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ADVANTAGES AND DISADVANTAGES OF THE SOLAR DRYING OF SEWAGE SLUDGE IN POLAND

ZALETY I WADY SOLARNEJ SUSZENIA OSADÓW ŚCIEKOWYCH W POLSCE

Abstract

Solar drying has become a popular method of sewage sludge processing in Poland over recent years. This is due to the possibility of using a renewable source of energy and the fact that solar dried sludges can be used for energy purposes. Over the last ten years in Poland, almost thirty solar or hybrid greenhouses of sewage sludge have been built. The aim of this work is to present the advantages and disadvantages of the solar drying method of processing sewage sludge. The advantage of using solar greenhouses are the use of renewable energy sources for sludge drying, their low operational costs, the reduced sludge volume, their preparation for thermal utilisation, simple construction and easy operation. The disadvantages are that drying efficiency depends on climatic conditions and season, the need to use additional heat sources, the fact that facilities occupy a large area and the possibility of odors emission released during drying of the sludge.

Keywords: sewage sludge, treatment, solar drying

Streszczenie

Suszenie słoneczne jest coraz popularniejszą metodą suszenia osadów ściekowych w Polsce w ostatnich latach. Wynika to z możliwości wykorzystania odnawialnego źródła energii oraz faktu, że osuszone słońcem osady mogą być wykorzystywane do celów energetycznych. W ciągu ostatnich dziesięciu lat w Polsce zbudowano prawie trzydzieści słonecznych lub hybrydowych suszarni osadów ściekowych. Celem niniejszej pracy jest przedstawienie zalet i wad suszenia słonecznego stosowanego w przetwarzaniu osadów ściekowych. Zaletą zastosowania szklarni słonecznych jest wykorzystanie odnawialnych źródeł energii do suszenia osadów, niskie koszty operacyjne, uzyskanie zmniejszonej objętości osadu, przygotowanie do energetycznego wykorzystania, prosta konstrukcja i łatwa obsługa. Do wad należy zależność skuteczności suszenia od warunków klimatycznych i pory roku, konieczności wykorzystania dodatkowych źródeł ciepła, faktu, że obiekty zajmują duży obszar i możliwość emisji odorów emitowanych podczas suszenia osadu.

Słowa kluczowe: osady ściekowe, przetwarzanie, suszenie słoneczne

1. Introduction

The preferred direction in the application of sewage sludge in Poland is its agricultural utilization. Sewage sludge which cannot be utilised in such a way, may be thermally used. According to assumptions of the National Plan of the Waste Disposal 2022 [1] in the coming years in Poland the proportion of sewage sludge that undergoes thermal treatment will increase. For thermal treating methods of sewage sludge are mainly meant combustion, co-combustion in cement plants as well as alternative processes, so as the pyrolysis or gasification [2–4]. Sewage sludge is characterized by a calorific value similar to that of brown coal, usually 9-13 MJ/kg. Their calorific value can be increased by mixing with higher calorific value wastes [5–6]. The calorific value of fuels, also sewage sludge, depends on their moisture content. Sewage sludge contains a significant percentage of water and should be dehydrated prior to thermal utilization [7, 8]. The thermal disposal of sewage sludge is related immediately to the dry matter content (d.m.) achievement of required level – at least 40%. However, cement producers usually require a degree of drying of sludge to more than 90% d.m. [7]. The drying process of sewage sludge can be conducted in a conventional manner in a dedicated dryer, where energy source is meant to be: fossil fuel such as natural gas or use of alternative methods, eg. use of sunlight in solar greenhouses. However, the efficiency of such kinds of drying processes is usually insufficient for obtaining a high proportion of dry matter; therefore, wastewater treatment plants use additional energy sources such as biogas for underfloor heating or infrared radiators. It is recommended that solar dried sewage sludge should be used for thermal disposal rather than for agricultural purposes. [10]. The conditions of applying sewage sludge as alternative fuel, e.g. in cement industry, are: a high percentage of dry matter, the physico-chemical stability, appropriately low content of pollutants. Under Polish law [9], all installations for waste co-burning are obliged to monitor the release of pollutants (Table 1).

Table 1. Emission standards applicable to the installation for co-combustion of waste [9]

Contamination	Value	Unit
total dust	30	mg/m ³
HCl	10	
HF	1	
NO _x	500	
SO ₂	50	
TOC	10	
CO	2,000	
Cd + Tl	0.05	
Hg	0.05	
the sum of the content of heavy metals	0.5	
dioxins and furans	0.1	µg/m ³

Because of the need to meet emission standards, thermal installations for co-combustion of waste, including sewage sludge, the requirements concerning the quality of fuels combusted in such installations, that means maximum values of pollutants are determined. Cement plants require high quality substrates and fuels as they are incorporated into the cement [6, 11]. In order to fulfil requirements concerning emissions from waste co-combustion installations, it is necessary to determine the content of pollutants within the input fuel. It is a requirement that the levels of heavy metals, sulphur and chlorine concentration be identified, because these substances affect the formation of gaseous pollutants. Cement plants also require the determination of the alkali content (K and Na) in the waste fuel, as they can adversely affect the cement kiln operation and cement quality. Table 2 shows the characteristics of sewage sludge taken in 2012 (dewatered sludge), 2014 and 2016 (solar dried sludge) from the waste water treatment plant in Antoniów, Poland [7, 11] compared with the formal requirements concerning co-combustion in Polish cement plants. The characteristic of the wastewater treatment plant in Antoniów is presented below (Chapter 2).

Table 2. Characterisation of sewage sludge from the waste water treatment plant in Antoniów compared with the formal requirements concerning co-combustion in Polish cement plants

Parameter	Sewage sludge(Antoniów)	EURITIS [10]	Lafarge groups [12]	Polish cement plants [13]
dry matter content, %	no data (2012) 75 (2014) 90 (2016)	NA	NA	>70%
dust, %	26 (2012) 25 (2014) 24 (2016)	5	NA	NA
calorific value , MJ/kg	12.7*(2012) 10.5 (2014) 13.3 (2016)	15	>14	>13
heavy metals, mg/kg d. m.	688 (2012) 837 (2014) 392 (2016)	NA	<2500	<2500
Cl / S	0.07/0.25 (2012) no data (2014) 0.16/0.89 (2016)	0.5 /0.4	<0.2/ <2.5	<0.3/ <2.5

NA - no available

* - calculated for 95% d.m.

Sewage sludge from the sewage treatment plant in Antoniów meets the specified requirements for the cement plants with regard to the contaminant content (metals, sulphur, chlorine). However, the low dry matter content influences its calorific value. The Cement Plant located in Góraźdże (Poland), which is a potential recipient of dried sludge, requires a dry matter content of sewage sludge of more than 85%.



2. Technologies used in the solar drying of sewage sludge

The solar drying process relies upon the occurrence of a greenhouse effect within the drying areas. Solar radiation is reflected back into the drying room from the roof, thus increasing the internal temperature. The covering of roof and walls of greenhouse should be made of materials which allow the free permeation of radiation into the interior, these materials are rarely glass but rather, polycarbonate and polythene foils. Greenhouses for sewage sludge should also include ventilators or overblowing exhausters as part of their construction. A crucial element within the greenhouse hall is a rotary sludge tedder. The function of the tedder is sewage sludge granulation and its aeration, homogenization and acceleration of drying process. The thickness of the sewage sludge layer and its degree of dehydration affect the tedder efficiency. In Poland, solar greenhouses for the drying of sewage sludge, rotary tedders made by the German company WENDEWOLF are often installed. The tasks of these devices are the turning over, cutting and forming granules of dried sewage sludge inside the hall. Another solution is presented by a nave tedder of German HUBER company, which enables flipping the layer of drying sewage sludge over on the entire width of the hall [14]. Tedders recirculate the sewage sludge by transporting dried sludge from the rear of the drying hall to the front. Other tasks of the tedder also include: partitioning and moving the transfer of dried granules to bulk channels. Other technology – so-called THERMO-SYSTEM, relies on tedders of type “Electric Mole” or “Sludge Manager”. The first one is an automated electric vehicle, which moves along a track in drying area. It is possible to install this device on an uneven floor. “Sludge Manager” is a device which moves along a beam putted crosswise and along the storage surface. Its efficient functioning does not require a perfectly equal level of area, because it’s able to create the map of floor unevenness. Both devices are designed for small size greenhouses. A novel solution was applied by SOLIA technology, using the SOLIAMIX robot. The device gathers fresh sewage sludge into piles parallel to itself along the entire length of greenhouse hall [15]. Special feeders for the transport of sewage sludge, a digger and belt or voluted conveyors are usually used in those technology [16]. During the drying process, ventilation is a very important consideration. In solar greenhouses, the drying of sewage sludge is also supported by ventilators in the interior. Deodorisation systems are also used in the greenhouses to control odours. In order to accelerate the drying process in solar greenhouses, an additional source of heat can be used in the form of underfloor heating and infrared radiants [17–19]. The construction of drying halls with underfloor heating and the associated infrastructure require almost double the investment of halls of similar size without such facilities [19]. The drying rate in solar greenhouses depends on the thickness of the layer of sewage sludge and climatic conditions [20]. In the summer period, a layer of 1 to 10 cm dries in around 10 days; however, in the autumnal period, this process lasts four times longer [16–18]. In the winter time, in many solar greenhouse which don’t have an underfloor heating installation, sewage sludge is kept in piles to spring [11].

Over the last 10 years in Poland, almost 30 solar or hybrid greenhouses for the processing of sewage sludge have been built. Solar greenhouses are located in such Polish towns as Kozienice, Tuchów, Łañcut, Żary, Myszków, Antoniów, Kłodzko; hybrid greenhouses are found in Iława, Końskie, Chełm, Morąg, Żarów, Żagań, among others.

3. Characteristics of the sewage greenhouses in the Wastewater Treatment Plant in Antoniów (Poland)

The wastewater treatment plant in Antoniów produces around 2400 Mg of sewage sludge at 20% s.m. per year. After dehydration on the filter press, sewage sludge is dried in two greenhouses with a total area of 2,750 m² (width 12 m, length 113.5 m) (Fig. 1a). In each greenhouse, a gravity ventilation system and 12 mechanical ventilators are used. When the air humidity growth inside the greenhouse the roof windows are automatically opened and after exchanging the air they are closed. At the bottom of the walls of greenhouse, there are 10 cm expansion joints which support the operation of gravity ventilation (Fig. 1.2). A rotary tedder from Huber Technology mixes and distributes the sewage sludge on the hall and finally converts it into granules (Fig. 1.3). The weight of the sludge after drying is about 650 t/a. The weight reduction is about 73% and the average dry matter content is about 75%. It was planned that the granules of dried sludge be co-combusted in Cement Plant in Górażdże (Poland). However, the tested sludge does not meet the dry matter content requirements specified by these cement plant. Currently, the wastewater treatment plant uses dry sludge for agricultural purposes. The problem in this case is incomplete hygienisation, this is why the *Salmonella* bacteria is present in the dried sewage sludge.



Fig. 1. Solar greenhouse in the wastewater treatment plant in Antoniów: a) outdoor view of the solar greenhouse; b) gravity ventilation system; c) rotary tedder (Huber) with granules of dried sewage sludge

4. Advantages and disadvantages of the solar drying process of sewage sludge

The effectiveness of the drying process depends mainly on the degree of solar exposure on drying location, therefore locations in the area of south-east Poland are the most profitable. The effectiveness of the solar drying process also depends on the initial method of sludge dehydration, its amount and the type of technology applied. Due to the fact that drying by using sunlight is most effective in the spring-autumn period, the use of an additional source of heat, e.g. underfloor heating, is a recommended solution. The described process is profitable for wastewater treatment plants located a short distance from installations which enable the co-combusting of dried sewage sludge, e.g. in cement plants. Dried sewage sludge should meet the requirements for alternative fuels and specified by the legal regulations for co-incineration plants. Drying sludge causes odour emission, this is linked with an additional investment in a system of filters. The use of dried sewage sludge in agriculture seems unreasonable because the soil can be fertilized with sewage sludge in liquid form. After drying, granules of sewage sludge are characterised by their very compact structure, similar to ceramic materials. This may suggest that, after application to the soil, fertiliser components will be very slowly released. Most often, other methods, such as liming or composting, are used to treat and fertilizer production from sewage sludge.

In conclusion, the advantage of solar greenhouse is the use of renewable energy sources, which reduces the cost of drying. Dried sewage sludge are characterized by a smaller volume and a ceramic structure, which facilitates storage and transport. Nowadays in Poland the simplicity of getting funding of greenhouse build investment partially from the EU may be one of the advantage. The disadvantage of solar drying of sewage sludge is the necessity of building a dryer, in which should be use additional energy sources, in order to obtain a high content of dry matter. In addition, the drying efficiency depends on the degree of sunlight and temperature, which varies throughout the year. Another disadvantage is the need to find a co-combustion instalation plant for dried sludge. Therefore, it is a cost-effective method for wastewater treatment plants located near the cement plant, which reduces transport cost. This method should be applied at sewage treatment plants which plan to thermal utylisation of dried sewage sludges, rather than their agricultural use.

5. Alternative approach for the use of the solar drying of sewage sludge in Poland

The main direction of sewage sludge drying is the energy recovery; therefore, the most important point is leading sewage sludge to the maximum participation of dry matter what causes increase in calorific value. Drying capacity in solar greenhouses may be insufficient to achieve optimal drying of sludge as it depends on sunlight. Therefore, wastewater treatment plants which use solar greenhouses for sewage sludge drying, should consider the additional option of their heating. Polish wastewater treatment plants show that the maximal value of dry substance content that is possible to achieve in the summer months

is at a level of 75–80%. In Poland, sun-dried sludge is usually co-combusted in cement kilns. Recently in Poland an alternative approach for the use of dried sewage sludge is its environmental application, mainly as fertilizer. It seems obvious that the use of dried fertiliser in the farming sector doesn't make sense because for environmental targets, it is also possible to apply sewage sludge in liquid or mud form. Macronutrients are more easily and quickly absorbed by plants if the fertilizer is introduced into the soil in a hydrated form. Moreover, drying of sewage sludge used as fertilizer seems economically unprofitable and too time consuming. Another disadvantage of using dried sludge as fertilizer is incomplete hygienisation. In 2014, a piece of research on the value of sewage sludge granules as a fertiliser was conducted, these granules were obtained from a solar greenhouse at the sewage treatment plant in Antoniów in the Opole region of Poland [11]. The research has shown that the drying process has provided to reduction content of assimilable forms of macro- and microelement. There is a suggestion that after applying dried sewage sludge to the soil, all fertiliser nutrients are released at a slower rate than from hydrated sewage sludge. It may hinder the calculation of nitrogen dose entered into the soil with sewage sludge and that may lower the nutrient bioavailability for crops [21]. It is interesting that during this study, after 24h of water extraction the dried sewage sludge granules did not completely not fall apart. Another consideration with the agricultural use of this granules is reduce the amount of useful microorganisms at higher temperatures during drying process what can lead to limitation of decomposition of organic matter and availability of nutrients. Summarizing, other methods of sewage sludge stabilization and hygienisation eg liming or composting, should be considered for their natural use than solar drying, which is time consuming and requires a greenhouse.

6. Summary

In summary, the advantages of using solar greenhouses are the use of renewable energy sources for sludge drying, the low operating costs, the reduced sludge volume and correct preparation for thermal disposal, simple construction and ease of operation of instalation. The disadvantages are the fact that drying efficiency depends on the climatic conditions and the season, the need to use an additional heat source, the fact that the required facilities occupy a large area and the possibility of odour emissions released during the drying of the sludge. The main direction of using dried sludge is their use for energy purposes. Co-combustion in cement kilns is the most ecological solution in view of waste-free technologies, due to the possibilities of heavy metals binding to cement and the limitation of the emission of gaseous pollutants. The thermal utylisation of sludge is limited by its high hydratation level, its adverse consistency, its low calorific value and pollution content.

However the solar drying of sewage sludge does not seem to be the most appropriate method of treatment for the purpose of use in agriculture, which is preferred way of using sewage sludge in Poland again.



References

- [1] Resolution No. 88 of the Council of Ministers of 1 July 2016 on the “National Waste Management Plan 2022”, *Monitor Polski* poz. 284.
- [2] Bień J.D., *Zagospodarowanie komunalnych osadów ściekowych metodami termicznymi*, *Inżynieria i Ochrona Środowiska*, 15(4), 2012, 439–449.
- [3] Bień J., Neczaj E., Worwąg M., Grosser A., Nowak D., Milczarek M., Janik M., *Kierunki zagospodarowania osadów ściekowych w Polsce po roku 2013*, *Inżynieria i Ochrona Środowiska*, 14(4), 2011, 375–384.
- [4] Lutzner K., *Uzdatnianie ścieków i osadów*, *Ekologia i Technika*, 2(8), 1994, 14–17.
- [5] Wzorek M., Król A., *Analysis of selected properties of sewage sludge within the consideration of its energetic application in forming alternative fuels*, *Polish Journal of Environmental Studies*, 6, 2009, 132–136.
- [6] Wzorek M., *Characterisation of the properties of alternative fuels containing sewage sludge*, *Fuel Processing Technology*, 104, 2012, 80–89.
- [7] Bożym M., *Wymagania jakościowe stawiane osadom ściekowym spalany w krajowych cementowniach/Sewage sludge quality standards required by Polish cement plants*, *Chemik* 67, 2013, 10, 1019–1024.
- [8] Burzała B., *Termiczne przekształcanie osadów ściekowych jako jedna z metod ich utylizacji*, *Nowa Energia*, 1(37), 2014, 29-32.
- [9] Regulation of the Minister of the Environment of 4 November 2014 on emission standards for certain types of installations, combustion sources and combustion or co-incineration facilities, *Dz.U.* 2014 nr 0 poz. 1546.
- [10] Bożym M., *Możliwości wykorzystania osadów ściekowych w przemyśle ceramicznym*, *Materiały Budowlane* 12(460), 2010, 1–3.
- [11] Bożym M., *Ocena możliwości wykorzystania suszonych solarnie osadów ściekowych/Evaluation of the possibilities of using of solar dried sewage sludge*, *Chemik* 69(10), 2015, 666–669.
- [12] Sarna M., Mokrzycki E., Uliasz-Bocheńczyk A., *Paliwa alternatywne z odpadów dla cementowni*. Doświadczenia Lafarge Cement Polska S.A., *Zeszyty Naukowe Wydziału Budownictwa i Inżynierii Środowiska Politechniki Koszalińskiej*, 21, Seria: *Inżynieria Środowiska* Wydawnictwo Uczelniane Politechniki Koszalińskiej, Koszalin 2003, 309–316.
- [13] Duda J., *Współspalanie węgla i paliw alternatywnych w cementowych piecach obrotowych*. *Prace Instytutu Mineralnych Materiałów Budowlanych*, 35/36, 2003, 7–24.
- [14] Sobczyk R., Dembińska J., *Suszarnia słoneczna osadów w Antoniowie*, *Forum Eksploatatora*, 4, 2013.
- [15] Sobczyk R., Sypuła M., *Słoneczne suszenie osadów ściekowych w technologii Solia*, *Forum Eksploatatora*, 3, 2012.
- [16] Trojanowska K., *Energetyczne aspekty solarnego suszenia osadów ściekowych*, [in:] Z. Sadecka, *Oczyszczanie ścieków i przeróbka osadów ściekowych*, OWUZ, Zielona Góra 2010, 159–165.

- [17] Trojanowska K., *Ogrzewanie podłogowe w solarnych suszarniach osadów*, *Wodociągi i Kanalizacja*, 9, 2010, 24–27.
- [18] Trojanowska K., *Suszenie osadów ściekowych energią słońca*, *Przegląd Komunalny* 10, 2010, 46–48.
- [19] Sadecka Z., *Suszenie osadów – hybrydowe?*, *Materiały III Ogólnopolskiej Konferencji Szkoleniowej “Metody zagospodarowania osadów ściekowych”*, Chorzów, 2012, 86–96.
- [20] Yilmaz E., Wzorek M., *Assessment of the impact of various parameters on solar drying process in Aydin region in Turkey*, 3rd International Conference on Sustainable Solid Waste Management, 2–4 July 2015 Tinos.
- [21] Regulation of the Minister of the Environment of February 6, 2015 on municipal sewage sludge, *Dz.U.* 2015 poz. 257.

