DOI: 10.2429/proc.2016.10(1)044 2016;10(2)

Michał KOZIOŁ[1]

CHANGE IN SELECTED PROPERTIES OF SEWAGE SLUDGE IN MEDIUM-TERM WASTE STORAGE

ZMIANA WYBRANYCH WŁAŚCIWOŚCI OSADÓW ŚCIEKOWYCH W TRAKCIE SKŁADOWANIA ŚREDNIOOKRESOWEGO

Abstract: In recent years, a number of relatively large installations for thermal disposal of sewage sludge was built. Despite that fact, its management is still the unsolved problem for large area of the country. One of the phenomena caused, inter alia, by still underdeveloped sewage sludge management is the need of its temporary storage. Such storage occurs, for example when there is no possibility of current management of sewage sludge produced by the wastewater treatment plant. The introduction of the paper briefly outlines the issues of sewage sludge management in Poland and the genesis of the research. In the following parts, the paper focuses on the methodology of the study. The research included the use of dewatered sewage sludge, stabilized in the process of anaerobic digestion, from three municipal wastewater treatment plants. Sewage sludge was subjected to storage for six months. The storage took place on a specially constructed place, in layers with a thickness of approximately 1 meter. The study included, inter alia, the changes of the properties of sewage sludge deposited depending on the depth from which it was taken. The paper presents the results concerning the changes in selected physicochemical parameters of the sewage sludge.

Keywords: sewage sludge, storage, physicochemical parameters, experimental research

Introduction

Sewage sludge from municipal sewage treatment plants is still one of the major and unsolved problems of waste management in Poland. Difficulties in managing sewage sludge result, inter alia, from the fact that it is generated across Poland in relatively large quantities. In 2014, over 550,000 Mg of sludge dry matter was produced in Poland. Sludge has a relatively high moisture content (over 70%). Therefore, the actual weight of the waste that needs to be managed is much larger. It can be estimated that it exceeds significantly 2 million Mg per year. In addition, due to the fact that in Poland 39.4% of population live in rural areas and only 36.6% of population live in cities with population over 50,000 [1], there is significant territorial dispersion of the sources of sewage sludge generation.

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.

Currently applicable legal regulations restrict significantly the natural use of sludge and prevent their storage (from 2016 onwards). Since 2010, there have been 9 sludge thermal treatment plants constructed in Poland. Thus, at present, there are a total of 11 plants operating in the country that incinerate only sewage sludge. Other plants where sewage sludge is managed are cement kilns. In these kilns sewage sludge that has been previously dried is incinerated (there are several sludge drying plants operating in Poland).

[1] Department of Technologies and Installations for Waste Management, Silesian University of Technology, ul. S. Konarskiego 18, 40-100 Gliwice, Poland, phone +48 32 237 11 23, fax +48 32 237 11 26, email: michal.koziol@polsl.pl

Contribution was presented during ECOpole'15 Conference, Jarnoltowek, 14-16.10.2015

All in, in 2014, over 84,200 Mg of sludge dry matter was managed by thermal methods in Poland [2]. It was over 15% of the total weight of sludge generated.

Currently, in highly-developed countries, we can observe two clashing concepts of sewage sludge management. In such countries as: Norway, Denmark, the UK, over 70% of sludge is managed in a natural manner. And in such countries as the Netherlands and Switzerland, over 90% of the generated sludge weight is managed with the use of thermal methods.

However, in the case of using each method of sewage sludge management, it may be necessary to store the sludge for some time. In the case of using thermal methods, it may result from the very fact of the sludge treatment system organisation. Therefore, the need to store sludge may result, for instance, from the need to collect a larger weight of sludge derived from a small sewage treatment plant prior to its further transportation, the need to store sludge in summer time when the thermal plant (*e.g.* a heat-generating plant) does not operate or operates with smaller output. The need to store sludge may also occur as a result of a failure of a thermal sludge treatment plant.

In the case of a natural sewage sludge management, the need for the sludge storage may also occur when it is required to collect a larger quantity of sludge before transportation, but also in the periods of the absence of recipients or in winter season, when its natural management is at least hampered.

Further in the paper, the results of tests on changes occurring in the sludge stored for the period of 6 months are presented.

Testing methodology

This paper presents the results of testing conducted on three samples of sewage sludge from large municipal sewage treatment plants (with output of over 30,000 m^3/day). All sewage treatment plants were mechanical biological treatment plants. In the plant, the sewage sludge was subject to anaerobic fermentation and mechanical dewatering processes.

In testing, batches of sludge were sampled from sewage treatment plants and put in special containers. The capacity of each container was over 1 m^3. The objective of the conducted tests was to replicate the process of landfilling sludge under actual conditions, that is occurring under conditions as in industrial processes. Under such conditions, the landfilled sludge is exposed to, among others, weathering factors. For this reason, the containers were open from the top. Additionally, in order to simulate interaction of the neighbouring batches of sludge, the sides of the containers were insulated. Moreover, the effluent could flow downwards the sludge layer and farther on. This was executed with permeable layers of sand placed at the bottom of the containers. When the test was started, the thickness of the sludge layers was 1.2 m (with up to 0.05 m accuracy). Within the test, samples for laboratory determination were collected from various depths (measuring from the top surface of the sludge layer in the container), and the results presented below refer only to the samples collected from the depth of 1 meter (with tolerance as stated earlier). Samples were taken preferably from the central part of the landfilled mass of sludge (the centre of the horizontal cross section of the container). Due to the depth of sampling, the effect of meteorological conditions was included in the test as a disturbing factor.

The samples for laboratory determinations were collected in monthly intervals for a period of six months, starting with the time when landfilling sludge began. Thus, the paper presents the results related to the seven dates of sampling.

The following part of the document presents the results of the following sample analyses from the group of several determinations of parameters:

- determination of combustible matter content (determination made by gravimetric method, according to PN-G-04516:1998 [3]),
- determination of total nitrogen content (total nitrogen was determined by the Kjeldahl method [4]),
- hydrogen content (pursuant to standard PN-87/C-04301 [5]).

It should be noted that all values presented further in the paper (*e.g.* on graphs) are mean values obtained based on the threefold repetition of each determination. The mean values of analysed parameters obtained in this manner, referring to individual sludge samples, were subsequently used to determine mean values referring to all sludge samples. These values were then used 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 (for 5 degrees of freedom amounting to $r_{kr} = 0.7545$).

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

Test results

Figure 1 presents the results of tests on the change in time of sludge storage of its combustible matter content. The figure presents the value of combustible matter content reported in subsequent months in all samples of sludge stored. The values were used to determine mean values. For mean values, the trend line equation and the linear correlation coefficient were determined (it was similar in the case of analysis of other parameters tested).

Combustible matter content in the analysed sludge throughout testing amounted from slightly more than 51% up to about 73% (dry matter). The greatest variation range was characteristic for measurement results of combustible matter content in sample "Sludge I". Readings for this sample demonstrated nearly 4.5% variation range. It was, however, mostly due to the value of the combustible matter content reported in the third month. The value of this measurement, clearly lower than the one reported in earlier and later months, is probably the result of the heterogeneity of the sample stored. In the case of other sludge samples, the variation range was approx. 3.3%.

Table 1 presents values of tested parameters for all sludge samples at the beginning and end of tests. In addition, a ratio of the end value to the initial value is presented. As the data in the table demonstrate, differences in the case of combustible matter content amounted from the value of 0 ("Sludge I") to over 3% ("Sludge III"). In the case of mean values, the discussed difference was 1.7%.

The determined trend line for mean values had the following form: $y = 0.29x + 63.92$. The linear correlation coefficient ($r = 0.780$) leads to the conclusion that there is a correlation between the analysed values.

Figure 2 presents the results of tests on the change in time of the total nitrogen content.

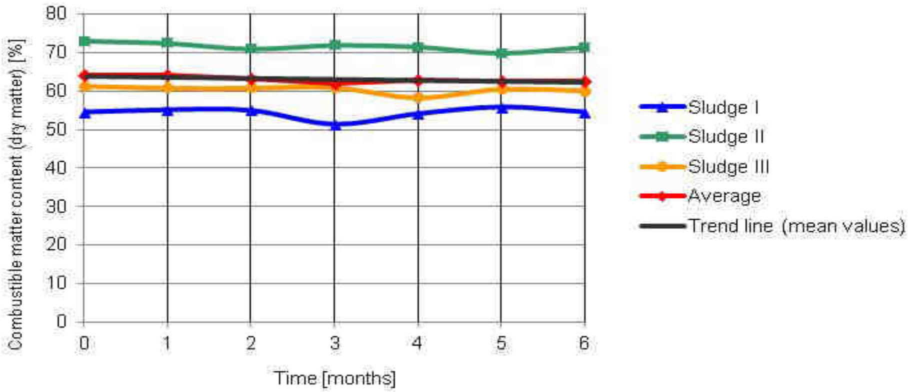

Fig. 1. Changes in time of the combustible matter content in stored sludge

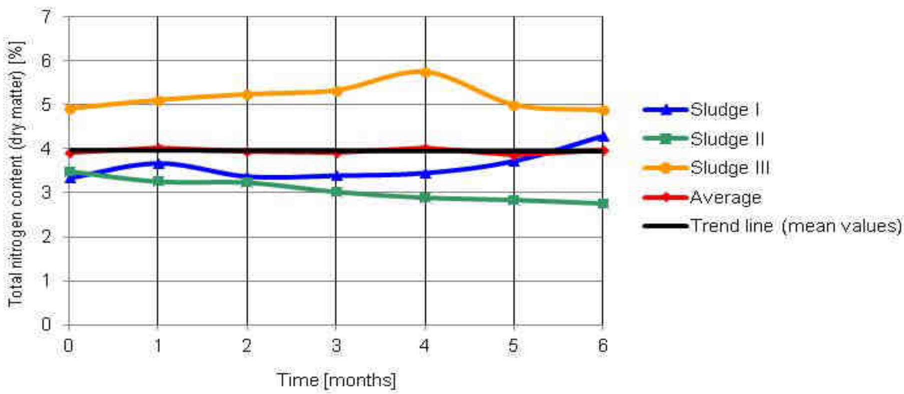

Fig. 2. Changes in time of the total nitrogen content in stored sludge

Total nitrogen content in the analysed sludge throughout testing amounted from over 2.8% up to about 5.8% (dry matter). The greatest variation range was characteristic for measurement results of total nitrogen content in sample "Sludge I". Readings for this sample demonstrated nearly 1% variation range. For sample "Sludge II" it was 0.7%, and for sample "Sludge III" 0.9%. No correlation was confirmed between the analysed factors during testing. The mean values determined for the beginning and end of tests have nearly identical values. Table 1 presents the values of nitrogen content reported in the case of individual sludge samples at the beginning and end of the analysed testing period.

The analysis of the presented data (in the graph and in the table) leads to the conclusion that the reason for failure to confirm the correlation is large heterogeneity of sludge samples in terms of the parameter analysed. It is proved by the fact that for "Sludge I", in the case of the last two readings, a sudden increase in the nitrogen content is clear. In the case of this sample, the total nitrogen content for the last determination is larger by over 25% than in case of the first one. And, in the case of "Sludge II" we observe for the whole time a visible downward trend of nitrogen content value during storage. And in the case of "Sludge III" for the first and last measurement, very similar values of the tested value were reported. Thus, in the case of each of the sludge sample tested, a different trend in changes of the total nitrogen content was reported during storage: drop, increase and a constant value.

Table 1

Initial and final values of analysed parameters for 3 sludge samples

Sample	**Combustible matter content [%]**		**End of testing/start of testing ratio**
	Start of testing	**End of testing**	
Sludge I	54.5	54.5	1
Sludge II	73.0	71.4	0.98
Sludge III	65.1	61.7	0.95
Share of total nitrogen [%]			
Sludge I	3.4	4.3	1.26
Sludge II	3.5	2.8	0.80
Sludge III	4.9	4.8	0.98
Hydrogen content [%]			
Sludge I	3.2	2.6	0.81
Sludge II	5.2	5.7	1.10
Sludge III	4.7	4.0	0.85

Figure 3 presents the results of tests on the change in time of the hydrogen content.

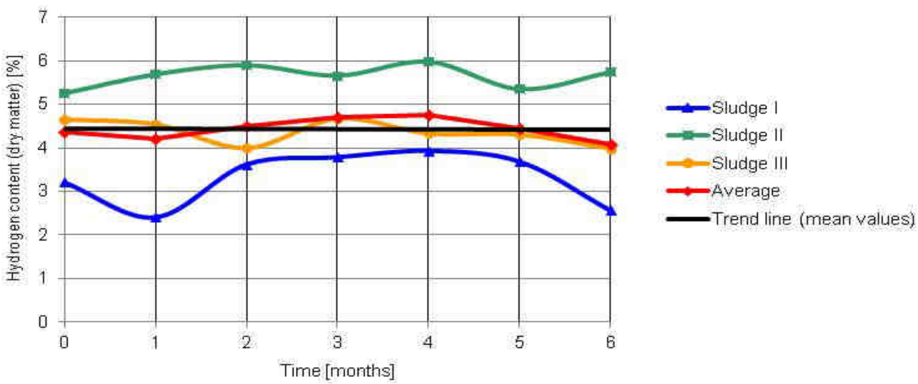

Fig. 3. Changes in time of the hydrogen content in stored sludge

The hydrogen content in the analysed sludge throughout testing amounted from nearly 2.5% up to almost 6% (dry matter). The greatest variation range was characteristic for measurement results of hydrogen content in sample “Sludge I”. Readings for this sample demonstrated the variation range of over 1.5%. In the case of other sludge samples, the variation range was approx. 0.7%. In the case of “Sludge II” the reading at the end of testing was higher than at the beginning (Table 1). No correlation was confirmed between the analysed factors during testing. It was probably caused by insignificant impact of storage time on the hydrogen content in sludge located at the depth of 1 m, as well as by the heterogeneity of sludge samples (resulting in greater variation of hydrogen content then the impact of the analysed process).

Conclusions

As it was presented in the introduction to the publication, irrespective of the management method of sewage sludge, its medium-term storage may be required.

Testing conducted leads to the conclusion that in deeper layers of the sludge stored (at the depth of 1 m), the physical and biological processes occur relatively slowly. The expected change in the combustible matter content for this period is less than 3%. In the case of other discussed parameters (total nitrogen, hydrogen content), testing conducted do not lead to the confirmation of a correlation between the storage time and a change in their value. Thus, if there are changes occurring for the period of 6 months, they are smaller than those resulting from the heterogeneity of sludge and accuracy of determinations performed.

References

[1] GUS: Rocznik Statystyczny Rzeczpospolitej Polskiej 2015 (GUS: Statistical Yearbook of the Republic of Poland 2015). Warszawa 2015. http://stat.gov.pl/obszary-tematyczne/roczniki-statystyczne/roczniki-statystyczne/rocznik-statystyczny-rzeczypospolitej-polskiej-2015,2,10.html.

[2] GUS: Ochrona Środowiska 2015 (GUS: Environmental Protection 2015). Warszawa: Dep. Bad. Reg. i Środ.; 2015. http://stat.gov.pl/obszary-tematyczne/srodowisko-energia/srodowisko/ochrona-srodowiska-2015,1,16.html.

[3] PN-Z-15008-03:1993. Odpady komunalne stałe. Badania właściwości paliwowych. Oznaczanie zawartości części palnych i nie palnych (Municipal solid waste. Research on the characteristics of fuel. Determination of combustible and flammable parts). http://sklep.pkn.pl/pn-z-15008-03-1993p.html.

[4] PN-Z-15008-06:1993. Odpady komunalne stałe. Badania właściwości paliwowych. Oznaczanie zawartości składników agresywnych (Municipal solid waste. Research on the characteristics of fuel. Determination of the aggressive components). http://sklep.pkn.pl/pn-z-15008-06-1993p.html.

[5] PN-73/G-04521. Paliwa stałe. Oznaczanie zawartości węgla i wodoru metodą Sheffield (Solid fuels. Determination of carbon and hydrogen content by Sheffield method). http://sklep.pkn.pl/pn-g-04521-1973p.html.

ZMIANA WYBRANYCH WŁAŚCIWOŚCI OSADÓW ŚCIEKOWYCH W TRAKCIE SKŁADOWANIA ŚREDNIOOKRESOWEGO

Katedra Technologii i Urządzeń Zagospodarowania Odpadów, Politechnika Śląska, Gliwice

Abstrakt: W ostatnich latach zrealizowano w Polsce szereg stosunkowo dużych instalacji termicznego unieszkodliwiania osadów ściekowych. Pomimo powyższego, ich zagospodarowanie wciąż stanowi nierozwiązany problem na znacznym obszarze Polski. Jednym ze zjawisk wynikającym m.in. z wciąż nie w pełni poprawnej gospodarki osadami ściekowymi jest konieczność ich okresowego składowania. Składowanie to ma miejsce np. w sytuacji, kiedy nie ma możliwości bieżącego zagospodarowania osadów wytwarzanych przez oczyszczalnię ścieków. We wstępie pracy krótko zarysowano problematykę zagospodarowania osadów ściekowych w Polsce oraz genezę prezentowanych badań. W dalszej części pracy omówiono metodykę przeprowadzonych badań. W ramach badań wykorzystano ustabilizowane w procesach fermentacji beztlenowej odwodnione osady ściekowe, pochodzące z trzech oczyszczalni ścieków komunalnych. Osady zostały poddane składowaniu przez 6 miesięcy. Osady składowano na specjalnie zbudowanych w tym celu stanowiskach, w warstwach o grubości ok. jednego metra. W badaniach uwzględniono m.in. zmiany właściwości składowanych osadów w zależności od głębokości, z jakiej je pobrano. W pracy przedstawiono wyniki dotyczące zmiany wybranych parametrów fizykochemicznych osadów.

Słowa kluczowe: osady ściekowe, składowanie, właściwości fizykochemiczne, badania eksperymentalne