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TECHNICAL AND ECONOMIC ASPECTS OF AUTOTHERMAL THERMOPHILIC AEROBIC DIGESTION EXEMPLIFIED BY SEWAGE TREATMENT PLANT IN GIŻYCKO

The process of autothermal thermophilic aerobic digestion (ATAD) is evaluated as an effective method of sludge disposal. ATAD installation, which has been working since 2003 in wastewater treatment plant of Giżycko, is described. The results of sludge testing in the above mentioned object and technological experience which can be useful in dealing with problems of sludge economy in sewage treatment plants are presented.

1. INTRODUCTION

It is recommended that the process of autothermal thermophilic aerobic digestion (ATAD) be implemented in sewage treatment plants whose flow capacity is up to 20,000 m³/day. Such a process provides full digestion and disinfection of sludge by transforming it into biomass which can be used for natural purposes.

Biological sludge digestion consists in reduction of organic substances contained in sludge. In ATAD technology, the process is carried out by aerobic microorganisms. Aerobic energy transformation is exothermic. As a result of oxidizing organic substances by microorganisms energy, mainly in the form of heat, is released. The final products are simple compounds, e.g., H₂O and CO₂. Due to effective accumulation of heat, which is released during decomposition of organic compounds, the working temperature of the process is high (>50 °C), hence the decomposition is efficient and pathogens are eliminated. The process requires preliminary sludge thickening up to over 4% of dry mass. This allows us to obtain a higher unitary content of organic substances which should not be lower than 40.0 g/dm³, expressed by COD value.

As a result of providing a digester with an appropriate amount of oxygen, the temperature rises spontaneously to of 55–80 °C. In most treatment plants, the process

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temperature is kept on the level of 55–60 °C which permits the heat recovery. Reduced chamber dimensions (retention time of 6–8 days) allow the reduction in sludge dry mass up to at least 38% and protect the sludge from pathogens. The technology under discussion has been applied within a very wide range. ATAD installations are considered to be very useful both in municipal and industrial sewage treatment plants. They can also be applied in the case of modernizing existing sludge lines as a preliminary system, e.g., before conventional sludge digestion chambers [5].

In Poland, the first ATAD installation has been in operation since 2003 in Giżycko. It allows an effective neutralization of sludge which, fully hygienized and digested, is used for natural purposes [1].

The paper presents the results of sludge digestion in the above mentioned plant and technological experience which can be useful in dealing with the problems of the profitability of sewage treatment in plants.

2. SLUDGE DISPOSAL AND ATAD INSTALLATION IN GIŻYCKO

Within the frames of modernization that was carried out in 2003 in sewage treatment plant in Giżycko, wastewater disposal was totally changed. Excessive sludge is directed to a flow gravity thickener and then to a mechanical drum thickener. Being thickened up to 5% of dry mass, it is stored in a thickened sludge tank. Next, the sludge is in cycles (once a day) directed to ATAD reactors. After ATAD process it is transported, also in cycles, to the tank with hygienized sludge (storage time of approx. 20 days). Next the sludge is pumped into decantation centrifuges where is dehydrated. After dehydrating up to 25–28% of dry matter, the sludge is directed to sludge lagoons, where it is temporary stored, or used directly for agricultural purposes.

The ATAD line has been operated based on the following design parameters:

- average daily sludge mass, 5500 kg of dry matter/day;
- maximum daily sludge mass, 6600 kg/day;
- average ATAD installation output, up to 110 m³/day;
- preliminary sludge thickening, approx. 50 g/kg, i.e., ≈ 5% of dry matter;
- the content of organic substances in raw sludge, min. 70%;
- reduction of organic substances in sludge, 38% (in weight);
- temperature, reactor I°, 40–50 °C; reactor II°, 55–60 °C;
- organic substance load, 7.4 kg of dry sludge matter/m³ d (for 5500 kg of dry matter), 8.9 kg of dry sludge matter/m³ d (for 6600 kg of dry matter);

- aeration time, 23 hrs/day;
- oxygen demand (20 °C), 1.5 g O₂/1 h;
- sludge retention time (hydraulically). 7–9 days.

The specific process of digestion and hygienization takes place in four tanks connected in parallel and operating as two two-stage lines. Two reactors connected in series provide full pasteurization and disinfection of sludge in the second tank because the discharged sludge is not infected with fresh organisms present in the sludge charged to the first tank. ATAD installation connected in series enables the transport of sludge in portions from one chamber to another – after removing a portion of digested sludge. Daily discharge of neutralized sludge is possible only from the tank operating in the second stage.

After such a discharge is completed, green sludge is charged to the first tank, while partially processed sludge is moved to the second reactor. After being fed with sludge, reactors are isolated for 23 hours when thermophilic decomposition takes place [2]. Odours produced in ATAD tanks are removed to the atmosphere through a biofilter installation.

3. TECHNICAL AND ECONOMIC ASPECTS OF ATAD PROCESS

3.1. TEMPERATURE CONTROL

Temperature recording by installed sensors allows the process to be evaluated. In each reactor, there are two temperature sensors, one on 1.0 m level and the second on 2.0 m level, measured from the tank bottom (T11 and T12 sensors, the first stage of the process; T21 and T22 sensors, the second stage). The measurement is carried out every hour. Average sludge temperature in the first quarter of 2006 was approx. 23 °C for the first technological line and approx. 55 °C for the second one. Temperature changes in one of the technological lines from January to March are presented in figure 1.

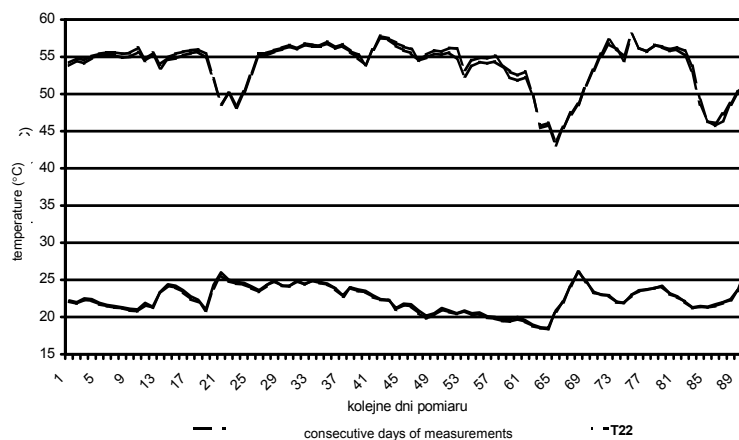


Fig. 1. Average daily changes of temperature in a chosen technological line

The values of temperature, reached in the first stage of the process, ranged from 18.4 °C to 26.5 °C. Lower temperature was caused by sludge charge which in winter is colder than in summer. Despite the above, in the second stage of the process, the temperature indispensable for a proper sludge hygienization was reached. It ranged from 43.1 °C to 58 °C. In both reactors, the differences in the impulses from both sensors are slight, which proves that chamber content is properly mixed. The differences were below one degree. The temperature changes in ATAD reactors are constantly monitored. When the temperature reaches 60 °C a cooling system is automatically engaged (heat exchanger) which protects the sludge temperature against uncontrolled increase. The exchanger enables heat recovery [3], [4].

3.2. CONTROLLING THE AMOUNT OF SLUDGE CHARGED TO ATAD INSTALLATION

In order to maintain an appropriate sludge temperature, its charge is controlled once a day. Average daily charge of sludge from January to March approached 86.3 m³/d. The volume of the sludge discharged in the second stage of the process was similar. The volumes of sludge delivered in the first stage of the process and discharged after the second stage of the process are presented in figure 2.

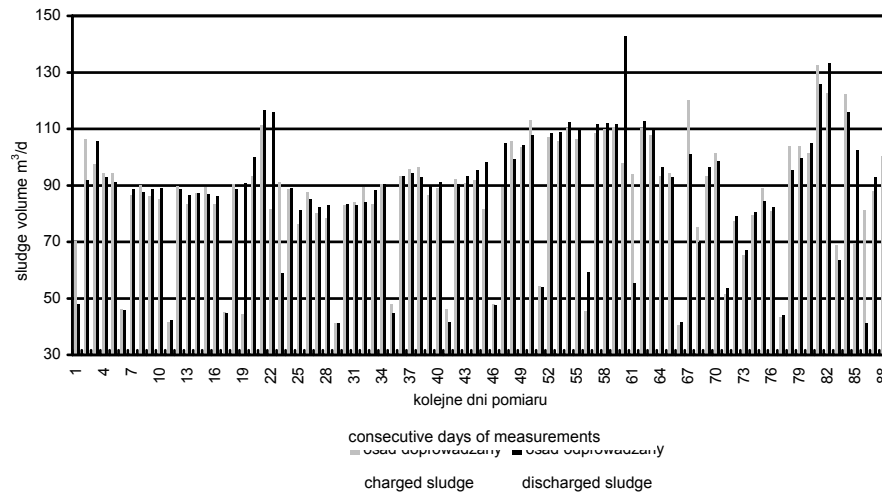


Fig. 2. Volume of charged and discharged sludge in a chosen technological line

In the first quarter of this year, the maximum and minimum volumes of a single sludge discharge from the second tank of one technological line amounted to 142.8 m³ and 41.0 m³, respectively. In the same period, the maximum portion of sludge charged to the first tank amounted to 132.6 m³, and minimum one – to 40.5 m³.

3.3. CONTROL OF PHYSICAL AND CHEMICAL PARAMETERS BEFORE AND AFTER ATAD PROCESS

Throughout the whole period of ATAD installation operation sludge is systematically examined in the sewage treatment plant laboratory. The content of dry matter, organic substance, total nitrogen, total phosphorus, calcium, and magnesium were determined. The content of heavy metals such as lead, cadmium, chromium, copper, nickel, mercury, and zinc was also determined.

The content of nitrogen, phosphorus, calcium or magnesium in sludge after ATAD process testifies to its usability for natural purposes. During the process their amount, in relation to green sludge, does not change. Cumulative sheet of examination results carried out in 2005 is presented in the table. Processes that take place prove that the nitrification process is correct. Percentage content of nitrogen in sludge dry matter only slightly decreases, but there is a visible decrease in organic nitrogen. Similarly,

Table

Cumulative sheet of examination results after ATAD

| Parameters determined | Results | | | |
|---|---------------|---------------|---------------|---------------|
| | 2005 | | | 2004 |
| | Minimum value | Maximum value | Average value | Average value |
| pH | 5.06 | 7.40 | 6.49 | 7.38 |
| Dry solids [%] | 18.98 | 23.26 | 21.19 | 27.00 |
| Volatile solids [%] | 63.2 | 68.8 | 65.37 | n.d. |
| Total nitrogen [% DS] including ammonia nitrogen [% DS] | 4.73 | 5.06 | 4.84 | 3.92 |
| | 0.44 | 0.51 | 0.47 | 0.66 |
| Total phosphorus [% DS] | 3.3 | 4.0 | 3.66 | 6.87 |
| Calcium and magnesium [% DS] | 4.6 | 5.81 | 5.39 | 8.18 |
| Lead [mg/kg DS] | 20.5 | 21.9 | 21.27 | 23.77 |
| Cadmium [mg/kg DS] | 1.54 | 2.45 | 1.99 | 1.70 |
| Chromium [mg/kg DS] | 18.4 | 20.0 | 19.10 | 24.37 |
| Copper [mg/kg DS] | 185.0 | 272.0 | 217.67 | 180.73 |
| Nickel [mg/kg DS] | 15.5 | 24.7 | 18.90 | 17.23 |
| Mercury [mg/kg DS] | 0.998 | 1.5008 | 1.19 | 1.67 |
| Zinc [mg/kg DS] | 810.0 | 1065.0 | 916.67 | 795.00 |

n.d. – analyzed parameter has not been detected.

the content of heavy metals does not change after digestion and hygienization. However, their content is a few times smaller (in the case of cadmium, copper, nickel, mercury or zinc) or even over twenty times smaller (in the case of lead and chromium) than their permissible content in sludge for agricultural use. As a result of the process there is a clear decrease in total content of organic compounds and their relative content can vary slightly because of simultaneous loss in dry matter. Due to ATAD process the content of organic substances decreases, on average, from 5 to 25% of sludge dry matter, and COD_{Cr} decreases by 25–35%.

3.4. CONTROL OF MICROBIOLOGICAL AND PARASITOLOGICAL PARAMETERS

Microbiological examinations of green sludge confirmed the presence of microflora and microfauna typical of activated sludge. There were rotifers (*Monostyla pyriformis*, *Monostyla* sp., *Rotaria rotatoria*, *Cephalodella gracilis*), settled ciliates (*Vorticella* sp.) – sporadically; floating ciliates (*Trachelophyllum pusillum*, *Prorodon teres*) – quite numerous; crawling ciliates (*Aspidisca costata*) – sporadically; amoebae (*Amoeba proteus*) – numerous; rhizopods (*Arcella vulgaris*, *Euglypha tuberculota*); flagellata (mostly *Bodo*) – extremely numerous; and dispersed bacteria of different kinds (bacilli, *Sarcina*, spiral) – on a mass scale. However, sludge examination after ATAD process revealed the lack of organisms typical of activated sludge. There were observed only empty scuta of *Euglypha*, *Arcella*, *Monostyla* organisms. The dominating form were dispersed bacteria of various kinds. There were neither *Salmonella* bacilli

nor living eggs of such intestine parasites as *Ascaris* sp., *Trichuris* sp. and *Toxocara* sp [1].

Sample microscopic photographs of sludge before and after ATAD are presented in figure 3.

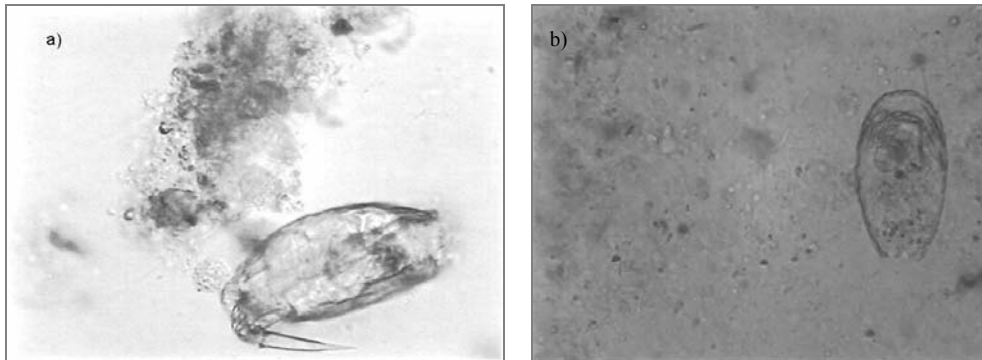
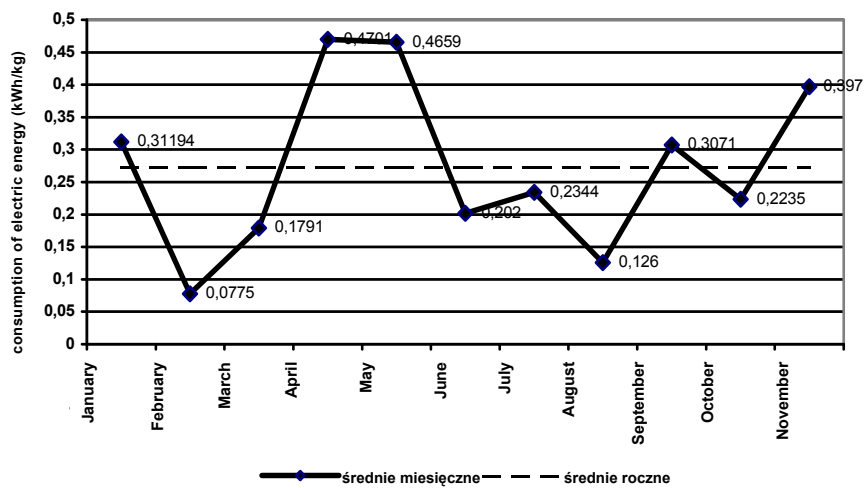


Fig. 3. Microorganisms of activated sludge before ATAD process (a), after ATAD process (b)

3.5. CONTROL OF ELECTRIC ENERGY CONSUMPTION IN ATAD INSTALLATION

ATAD installation in sewage treatment plant in Giżycko has separate measuring devices enabling us to record the consumption of electric energy necessary for sludge digestion and hygienization. Electric energy consumption for 1 kg of dehydrated sludge is presented in figure 4. The diagram shows the lack of the relationship between sludge temperature and the season.



monthly averages yearly averages

Fig. 4. Electric energy used for producing 1 kg of dehydrated sludge in 2005

Data concerning electric energy consumption allowed us to describe the following general indices:

- power demand index, 0.02 kW/kg of dry matter,
- electric energy consumption index, 0.5 kWh/kg of dry matter,
- electric energy consumption cost index, 0.10 PLN/ kg of dry matter.

4. CONCLUSION

Autothermal thermophilic aerobic digestion is the process which provides full hygienization and, simultaneously, effective digestion of sludge. Due to a full automation of the process the sludge obtained is devoid of pathogenic bacteria and as a valuable fertilizer can easily be returned to natural circulation. The process is characterized by very stable biochemical reactions and quick computation of the sludge storage time. The installation requires little space, which decreases the cost of investment.

Two-year examination conducted on a real object allows the following conclusion to be formulated:

1. ATAD process is a good way of adjusting sludge to fertilizing. It does not require, as e.g. composting, any additional enriching materials. The space occupied by the installation is little. Full air-tight sealing of tanks and the use of gas purification devices make the installation environmentally friendly.
2. The process is controlled based on two basic indexes: sludge temperature and volume of its daily charge.
3. Economic indices that have been received during operation so far clearly show the competitiveness of ATAD method while comparing it with other ways of sludge disposal in the aspect of electric energy consumption costs (0.10 PLN/kg of dry mass in the case of ATAD against 0.50 PLN/kg of dry mass in the case of liming method, and 1.0 PLN/kg of dry matter in the case of sludge drying).

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ASPEKTY TECHNICZNO-EKONOMICZNE PROCESU AUTOTERMICZNEJ
TLENOWEJ STABILIZACJI OSADÓW ŚCIEKOWYCH
NA PRZYKŁADZIE OCZYSZCZALNI ŚCIEKÓW W GIŻYCKU

Oceniono przebieg procesu autotermicznej tlenowej stabilizacji osadów ściekowych (ATSO) jako metody skutecznego ich unieszkodliwiania. Zaprezentowano instalację ATSO pracującą od września 2003 r. w oczyszczalni ścieków komunalnych w Giżycku. Przedstawiono wyniki kontroli parametrów eksploatacyjnych instalacji ATSO takich jak: temperatura osadu, ilość osadu doprowadzanego, wskaźniki fizykochemiczne, mikrobiologiczne i parazytologiczne oraz wskaźniki zużycia energii elektrycznej. Uwagi i wnioski, wynikające z własnych doświadczeń, dotyczyły przydatności omawianego procesu do unieszkodliwiania osadów ściekowych.