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FUNCTIONAL RELATIONSHIPS BETWEEN SELECTED FUEL PARAMETERS OF SEWAGE SLUDGE AND THE TIME OF ITS STORAGE

ZALEŻNOŚCI FUNKCYJNE POMIĘDZY WYBRANYMI PARAMETRAMI PALIWOWYMI OSADÓW ŚCIEKOWYCH A CZASEM ICH SKŁADOWANIA

Abstract: Sewage sludge is waste whose disposal causes a number of problems in many countries (including even highly developed ones). The paper presents the genesis, methodology and results of conducted tests. The study presents results of research conducted for 4 samples of sludge stored for the period of 3 months each in a pile, in conditions similar to natural ones (eg exposed to the atmospheric conditions). The paper discusses test results of sludge samples derived from various depths of their location in the pile. In the research the stabilized by anaerobic fermentation processes and dehydrated wastewater sludge was used, which was derived from large, municipal wastewater treatment plants. The paper focuses on the results pertaining to the sludge fuel parameters, including combustible and volatile matter, calorific value, elemental composition.

Keywords: sewage sludge, fuel properties, experimental research, changes in time

Sewage sludge from municipal sewage treatment plants is one of the major problems of waste management. This waste is troublesome in management due to a number of its properties. The major of them include, inter alia: a large volume of its production and its moisture content. For example, in the second half of the first decade of the 21st century, there were from 900 000 to over 1 100 000 Mg of sludge dry matter generated annually in Poland (in that period there were 2 050 000 Mg of sludge dry matter generated in Germany, 1 770 000 Mg in Great Britain, approx. 1 060 000 Mg of sludge dry matter in Spain, France and Italy) [1]. At the same time, most frequently, the moisture of sewage sludge at the treatment plant outlet ranged from 70÷85%. Thus, the actual weight of the waste that needs to be managed is several times larger than the specified quantities of dry matter.

Another property of the sludge, contributing to the fact that its neutralisation is troublesome, is its content of heavy metals and pathogens. Heavy metals content is significant particularly in the sludge derived from large urban agglomerations.

Therefore, for a number of years we can observe an increasing importance of thermal methods in the treatment of sewage sludge in highly-developed countries. In Poland, however, until 2008 there was de facto only one technologically advanced thermal treatment plant of sewage sludge management. It was the fluidized-bed incineration plant, put into operation in 1998 in Gdynia-Debogorze. Until 2008 a series of studies on the sludge co-combustion process in grate furnaces were undertaken, and even for some time such process was conducted, on a small scale, in one of the sewage treatment plants.

The sludge co-combustion in cement kilns may be also considered a modern method of thermal sludge treatment, which has been used in Poland already for a long time. However, this method started to be widely used after 2005.

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In recent years in Poland, thermal methods of sludge treatment in plants constructed only for this purpose have been developed intensely. After 2008, plants in the following cities were built or are still under construction: Lomza, Olsztyn, Bydgoszcz, Gdansk, Kielce, Krakow, Lodz, Warszawa, Zielona Gora.

Moreover, several sludge drying plants operate in Poland. Sludge from such plants is used for firing cement kilns.

The main advantages of thermal processes include:

- waste weight reduction (for dry sludge - 55÷70%, for wet sludge - over 90%);
- complete neutralisation of the sludge in terms of biological threats;
- possibility to dispose of large quantities of waste.

The disadvantages of sewage sludge combustion in plants dedicated exclusively for that purpose include:

- the necessity to incur high capital expenditures;
- the necessity to incur high operating costs;
- the necessity to manage the solid, post-process residue.

The sludge co-combustion processes in power and cement plants are free from the above defects. In these processes the already existing plants are used and the post-process residue is built in the material that leaves the process (cement kilns) or managed along with the residue after the combustion of coal (due to the negligible sludge content it does not have a substantial effect on the properties of slag and ashes).

However, both for the co-combustion and independent combustion, an important problem affecting the operating costs are fuel parameters of the sludge, and in particular, its moisture content. Furthermore, due to temporary outages and seasonality of the implementation of certain processes in the power industry (heating season), as well as the distance from the potential sources of sewage sludge generation and plants for its thermal treatment, the necessity of periodic sludge storage may arise.

Further in the paper, changes in the basic properties of sludge occurring during a 3-month storage in the autumn and winter period (October - January) are presented.

Testing methodology

This paper presents the results of testing conducted on four samples of sewage sludge from a large municipal sewage treatment plant (with capacity above 30 000 m^3/day). The sewage treatment plant was a mechanical biological treatment plant. In the plant, sewage sludge was subject to anaerobic fermentation and mechanical dewatering processes.

Under testing, batches of sludge with a volume of over 2 m^3 were taken and placed in two special containers with a capacity of over 1 m^3 each. During testing, the conditions of sludge storing in natural conditions - storing in a pile - were simulated. Thus, the containers were open at the top and exposed to the atmospheric conditions. Sides of the containers were insulated and the bottom of the container enabled the leachate drainage. Sludge subject to testing was stored in layers with thickness of about 1.2 m. As part of testing, from the sludge stored in such manner samples were taken for analytical determinations. Samples were taken from the depth of approx. 1 m (hereinafter "Sludge bottom") and 0.20 m ("Sludge top II") - measured from the surface layer of the stored sludge. The atmospheric conditions in the presented tests were found to be disturbing factors.

The aim of testing the sludge derived from one source but stored separately was to determine the scatter of results arising from the fact of the natural, various dynamics of phenomena occurring in the stored material in similar conditions.

Samples for analytical determinations were taken at the beginning of the sludge storing process and then they were taken at two-week intervals for the period of 12 weeks. Altogether, the article presents the results concerning seven dates of sample taking (at present, tests are still in progress).

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 the results of the following analyses are presented:

- determination of volatile matter content (determination made by gravimetric method, according to PN-G-04516:1998 [2]),
- carbon and hydrogen content (determination made by Sheffield's method, according to PN-C-04301:1987 [3]).

It should be noted that all values presented further in the paper (eg on graphs) are average values obtained based on the threefold repetition of each determination. Average values obtained in this manner were used (in different configurations) for the analyses of correlation between the lapse of time and tested parameters. Determined Pearson's linear correlation coefficients were compared with critical values of the correlation coefficient for the significance level of 0.05 (amounting for 5 degrees of freedom to $r_{kr} = 0.7545$).

As part of the presented tests, tested parameters were analysed calculated to dry matter.

Test results

As mentioned above, testing concerned the determination of the properties of several parameters. Below exemplary results for two of them are presented.

Figure 1 shows the observed changes in the volatile matter share, occurring in the top layers of the stored sludge. Figure 2, on the other hand, presents similar results for the bottom layers of the sludge.

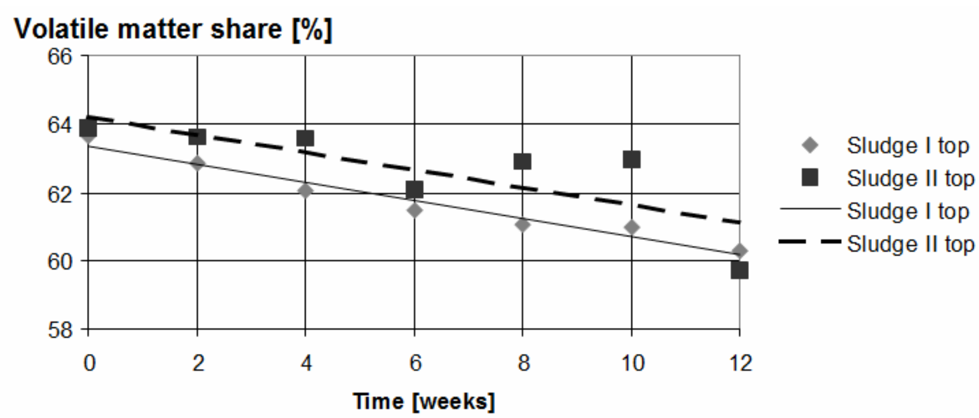

Fig. 1. Changes in time of volatile matter share in sludge derived from top layers

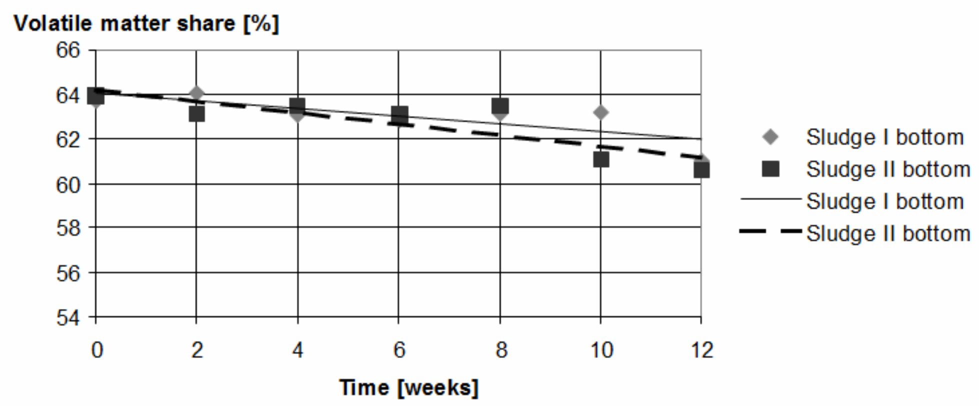

Fig. 2. Changes in time of volatile matter share in sludge derived from bottom layers

As illustrated in the charts, in all cases, the determined trend line indicates a decreasing volatile matter share in time, and in case of sludge derived from the top layers, the declines are larger, approx. 3.5÷4% (in sludge from bottom layers the declines amount to approx. 2.5÷3%).

The determined linear correlation coefficients are as follows:

- Sludge I top, $r = 0.977$;
- Sludge II top, $r = 0.777$;
- Sludge I bottom, $r = 0.777$;
- Sludge II bottom, $r = 0.837$.

Thus, in the case of the parameter in question, the correlation was found in sludge derived from all analysed points of their collection from containers.

The scatter of results between volatile matter shares derived from similar collection points ranged from 0.23 to 2.12%. The average difference between values obtained for sludge derived from two containers, from analogous collection points (at the same time) amounted to:

- at the top - 1.08%,
- at the bottom - 0.67%.

At the same time, the average standard deviations were as follows:

- at the top - 0.26%,
- at the bottom - 0.27%.

Thus, the obtained mean differences are as much as 4.15 times larger at the top and 2.50 times larger at the bottom than the average standard deviation.

The regression line equations for the obtained results took the following form:

- Sludge I top, $y = -0.266x + 63.372$;
- Sludge II top, $y = -0.260x + 64.245$;
- Sludge I bottom, $y = -0.172x + 64.024$;
- Sludge II bottom, $y = -0.253x + 64.192$.

Figure 3 shows the observed changes in carbon element content, occurring in the top layer of stored sludge samples. Figure 4, on the other hand, presents similar results for the bottom layers of the sludge. These figures present also trend lines for each analysed sludge.

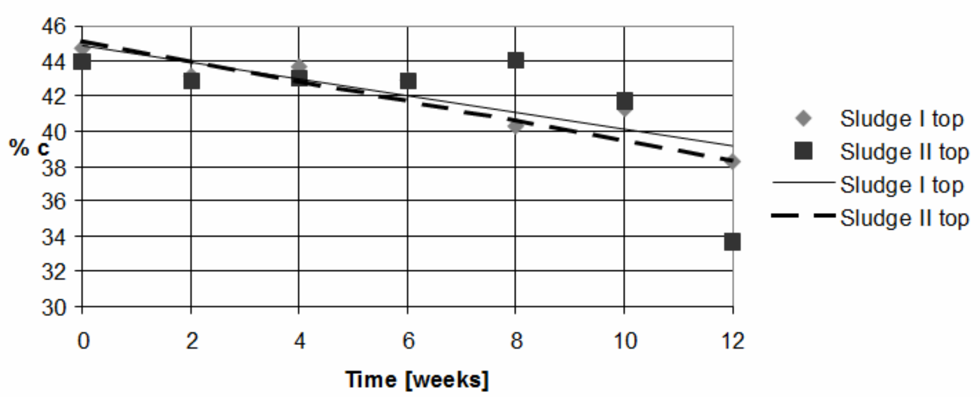

Fig. 3. Changes in time of carbon share in sludge derived from the top layer

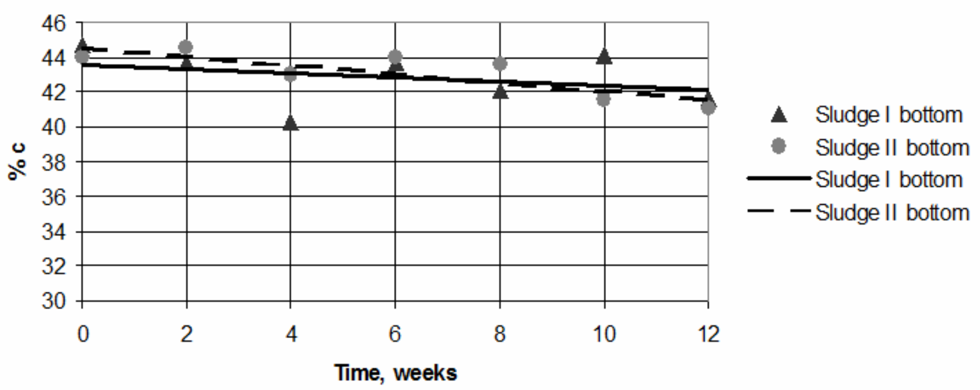

Fig. 4. Changes in time of carbon share in sludge derived from the bottom layer

As illustrated in the charts, in all cases, the determined trend line indicates a decreasing carbon share in time. And changes are more dynamic in the case of samples derived from the top sludge layers. In the top layers the declines of about 3÷5% and in bottom - of 2.5÷3% were observed.

The determined linear correlation coefficients are as follows:

- Sludge I top, $r = 0.919$;
- Sludge II top, $r = 0.679$;
- Sludge I bottom, $r = 0.317$;
- Sludge II bottom, $r = 0.822$.

Thus, a correlation can be found only in two cases: "Sludge I top" and "Sludge II bottom".

The difference between carbon shares derived from similar collection points in both containers (at the same time) ranged from 0.07 to 4.55%. With the largest differences occurring in the case of determinations characterised by the largest standard deviations.

The average difference between values obtained for sludge derived from two containers amounted to:

- at the top - 1.52%,
- at the bottom - 1.33%.

At the same time, the average standard deviations for sludge stored in two containers were as follows:

- at the top - 1.64%,
- at the bottom - 0.64%.

Thus, the obtained mean differences are smaller at the top than the average standard deviation and at the bottom they are 2.1 times larger.

The regression line equations for the results obtained in the case of measurement series allowing to find a correlation, took the following form:

- Sludge I top, $y = -0.476x + 44.906$;
- Sludge II bottom, $y = -0.25x + 44.600$.

Conclusions

Sewage sludge is still a major problem of waste management in Poland and around the world. Although in recent years a few large plants for the thermal sludge treatment were established in Poland, still on a large part of the territory of our country sewage sludge management is solved in a provisional manner, at most. Much of the sludge, before being subject to the final treatment, is stored for a certain period of time. Hence, it becomes important to know the processes of changes occurring in the stored sludge.

During the tests presented in the article, it was found that in the 3-month period, in the sludge subject previously to biological stabilization processes, processes resulting in the decrease in volatile matter share of 3.5÷4% and the decrease in carbon share of 2÷5% occur. Moreover, it was found that in the top layer of the stored sludge, processes progress in a more dynamic manner (observed declines in analysed shares are larger).

When comparing the sludge stored separately, the obtained differences between similar measurements - except for one case - were significantly higher than the average standard deviations.

In case of finding a correlation between the tested values and the time of storage, regression line equations are presented in the article.

Acknowledgements

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[2] PN-G-04516:1998 Paliwa stałe. Oznaczanie zawartości części lotnych metoda wagowa.
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ZALEŻNOŚCI FUNKCYJNE POMIĘDZY WYBRANYMI PARAMETRAMI PALIWOWYMI OSADÓW ŚCIEKOWYCH A CZASEM ICH SKŁADOWANIA

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Abstrakt: Osady ściekowe stanowią odpad, którego unieszkodliwienie nastręcza szereg problemów w wielu krajach (w tym nawet w państwach wysokorozwiniętych). W pracy przedstawiono genezę, metodykę oraz wyniki przeprowadzonych badań. Zaprezentowano także wyniki badań przeprowadzanych dla 4 próbek osadów składowanych każdorazowo przez okres 3 miesięcy w pryzmie w warunkach zbliżonych do naturalnych (m.in. narażonych na wpływ czynników atmosferycznych). Omówiono również wyniki badań próbek osadów pochodzących z różnych głębokości ich położenia w pryzmie. W badaniach wykorzystano ustabilizowane w procesach fermentacji beztlenowej i odwodnione osady ściekowe pochodzące z dużych komunalnych oczyszczalni ścieków. Skupiono się na wynikach dotyczących parametrów paliwowych osadów, m.in.: wilgotności, części palnych i lotnych, wartości opałowej, składu pierwiastkowego.

Słowa kluczowe: osady ściekowe, właściwości paliwowe, badania eksperymentalne, zmiany w czasie