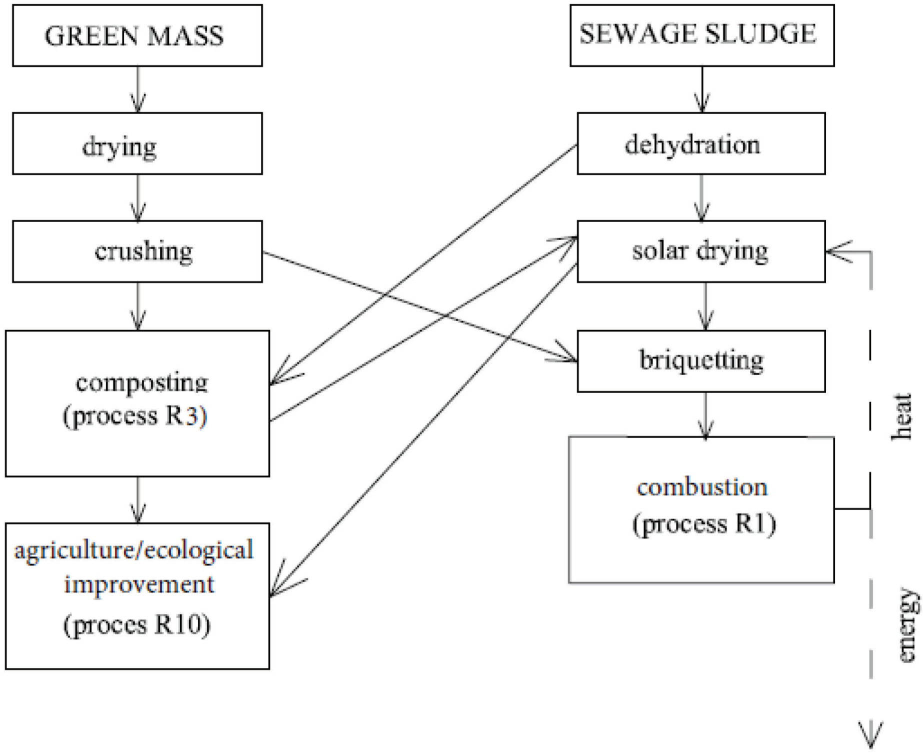

Figure 4. Variants of alteration and management of sewage sludge and green mass

Variant 2.

The variant also provides sludge dehydration (belt press) to the moisture level of 85%. The drying process applies only to green mass, the anticipated moisture level is15%. Next, green mass is crushed and mixed with dehydrated sludge. The moisture of sludge and green mass is 50-55%. The next stage is to compost the mix as part of R3 recovery process (Jędrczak 2005). Composting will take place in a disused concrete tank sized 80 × 30 m, where 12 parallel piles of sludge with a height of 2 m can be placed. The final assumption of variant 2 is the agricultural/ecological use of compost in R10 recovery process (Siuta *et al.* 2007).

Variant 3.

The variant assumes the processes of dehydration of sewage sludge and drying of green mass. Next, crashed green mass is mixed with dehydrated sludge.

The mix (moisture level of 50-55%) is used in a composting process as part of R3 recovery process, as under variant 2.

The obtained compost is partially dried in the solar drying chamber to the moisture level of 20-30%. The partially dried compost is briquetted and burned as part of R1 recovery process (Kucharczak *et al.* 2010).

Variant 4.

The variant includes only dehydration, drying and sewage sludge management processes. Subsequently, there are anticipated the following processes:

- sewage sludge dehydration on the belt press (to the moisture level of approx. 85%),
- partial sludge drying in the solar drying chamber (to the moisture level of 20-30%),
- agriculture/ecological use of dried material (R10 recovery process).

Variant 5.

In variant 5 sewage sludge is dehydrated (the moisture level of approx. 85%) and partially dried in the solar drying chamber to the moisture level of 20-30%, as under variant 4. Next, sludge is briquetted and burned (R1 recovery process).

Variants 1 and 2 are considered to be primary options. Variant 3 may be used for simultaneous implementation with variant 1 and/or 2. The need for implementing variant 2 arises due to difficulties associated with the excess compost produced. Variants 4 and 5 make an alternative solution to problems related to obtaining green mass.

SUMMARY

The proposed variants aim to reduce costs being incurred when implementing the methods complying with currently applicable regulations. In principle, two basic methods of sludge treatment are proposed: solar drying and composting. The use of existing facilities and equipment provides a significant opportunity. Depending on the demand, the processes can be carried out in parallel. Both ecological use (Wydro 2014) or energy utilisation of the product obtained are proposed as improvement.

The introduction of new solutions will take effect that the municipal facility will not bear multiple previous costs of sludge neutralisation. The benefits will consist in:

- elimination of sludge disposal costs (approx. PLN 300 000 per year),
- elimination of sludge hygienisation costs,
- elimination of urban lawn fertilisation costa,

- profit from the sale of compost,
- profit from energy production,
- profit from the sale of briquettes as heating material.

Sewage sludge is one of the non-agricultural sources of organic matter. Sewage sludge from municipal wastewater treatment plants can be used in agriculture after appropriate alteration and disposal. Composting is a simple method for preparing sludge. Agriculture improvement is very important from the viewpoint of the deteriorating condition of polish soils. Sewage sludge contains a large amount of organic compounds that do not degrade in wastewater treatment processes and alteration of sludge. Therefore, solar drying and combustion is recommended.

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