Proceedings of ECOpole
Vol. 5, No. 2 2011

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EFFECT OF STORAGE TIME OF WASTEWATER SLUDGE ON ITS MOISTURE CONTENT, CALORIFIC VALUE AND CONTENT OF AGGRESSIVE SUBSTANCES

WPŁYW CZASU SKŁADOWANIA OSADÓW ŚCIEKOWYCH NA ICH WILGOTNOŚĆ, WARTOŚĆ OPAŁOWĄ ORAZ ZAWARTOŚĆ SUBSTANCJI AGRESYWNYCH

Abstract: The problem of the issue which still remains unresolved in many countries - including Poland - related to the management of wastewater sludge derived from municipal wastewater treatment plants was outlined. Later the possibility of solving the problem of the growing amount of generated sludge with the application of, *inter alia*, thermal methods is discussed and the origin of the research presented in the paper is explained. The paper presents results of research conducted on two samples of sludge stored for the period of 5 months each in conditions similar to natural ones. In the research the stabilized by anaerobic fermentation processes and dehydrated wastewater sludge was used. Sludge originated from large municipal wastewater treatment plants. From among a large number of parameters set during the research, the paper focuses on the presentation of the results regarding: moisture content, calorific value as well as phosphate and nitrate contents. Data obtained in the presented research demonstrates the presence of continuous processes taking place in the stabilized, stored sludge, which significantly affect its fuel properties.

Keywords: wastewater sludge fuel properties, calorific value, moisture content, sludge storage

As a result of wastewater treatment by wastewater treatment plants the substance known as wastewater sludge is formed. The amount and composition of the formed sludge depend on a significant number of factors, however, mainly on the parameters of wastewater treatment plants and their treatment technologies (technological solutions of wastewater treatment).

In case of biological municipal wastewater treatment plants, the quantity of formed sludge before it is subject to stabilization processes may be estimated to 60÷80 g of sludge dry matter per resident a day [1]. The value of this index usually increases, *inter alia*, with the level of social wealth and the size of the serviced agglomeration.

The popularization of wastewater treatment results in the problem of the formation of ever larger amounts of sludge. In 2008 in Poland there was the total of 567.3 thousand Mg of sludge dry matter produced in municipal treatment plants. In the next few years, further increase of quantity of the generated sludge should be expected, among others in relation to the application of the significant part of UE funds for investments within the scope of the sewage system development as well as the construction and expansion of wastewater treatment plants. In the "National Waste Management Plan 2010" it is predicted that in 2018 there will be over 706 000 Mg of sludge dry matter produced [2].

It can be estimated that the theoretical amount of sludge which needs to be removed in Poland, with the assumption that 90% of the Polish population is serviced by biological wastewater treatment plants, is about 900 000 Mg of dry matter. It should be also noted that

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the sludge generated is mostly characterised by moisture content at the level of over 75%. Thus, the quantity of substance which needs to be neutralised amounts to over 4,000,000 Mg.

The average flow capacity of Polish municipal wastewater treatment plants classifies them as small treatment plants since in 2008 it amounted to about 1.5 thousand m^3/day (over 77% had flow capacity lower than 1000 m^3/day) [2]. It should be expected that along with the growing popularity of wastewater treatment, the average daily flow capacity of plants will continue to decrease.

In highly developed countries thermal methods belong to one of the basic ways of wastewater sludge neutralisation. Thus, eg in 2006 in Switzerland thermal methods were used to process as much as 90% of sludge (by volume), in the Netherlands almost 70%, in Germany nearly 50% (own calculations based on [2]).

In Poland thermal methods have been used to manage only very little amount of sludge. Since the second half of the 1990s, there has been operating a plant of sludge thermal utilization in Poland, located on the premises of the Joint Wastewater Treatment Plant in Gdynia-Debogorze. According to [2], in the years 2000-2008 only 1.5÷2% of produced sludge dry matter (1.7÷6.2 Mg/year of sludge dry matter) were managed by means of thermal methods.

In the "National Waste Management Plan 2010" [3] it was predicted that in 2018 over 50% of produced sludge would be subject to thermal transformation. Despite the projects of sludge wastewater incineration plant construction which are currently carried out and prepared for execution, the implementation of this objective appears to be very unlikely. The achievement of the intended goal would be possible in case of the implementation of the co-combustion process of sludge wastewater with coals in the existing facilities of the power system. One of the countries with exceptionally rich experience in co-combustion of sludge is Germany, where ten-odd percent of the produced sludge is neutralized in the result of co-combustion. In Poland, in the industrial facilities there were de facto only tests for the sludge co-combustion process conducted. There is no information on the officially implemented sludge co-combustion processes on the industrial scale.

A reason supporting the implementation of co-combustion processes in Poland is the fact that hard coal is still the basic fuel here and its share in the structure of covering the demand for primary energy will continue to be significant - at least until 2030 [4]. Moreover, across the country there is a large number of coal-fired power boilers with relatively small capacity - up to ten-odd MW. Such capacity is completely sufficient for the utilization of wastewater sludge derived even from 90% of the national wastewater treatment plants. Additionally, these boilers are relatively equally distributed across Poland. An argument against the implementation of the discussed solution in Poland is the technical condition of boilers, the fact that the overwhelming majority of low and medium capacity boilers do not possess the flue-gas purification equipment other than the dust extraction equipment.

Origin of testing

One of the most important issues during the implementation of the co-combustion process of sludge with coal is the stability of their properties. There is a considerable

number of parameters determining sludge properties. The basic ones, significant in case of submitting wastewater sludge to neutralization by means of thermal methods, include: moisture content, calorific value, elemental composition, fraction of combustible and volatile matter, chlorine and fluorine content, characteristic ash softening points, heavy metal content.

Sludge properties depend on a number of factors, and above all, on the properties of wastewater and applied technologies of their treatment. Types of sludge from individual wastewater treatment plants differ significantly between one another. Even sludges produced in the same wastewater treatment plant in different periods of time demonstrate quite significant differences.

In case of using thermal methods of sludge neutralization, many a time there is the necessity of medium or long term storage of the produced sludge. For conducting the sludge co-combustion process in boiler plants of medium and low capacities, this necessity may result, *inter alia*, from the fact of storing the sludge, eg in summertime, when these plants do not operate or operate with significantly limited capacities. Whereas in case of sludge co-combustion in the plants designed solely for this process, this necessity is the result of the periodic plant stoppages (eg due to overhauls or modernisations).

Current observations performed among others at the JWTP Debogorze, allow to conclude that there is significant influence of the storage time of wastewater sludge on the progress of its combustion.

Testing methodology

Further in this paper, test results of two batches of sludge derived from two different wastewater treatment plants are presented.

The following sludge was used for testing:

- Sludge I - sludge from a large municipal biological wastewater plant with the capacity of approx. 60,000 m^3/day - sludge after the anaerobic fermentation process.
- Sludge II - sludge from a municipal industrial wastewater plant (located near a paper plant) with the capacity of approx. 1500 m^3/day of industrial sludge and 1000 m^3/day of municipal sludge - sludge after the anaerobic fermentation process.

Within the framework of presented tests, sludge provided from the treatment plant was placed in containers made for this purpose. During testing, the conditions of sludge storing in a pile were simulated. For this purpose, the containers were opened at the top and exposed to the atmospheric conditions. Sludge subject to testing was stored in layers of about 1 m thick. Within the framework of presented tests, samples for the conducted measurements were taken from the depth of about 80 cm - measured from the surface of the stored sludge.

Samples were taken at monthly intervals for the period of 4 months. Altogether, there were five samples taken - at the beginning of the period and in the subsequent 4 months. In the figures in the further part of the study, these samples were marked with subsequent numbers from 1 to 5.

Within the framework of conducted tests, ten-odd parameters were determined, including: gross calorific value, moisture content, fraction of combustible and volatile

matter, elemental composition, aggressive substance content. Further in the paper only the results of the following analyses are presented:

- moisture content (according to the PN-80/G-04511 standard [5]);
- calorific value (established based on the determination of gross calorific value according to the PN-ISO 1928:2002 standard [6]).

Moreover, the results of determining the content of aggressive compounds marked as nitrogen dioxide and orthophosphates are indicated.

The study refers to test results obtained within the execution of works [7, 8].

Obtained test results underwent statistical and substantial analysis. It should be stated here that in case of each sample taken from laboratory stands, at least three repetitions of each measurement were performed. Based on these repetitions the values of standard deviations and relative errors were determined. Obtained average values were used to determine a trend line in the form of a straight line. Such adoption of the trend line was the result of a relatively small number of measurement points and lack of basis for the adoption of a trend line in a different form. Further on, the assessment of the existing correlation between the tested parameters and time was made (a linear regression coefficient was compared with the critical regression coefficient for the significance level 0.05 and amounting to $R_{kr} = 0.878$).

Test results

Figure 1 presents the results of moisture content measurement for tested sludge. Apart from the moisture content changes at the depth of 80 cm, this figure shows also moisture content changes of analysed sludge in the upper part of the pile (at the depth of about 15 cm).

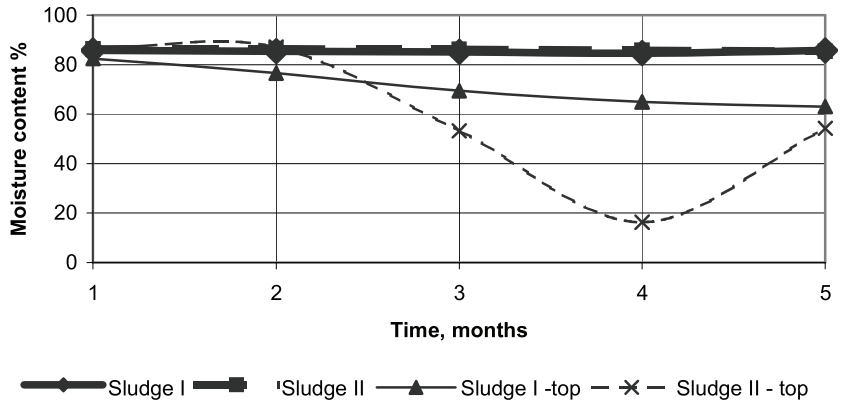

Fig. 1. Moisture content changes of the stored sludge (in upper and lower layers)

As Figure 1 shows, in case of samples taken from the depth of approx. 80 cm, for both analysed types of sludge there were practically no changes in their moisture content discovered. In case of both analysed types of sludge, the moisture content amounted to approx. 85% for the entire period of time. At the same time, in case of the upper layer of

the sludge, significant moisture content changes could be observed. These changes were caused by the influence of atmospheric conditions. Significant differences in moisture content changes between the samples Sludge I - top and Sludge II top, were caused, among others, by the fact of conducting tests on different dates.

Figure 2 presents changes of calorific values of tested sludge types (calculated for dry matter).

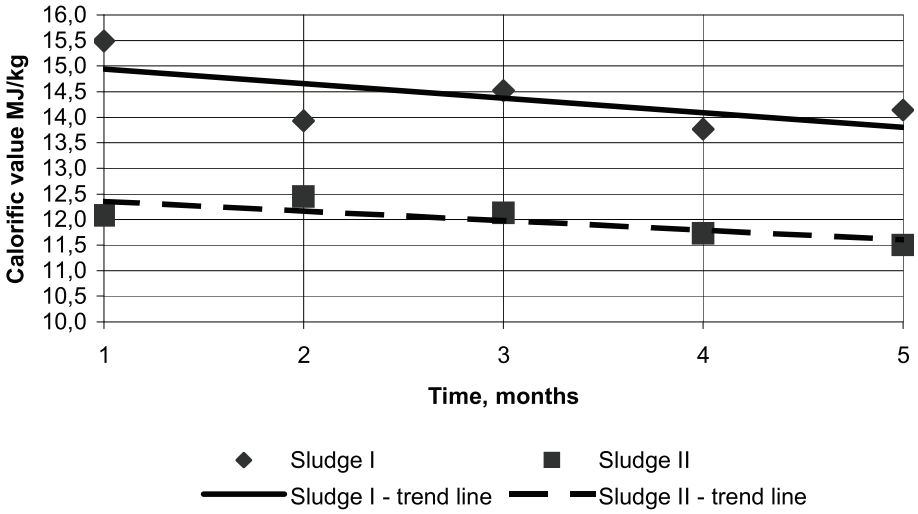

Fig. 2. Changes of calorific value of sludge dry matter

As Figure 2 shows, a falling tendency of the sludge calorific values in time for the presented tests can be observed. At the same time, in case of the first sample the tendency has clearer character. It should also be noted that according to the accepted criteria for both samples no statistical correlation between the sludge storage time and the tested parameter was demonstrated.

Calorific value in case of:

- "Sludge I" varied from 13.8 MJ/kg (fourth measurement) to 15.5 MJ/kg (first measurement);
- "Sludge II" varied from 11.5 MJ/kg (fifth measurement) to 12.5 MJ/kg (second measurement).

Conclusions

As the first part of the study shows, wastewater sludge management continues to be a significant problem in Poland. This problem could be solved *inter alia* by a broad application of the thermal method of sludge utilization. Thermal methods are currently commonly applied in a number of highly developed countries. A method which could be more broadly used in Poland is the co-combustion of wastewater sludge with coal, eg in the existing power facilities.

One of the issues related to thermal methods of sludge utilisation is the change of sludge fuel parameters during storage (induced eg by a periodical change of power facility capacity or a stoppage in the operation of sludge incineration plant). The second part of this study is devoted to the presentation of a small section of the conducted tests on this issue.

Conducted tests prove that the properties of stored sludge may be significantly different along the height of the pile vertical section. Sludge parameters in the upper layer are subject to considerable changes caused by the influence of atmospheric conditions. In the lower layer, the same parameters are not subject to change or their changes are relatively slow. The above relationship was characterized on the example of sludge moisture content changes.

During conducted tests it was also discovered that there is a falling tendency of calorific values in the lower layers of stored sludge. However, eg in case of nitrogen dioxide a growing tendency was discovered. In case of orthophosphates in "Sludge I" a growing tendency was found and in "Sludge II" a falling one.

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Abstrakt: Przedstawiono wciąż nierozwiązane w szeregu krajów - w tym w Polsce - zagadnienia zagospodarowania osadów ściekowych pochodzących z komunalnych oczyszczalni ścieków. W dalszej części omówiono możliwość rozwiązania problemu narastającej masy wytwarzanych osadów ściekowych przy wykorzystaniu m.in. metod termicznych oraz wyjaśniono genezę badań prezentowanych w pracy. Przedstawiono wyniki badań przeprowadzanych dla dwóch próbek osadów składowanych każdorazowo przez okres 5 miesięcy w warunkach zbliżonych do naturalnych. W badaniach wykorzystano ustabilizowane w procesach fermentacji beztlenowej i odwodnione osady ściekowe. Osady pochodziły z dużych komunalnych oczyszczalni ścieków. Spośród dużej liczby oznaczanych w trakcie badań parametrów skupiono się na prezentacji wyników dotyczących: wilgotności, wartości opałowej oraz zawartości fosforanów i azotanów. Uzyskane wyniki badań wskazują na procesy wciąż zachodzące w ustabilizowanych, składowanych osadach, istotnie wpływające na ich właściwości paliwowe.

Słowa kluczowe: osady ściekowe, właściwości paliwowe, wartość opałowa, wilgotność, składowanie osadów