

SLUDGE AS AN AGENT IMPROVING SOIL PROPERTIES

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ABSTRACT

Sewage-treatment plants generate sludge which needs to be neutralized for legal, esthetical, and practical reasons. Economical and ecological concerns indicate that sludge, as long as it is possible, should be returned to the natural environment. The article presents the process of autothermal thermophilic aerobic digestion (ATAD) as a measure to produce biomass, which can be naturally utilized. The description of theoretical principles of the process in question is accompanied by presentation of an ATAD installation which has been functioning since 2009 at the municipal sewage-treatment plant in Olecko. Results of microbiological and chemical tests carried out in the years 2010–2012 have been analyzed. Examinations embraced sludge which was the final product of the aforementioned sewage-treatment plant.

Keywords: sludge, digestion of sludge, sanitation of sludge, natural utilization of sludge, agent improving the properties of sludge.

INTRODUCTION

Sewage-treatment plants are facilities which constitute a necessary element of preservation of superficial waters, on the other hand, they are, through their activity, a burden to the environment, concerning the acoustic climate or protection of the earth surface. These plants generate various kinds of waste material, whose quantity depends on the size of a plant and on the engaged technological processes. The necessity of using highly effective methods of sewage treatment may cause generation of preliminary sludge, excessive sludge after chemical precipitation, and dosage of external source of organic carbon, necessary for conduct of technological processes connected with the removal of nitrogen compounds (denitrification).

Domestic sewage, apart from physical and chemical impurities, contains biological contaminants. These are: viruses, bacteria, fungi, and helminthic eggs. Most of these microorganisms belong to the typical heterotrophic gastrointestinal flora of humans and animals. Some of these organisms are pathogenic. Significant amounts of

these impurities are eliminated during the process of mechanical and biological purification. However, they are not rendered harmless but penetrate into sludge, which should be properly processed for this reason.

Neutralization of sludge involves reduction of its putrescibility, elimination of pathogenic organisms, reduction of volume and mass of sludge. Sludge is transported from the plant area to the place of its ultimate utilization when it satisfies certain conditions. It will ensure a proper sludge processing, safe for the plant crew as well as for the environment. The cheapest method of neutralization of sludge is its return to the natural environment. However, natural utilization is possible only when sludge is stabilized, sanitary safe, and not containing excessive concentration of heavy metals. Moreover, we have to ensure proper areas for its disposal. There are many known methods of transforming sludge into biomass. One such method is termed as autothermal thermophilic aerobic digestion, whose efficacy of preparation of product meeting requirements, is presented in this article.

The aim of this publication is to present the autothermal thermophilic aerobic digestion method as a measure to produce biomass, which can be used as an agent for improvement of soil properties. In this way, the ATAD process contributes to solution of the problems connected with neutralization of still growing amount of sludge. ATAD enables reduction of sludge amount, its stabilization, and sanitation.

CHARACTERISTICS OF THE PROCESS AND TECHNICAL SOLUTION

Autothermal thermophilic aerobic digestion of sludge is becoming more commonly applied in the Western European and North American countries. In Germany this system is called ATS (die aerob-thermophile Schlammbehandlung), in America and Canada it is called ATAD (autothermal thermophilic aerobic digestion), in Poland it is termed ATSO (autotermiczna termofilna stabilizacja osadów).

Microorganisms play an important role on the process of thermophilic aerobic digestion, as they enable decomposition of organic compounds present in sludge. The process comprises two stages. At the first stage complex organic compounds (proteins, carbohydrates, and lipids) undergo hydrolysis and atrophying cells undergo a lysis. These changes are facilitated by intracellular enzymes produced by thermophilic bacteria. At the second stage products of hydrolysis dissolved in water are oxidized to low-energy compounds. These reactions are accompanied by heat emission, and the finally generated substances are CO_2 , H_2O and NH_3 [Bartkowska 2005; Wersocki, Hupka 2006; Zupančič, Roš 2008]. Feeding properly concentrated substrates and sufficient amounts of oxygen, in the thermally insulated tanks sludge warms up spontaneously reaching the temperature of 55–80 °C [Zhou et al. 2002; Kelly 2006; Layden 2007; Nosrati et al. 2007].

The process of thermophilic aerobic stabilization usually takes place in tanks connected in series. At the first stage of the installation the temperatures of the lower range of thermophilic distribution are reached, maximal disinfection and the highest temperatures are reached at the last stage. Daily dispersion of neutralized sludge takes place at the final stage only. When next dump of raw sludge is finished, sludge is fed to the first stage, while partially processed sludge

is moved to the next reactor. Displacement of sludge from the first reactor to the next one results in a slight temperature fall. When reactors have been fed with sludge they are insulated for 23 hours, when thermophilic decomposition takes place. To limit the rise of temperature in the last tank a heat-exchanger can be installed.

The process requires constant air supply, which is ensured by aerators. Moreover, they have to enable effective mixing of the reaction chamber contents.

An important element is regulation of the amount of the formed foam. The process is not supposed to totally liquidate the foam, since its presence is beneficial, yet, its thickness and density should be controlled by means of e.g. froth breakers. Mechanic action of these rotating devices literally cuts the foam, which is later carried away as a liquid onto the sludge surface in the reactor mixed with its contents. The amount of foam must not be regulated by limitation of air input, because it may evoke oxygen deficit and increase the odorous burden of sludge and waste gases, caused by excessive formation of fermentation products.

Even the most efficiently designed installation for thermophilic aerobic digestion requires a system to clean the air in the reactors before it is released to the atmosphere. Commonly, water scrubbers are applied to remove ammonia, and bio-filters, or recently introduced chambers, in which a process of photo catalytic oxidation of the substances responsible for odor emanation [Bartkowska et al. 2007].

In the above described sewage-treatment plant excessive sludge from particular reactor SBR is periodically carried away to a tank. The tank is equipped with stationary system which carries off the super sludge waters (an outlet pipe with a bolt and electric drive) and a measuring device (a sensor of the filling level and a sensor of phase separation). Additionally, the sludge feeding duct is fitted with an electrically driven wedge bolt. Next, the excessive sludge is led to the building of mechanical sludge processing. In this building there is a condensing centrifuge which enables concentration of sludge prior to the autothermal thermophilic aerobic digestion process. There is also a spin-drier of stabilized sludge; the effluent is carried off to the sewage system of the plant. Excessive sludge preliminarily concentrated is fed to two ATAD reactors connected in series. Those reactors were the object of examina-

tion. Both reactors are of this design: steel round tanks, made of enameled sheet, insulated by mineral wool 10 mm thick in a sheet aluminum coat. The diameter of a single tank is 7.71 m, its height 3.60 m. The sludge filing level is 2.80 m, which means the functional volume is 130 m³. The basic technological equipment of both reactors consists of: central aerator, spiral aerator (2 units), froth breakers (4 units), plate-pipe exchanger (only in the second reactor), temperature sensor (2 units), hydrostatic sensor of level, and cut-off fittings.

Stabilized and sanitized sludge after the ATAD process is carried away to a multi-function tank, to one of its chambers, precisely speaking. Cooled down sludge in a chamber of the multi-function tank is dehydrated in a centrifuge and moved by means of a worm transport to a sludge box. The ultimate place where stabilized and dehydrated sludge is stored is the island station roof. The surface of its interior is concrete. Linear dehydration was made to carry off the effluent from the island station roof and from precipitation. A scheme of a sludge center in shown in Figure 1.

To limit the negative impact of gas products of the ATAD process on the environment, they are treated before their release to the atmosphere. The waste gas treatment installation consists of a scrubber whose diameter is 1.0 m, height 3.35 m, and capacity 2.5 m³, with a treating module whose dimensions are 2.27×2.24×3.30 m. The devise was designed allowing for anticipated amount of ventilating air $Q = \text{app. } 3200 \text{ m}^3/\text{h}$. The treatment process involves rinsing out the soluble impuri-

ties in the water scrubber, and deodorization in the installation using photo oxidation and catalytic oxidation. Photo catalytic oxidation involves two-stage treatment of waste gases: first, with the use of UV lamps, then, by means of catalytic bed of active carbon (so-called catalytic converter).

METHODOLOGY, STUDY RESULTS AND DISCUSSION

The assessment of the ATAD process as used for sludge neutralization, which then can be naturally utilized, is based on the results of the study carried out outside the here-presented sewage-treatment plant in specialist laboratories. Sludge samples, collected in accordance with the required methodology, were subjected to microbiological and chemical tests. Those tests were carried out in the years 2010–2012. The results of microbiological tests are shown in Table 1.

Domestic sewage contains biological impurities such as bacteria, viruses, fungi, and parasitic worms, which may be dangerous to human and animal health. The following are isolated most frequently: *Escherichia coli*, *Shigella* spp., *Yersinia enterocolitica*, *Salmonella* spp., *Clostridium perfringens*, *Streptococcus faecalis*, *Leptospira* spp, *Mycobacterium tuberculosis*, *Shigella flexneri* [Budzińska et al. 2009]. The mechanical and biological processes of sewage treatment enable elimination of great amounts of microorganisms. However, they are not rendered harmless, but

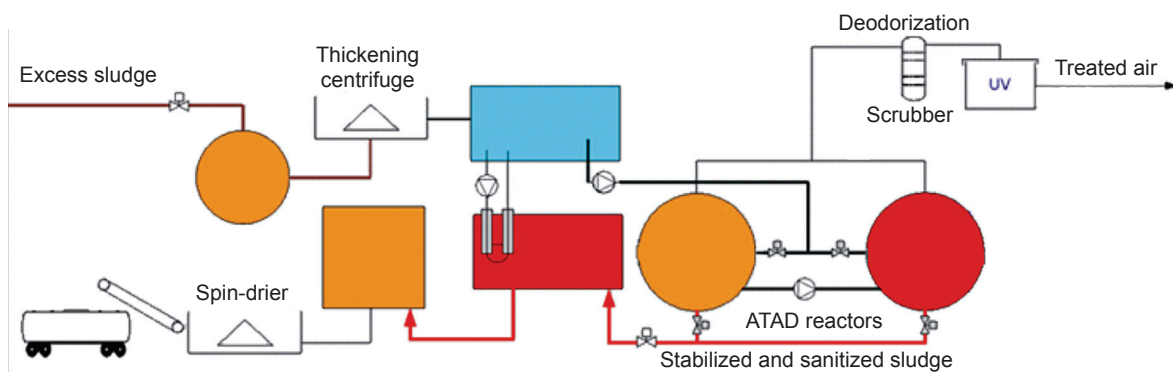


Fig. 1. Diagram of the examined sludge center of sewage-treatment plant

Table 1. Results of microbiological examinations of sludge after ATAD process

Tested parameter	Unit	Method of examination	Results
Bacteria of the <i>Salmonella</i> strain	in 100 g	PB/BB/7/D:01.05.2010	absent
Number of live eggs of intestinal parasites (<i>Ascaris</i> sp., <i>Trichuris</i> sp., <i>Toxocara</i> sp.)	pieces/kg dry-mass	PB/BB/5/C:01.05.2010	0
Bacteria of the <i>Enterobacteriaceae</i> family	jtk/1 g	PN-ISO 21528-2:2005	$3,2 \times 10^4$

Source: material from the plant.

transferred to the generated sludge. Although the majority of these microorganisms belong to physiological heterotrophic gastro intestinal flora in humans and animals, there are also pathogenic species. Municipal sludge may be used in agriculture and for reclamation of tilled land, if the *Salmonella* bacteria cannot be isolated from 100 g of examined sludge, and the total amount of live eggs of intestinal parasites such as *Askaris sp.*, *Trichuris sp.*, *Toxocara sp.* in 1 kg of dry mass equals zero [ACT 2010]. Repeated examinations of sludge which underwent the ATAD process did not confirm the presence of *Salmonella* bacteria, live eggs of intestinal parasites [ACT 2008]. In single cases bacteria of the *Enterobacteriaceae* family could be isolated. Large number of them is present in sludge together with other Gram-negative rods. Other tests also confirm their presence. Mean number of Gram-negative rods decreases when sludge is stored. Further studies demonstrated continual necrosis of these cells [Budzińska et al. 2009].

Considering the usability of sludge in agriculture, not only its hygienic sanitary safety is important, but also its composition. Table 2 lists the mean values of the chemical parameters in the studied sludge in the mentioned period.

The content of heavy metals in sludge did not exceed admissible values [ACT 2010]. In comparison to mean values, given in Table 2, this content was even multiple times lower. The content of zinc in dry mass of sludge was three times lower, the content of mercury was over

sixteen times lower, and the content of lead was even thirty times lower. The recorded amounts of heavy metals in the examined sludge did not exceed admissible values determined by regulations of fertilizers and fertilization [ACT 2008]. The content of nitrogen compounds and phosphorus compounds was greater than the minimum recommended for fertilizers values [ACT 2008]. The reaction of sludge after the ATAD process was alkaline [Nosrati et al. 2007; Parsons 2008; Piterina et al. 2010]. In Poland the proportion of acid and very acid soils to other soils is still very high and exceeds 50% of all profiles [Siebielec et al. 2012]. Because all soils are usually sour, alkaline reaction has a negative influence on them now.

SUMMATION

The autothermal thermophilic aerobic digestion of sludge is a process, which ensures its full sanitation and simultaneous effective stabilization. Full automation of the process enables generation of sludge which is free of bacteriological impurities being valuable manure which can be successfully returned to the natural circulation. The process is characterized by very stable biochemical reactions at short computation time of sludge storage. An additional advantage of the ATAD process is a significant reduction of the sludge amount produced by the sewage-treatment plant [Bartkowska 2011; Bartkowska, Dzienis 2009].

Table 2. Results of studies of the chemical composition of sludge after the ATAD process

Tested parameter	Unit	Test method	Results
Dry mass	%	PN-EN 12880:2004	24.4
Reaction	–	PN-EN 12176:2004	8.1
Organic substances	% d.m.	PN-EN 12879:2004	62.1
Kjeldahl's total nitrogen	% d.m.	PN-EN 13342:2002	5.28
Ammonia nitrogen	% d.m.	PB/FCH/15/A: 10.06.2008	1.73
Total phosphorus	% d.m.	PN-EN ISO 11885:09	3.8
Calcium	% d.m.	PN-EN 13657:2006	6.71
Magnesium	% d.m.	PN-EN 13657:2006	1.69
Zinc	mg/kg d.m.	PN-EN 13657:2006	790
Lead	mg/kg d.m.	PN-EN 13657:2006	21.7
Cadmium	mg/kg d.m.	PN-EN 13657:2006	0.952
Chrome	mg/kg d.m.	PN-EN 13657:2006	43.7
Copper	mg/kg d.m.	PN-EN 13657:2006	147
Nickel	mg/kg d.m.	PN-EN 13657:2006	19.0
Mercury	mg/kg d.m.	PB/II/11/B:01.05.2010	0.97

Source: materials from the plant.
d.m. = dry mass.

The results of the study yielded during the ATAD process, as well as rich experience stemming from the observations let us formulate these conclusions:

1. The ATAD process is a good manner of using sludge for fertilization. The generated sludge fulfills the conditions as required when used in agriculture. Full airtight sealing of reactors makes it impossible to secondarily infect the processed sludge.
2. Generation of stabilized and sanitized sludge in course of the ATAD process does not require, as for instance compost formation, the use of additional enriching materials. The properly insulated tanks ensure suitable process conditions no matter what the ambient temperature is.
3. Spontaneous generation of high temperatures enables the recovery of excessive heat and its utilization. Airtight sealing and the use of devices for neutralization of odor render the installation environmentally friendly.

Natural use of sludge appears to be its rational utilization, contributing to the improvement of the balance of organic matter in soils. However, the quality of sludge should be controlled, as sludge carried off to ground may act upon superficial and underground waters. Soils exploited in agriculture and fed with municipal sludge also must be examined periodically. Statement issued by National Veterinary Institute confirms the quality of tested sludge which then can be used as an agent to improve soil properties named "BIO-WOZ". This agent, systematically tested, attracts individual farmers' attention.

REFERENCES

1. Bartkowska I. 2005. Operation's initial period of the autothermal thermophilic sludge installation (ATAD) in Giżycko waste water treatment plant. *Pol. J. Natur. Sci.*, 18(1).
2. Bartkowska I. 2011. Ocena wybranych parametrów technologicznych procesu autotermicznej tlenowej stabilizacji osadów (ATSO) na przykładzie oczyszczalni ścieków w Lubaniu. *Inżynieria Ekologiczna*, 25: 7-19.
3. Bartkowska I., Dzienis L. 2009. Assessment of Operating Efficiency of Autoheated Thermophilic Aerobic Digestion (ATAD) In Two- and Three-Stage Configurations, *Polish Journal of Environmental Studies*, 6: 11-16.
4. Bartkowska I., Dzienis L., Augustin O. 2007. Odor purification in sewage management object with application of photocatalytic oxidation, *Polish Journal of Environmental Studies*, 16(2)A, Part III: 461-466.
5. Budzińska K., Jurek A., Michalska M., Berleć K., Szejniuk B. 2009. Dynamika zmian mikroflory bakteryjnej w składowanych osadach ściekowych. *Rocznik Ochrony Środowiska*, 11: 1155-1164.
6. Kelly H.G. 2006. Emerging processes in biosolids treatment. *J. Environ. Eng. Sci.*, 5: 175-186.
7. Layden N.M. 2007. An evaluation of autothermal thermophilic aerobic digestion (ATAD) of municipal sludge in Ireland. *J. Environ. Eng. Sci.*, 6: 19-29.
8. Nosrati M., Sreekrishnan T.R., Mukhopadhyay S.N. 2007. Energy Audit, Solids Reduction, and Pathogen Inactivation in Secondary Sludges during Batch Thermophilic Aerobic Digestion Process. *Journal of Environmental Engineering*, 133(5): 477-484.
9. Parsons B.G. 2008. Impacts of temperature and hydraulic retention time on odours produced from autothermal thermophilic aerobic digestion. A thesis submitted in partial fulfillment of the requirements for the degree of master of applied science in the faculty of graduate studies, The University of British Columbia.
10. Piterina A.V., Bartlett J., Pembroke T.J. 2010. Evaluation of the Removal of Indicator Bacteria from Domestic Sludge Processed by Autothermal Thermophilic Aerobic Digestion (ATAD). *Int. J. Environ. Res. Public Health*, 7(9): 3422-3441.
11. Rozporządzenie Ministra Rolnictwa i Rozwoju Wsi z dnia 18 czerwca 2008 r. w sprawie wykonania niektórych przepisów ustawy o nawozach i nawożeniu. *Dz. U.* 119, poz. 765, 2008.
12. Rozporządzenie Ministra Środowiska z dnia 13 lipca 2010 r. w sprawie komunalnych osadów ściekowych. *Dz.U.* 137, poz. 924, 2010.
13. Siebielec G., Smreczak B., Klimowicz-Pawalas A., Maliszewska-Kordybach B. 2012. Monitoring chemizmu gleb ornyc w Polsce w latach 2010-2012. Instytut Uprawy Nawożenia i Gleboznawstwa Państwowy Instytut Badawczy w Puławach.
14. Wersocki S., Hupka J. 2006. Autotermiczna higienizacja tlenowa osadów nadmiernych, *Inżynieria ekologiczna*, 14: 63-69.
15. Zhou J., Mavinic D.S., Kelly H.G., Ramey W.D. 2002. Dewaterability of thermophilically digested biosolids: effects of temperature and cellular polymeric substances. CSCE/ASCE-EWRI Environmental Engineering Conference, Niagara Falls, Canada.
16. Zupančič G.D., Roš M. 2008. Aerobic and two-stage anaerobic-aerobic sludge digestion with pure oxygen and air aeration. *Bioresource Technology*, 99: 100-109.