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Sewage sludge management – a case study

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Abstract: Currently, the constantly growing problem in the municipal economy is the management of sewage sludge. According to the law, it is the local government that is responsible for the utilization of sewage sludge and is obliged to select optimal technologies, obtain funds and convince the community of the necessity of its implementation. BIONOR Company has developed an innovative concept for the separation and utilization of sewage sludge in the BIONOR SLUDGE compact installation. This innovative technology is effective from the perspective of reducing the waste amount and can be used to solve the problem of utilization of sewage sludge produced in small, rural wastewater treatment plants. The aim of the article is the characterization of the BIONOR SLUDGE technology, a comparative analysis of costs of sludge disposal using a variety of methods and an indication of the importance of sludge management for the local development. To achieve the goal set in the article, a discriminative method was used - a description of the BIONOR SLUDGE technological line as well as a case study method - a comparative analysis of the costs of operation of BIONOR SLUDGE technological line and the costs of landfilling and utilizing of sewage sludge. The research results confirm that the monthly operational costs of the BIONOR SLUDGE technological line are lower than the costs of monthly landfilling or disposal. For potential municipalities, the introduction of BIONOR innovative technology is economical. Moreover, its usage is currently essential for many municipalities due to the introduction of a ban on landfilling of this type of waste from 1 January 2016. This technology can be used to solve the problem of utilization of sewage sludge generated in small, rural wastewater treatment plants.

Keywords: sludge management, local development, BIONOR SLUDGE technology

JEL codes: O18, O44

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1. Introduction[1]

Currently the most significant challenge in the aspect of environmental engineering and legal requirements that must be met by municipalities is the management of both municipal waste and sewage sludge (Kijak and Moy, 2008: 33-50). On 1 January 2016 Poland introduced a legal standard consistent with the requirements of the European Union, which imposed a ban on the landfilling of sewage sludge (Council Directive 99/31/EC, Regulation of Economy Minister on the admission of waste on landfills, Journal of Laws 2015 No. 0, item 1277). According to the law, it is the local government that is responsible for the utilization of sewage sludge and is obliged to select optimal technologies, obtain funds and convince the community of the necessity of its implementation. The measure of modernity of a wastewater treatment plant is the applied method of sewage sludge utilization. A target direction of the utilization of waste from municipal wastewater treatment plants will be mainly thermal methods due to the fact that they are ecologically safe and economical. One of the most technically advanced methods of utilization of sludge is its thermal treatment with the recovery of energy. Such methods are considered the most effective and favourable from the perspective of environmental engineering and energy saving. Moreover in the light of limitations of other methods of sludge utilization, they are considered a priority (Bień et al., 2011: 375-384; Latosińska et al., 2012: 31-44; Latosińska et al., 2014: 465-475).

In order to meet the challenges concerning the waste management, BIONOR Company has developed an innovative concept for the separation and utilization of sewage sludge in the BIONOR SLUDGE compact installation. This innovative technology is effective from the perspective of reducing the amount of waste. However, in order to be competitive, the installation needs to be cheaper in comparison with other existing ones, which requires the determination of the economic calculation.

Thus, the aim of the article is to give characteristics of the innovative BIONOR SLUDGE technology, a comparative analysis of costs of sludge disposal using a variety of methods, and an indication of the importance of sludge management for the local development. To achieve the

[1] The article presents the research results elaborated during the scientific internship in Bionor Company 02.06. – 30.09.2014. The scientific internship was organized within the framework of the project "Invention II – Transfer of knowledge, technology and innovation as a support for Świętokrzyskie region key specializations of economy and competitiveness of companies", co-funded by the European Union within the ESF – Human Capital Operational Program, Priority VIII. Regional human resources, Activity 8.2 Transfer of Knowledge, Sub-activity 8.2.1. Support for cooperation of science and companies.

purpose of the article, a discriminative method was used – a description of the BIONOR SLUDGE technological line as well as a case study method – a comparative analysis of the operational costs of BIONOR SLUDGE technological line and the costs of landfilling and utilizing of sewage sludge.

2. Characteristics of BIONOR SLUDGE technology[2]

The utilization of municipal sewage sludge consisting in its introduction into the natural environment presents a potential ecological hazard. The limit values of the criteria defined for sewage sludge on its usage in agriculture and in soil reclamation (Regulation of the Minister of the Environment Journal of Laws 2015 No. 0, item 257, Act on waste Journal of Laws 2013 No. 0, item 21, as amended), the decreasing social acceptance of its environmental usage and the introduction of the ban on its admission on landfills (Regulation of the Minister of the Environment Journal of Laws 2015 No. 0, item 1277) result in searching for alternative methods of sewage sludge utilization among the owners of wastewater treatment plants. One of the suggested solutions designed for small wastewater treatment plants is BIONOR SLUDGE technology.

The main assumption of the discussed technological process is the utilization of sludge obtained from wastewater treatment plants with a throughput of approximately 250 m^3/24 h, in accordance with the rule "Wastes should be neutralized in the place of their formation" *(*Act on waste Journal of Laws 2013 No. 0, item 21, as amended). BIONOR SLUDGE technology consists in the utilization of waste with the possibility of their usage as fertilizing biomass or alternative fuel. Its functioning is based on the recovery of energy and matter together with reasonable management of resources.

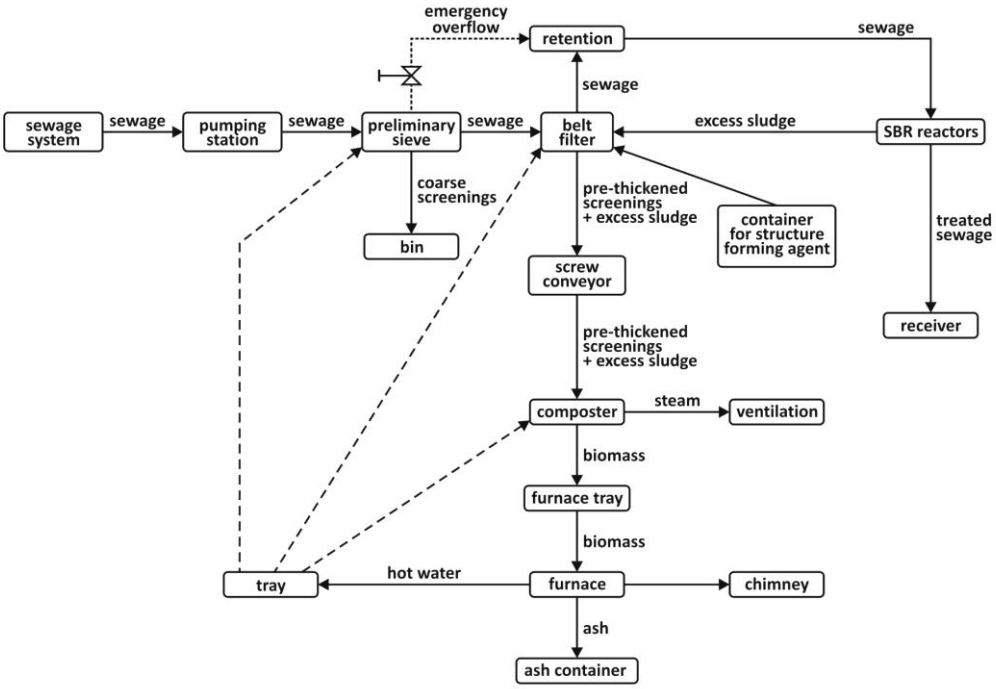
The scheme of BIONOR SLUDGE technology is presented in Figure 1. Domestic wastewater from sewage system is directed to a pumping station, and subsequently to a screen channel where after separation, coarse screenings are accumulated in a bin, whereas sewage with small screenings is directed to a belt filter. Having passed through the bag filter, sewage flows into a retention container, and small screenings are transported on a belt to a screw press integrated with a belt filter. After their retention, sewage is pumped to cyclically operating

[2] The elaboration of the chapter was based on the relevant materials provided by BIONOR Company.

biological reactors. After every cycle of reactors operation, the excess sludge is discharged by gravity to the belt filter for separation and drainage. At this stage of the process a structure-forming agent is added, e.g. cellulose.

The drained sludge is transported by a screw conveyor to a three-chamber composter. In the first two chambers, there follows a 5-7-day process of composting at a controlled temperature – max. 70°C. The temperature causes the hygienization of biomass and reduces moisture from 60% to 20%.

Figure 1. Scheme of the technological line for separation and utilization of sewage sludge in a wastewater treatment plant, in a compact installation



Source: elaboration based on the materials provided by BIONOR Company.

In the composter, a rotating shaft moves a warmed-up product to the third chamber, where a screw conveyor transports the biomass to a furnace tray. Fuel in the form of biomass is automatically fed to the furnace from the tray. As a result of the biomass combustion, water

heated up to 80°C is directed to a boiler and used for the composter heating. Hot water from the boiler is used also for rinsing the screen channel and the belt filter.

The presented installation transforms 200 kg of sewage sludge into 5-7 kg of ash within 24 hours. The accumulated ash is stored in a steel container.

The advantage of small, local installations for the utilization of sewage sludge is the possibility of using it on the site of a wastewater treatment plant or in a close location in relation to the place of sludge formation. Simultaneously such an installation limits nuisance and costs of transport, which are an obstacle from the economical and ecological perspective. The biomass obtained from the biological process can be used for agricultural purposes – the problem is storing, the examination of its composition in certified laboratories (e.g. qualification of compost as biomass) and the process of possible distribution of the biomass. The biomass can be also combusted in a furnace with the energy recovery. The energy can be used in a wastewater treatment plant.

3. Comparative analysis of costs of sludge disposal

The analysis consists in determining the volume and structure of investment spending, total monthly costs of operation and a comparison between costs of BIONOR SLUDGE technological line and costs of landfilling and utilization of sludge (the landfilling was still allowed in 2015). Simultaneously the income based on the introduction of the line into the regular operation was not defined because it could concern, e.g. combustion of sludge in a furnace with the energy recovery, and so far no combustion processes of sludge have been realized in the company and, consequently, there is no data available regarding this area.

The amount and the structure of the capital expenditures on the construction of BIONOR SLUDGE technological line are presented in Table 1. The total capital expenditures to purchase devices and start up the technological line equalled 619 200 PLN. The greatest contribution in the structure of capital expenditures on the construction of BIONOR SLUDGE technological line characterized the following: the SALSNES belt filter (51.68%) and the ACU composter (19.38%). The analysis revealed a relatively high contribution of costs of the sieve purchase as well as the design and permits – 8.07% for both. The lowest contribution in the total capital expenditures was demonstrated for the cost of cellulose dosing installation (1.61%) and the

purchase of sewage and excess sludge conveyor (1.61%) as well as the costs of supervision over the realization of the technological line (0.24%).

The amount of monthly operational costs of the sewage sludge separation and utilization technological line depends on the following factors (Roman et al. 2000).

1. type and throughput of the treatment plant;
2. technology used for separation and utilization of sewage sludge;
3. efficiency of the sewage sludge separation and utilization of technological line;
4. composition of contaminants in sewage

The amount and the structure of monthly operational costs of sewage sludge separation and utilization technological line are presented in Table 1.

Table 1. Capital expenditures on the BIONOR SLUDGE technology (prices from 2015)

Elements of capital expenditures (Capex)	Value of capital expenditures (PLN)	Structure of capital expenditures (%)
Sieve	50 000	8.07
Cellulose dosing installation	10 000	1.61
SALSNES belt filter	320 000	51.68
Sewage and excess sludge conveyor	10 000	1.61
ACU composter	120 000	19.38
REKA furnace	27 700	4.47
Installation of technological line	30 000	4.84
Design and permits (costs of preparation of design documentation and costs of obtaining permits for the start-up and operation of the technological line)	50 000	8.07
Supervision over the realization of the technological line	1 500	0.24
TOTAL	**619 200**	**100.00**

Source: own elaboration based on the materials provided by BIONOR Company.

The total monthly operational costs of the technological line equalled 7 593.51 PLN (Table 2). The greatest share (38.36%) in the total monthly operational costs of the technological line is the cost of depreciation of devices. The share of cost of periodic inspections authorizing the operation (21.95%), the cost of electricity (18.50%) and the cost of salaries incl. taxes

(13.17%) are also high. The lowest share in the total operational costs is the cost of water consumption (1.94%).

Table 2. Monthly operational cost of BIONOR SLUDGE technology (prices from 2015)

Sources of operational costs (Opex)	Quantity	Price (PLN)	Value/ per 24 h (PLN)	Monthly costs (PLN)	Structure of costs (%)
Cost of electricity (kWh)	83.627	0.56	46.83	1 404.93	18.50
Salary of the employee operating the technological line incl. taxes (1/4 part time)				1 000.00	13.17
Cost of material purchase (cellulose kg/24 h)	4	2	8	240.00	3.16
Cost of water consumption (m^3)	2.30	2.13	4.90	146.97	1.94
Cost of operation of devices used in the technological line (maintenance, repairs, etc.)				222.4	2.93
Cost of depreciation of devices				2 912.54	38.36
Cost of periodic inspections authorizing the operation*				1 666.67	21.95
TOTAL	**-**	**-**	**-**	**7 593.51**	**100.00**

* estimated cost: 20 000 PLN per year
Source: own elaboration based on the materials provided by BIONOR Company.

The consecutive stage of the analysis was the comparison of costs of BIONOR SLUDGRE technological line with the costs of landfilling and utilization of sewage sludge in the case when the Bionor innovative process was not elaborated and was not introduced into operation. The amount of sewage sludge for transport formed in the studied wastewater treatment plant equalled 100-120 m^3 during one month. The cost of landfilling and utilization of 1m^3 of sewage sludge was calculated for 90 PLN a month (data from 2015).[3] Thus, the total cost of landfilling and utilization of sewage sludge produced within one month in a wastewater treatment plant equalled 9 000 PLN (100 m^3/month * 90 PLN/m^3). The depreciation of the technological

[3] The details have been supplied by a waste landfilling company.

equipment equals approximately 6.5% (Wójtowicz et al. 2013). The total monthly cost of operation with the depreciation, as above-mentioned, equalled 7 593.51 PLN.

The comparative analysis of costs of landfilling and utilization of sewage sludge with the costs of operation of Bionor technological line revealed that the monthly operational cost of the BIONOR SLUDGE technological line is lower than the monthly cost of landfilling and utilization of sewage sludge by 1 406.49 PLN (9 000 PLN – 7 593.51 PLN). It should be emphasized that the usage of BIONOR SLUDGE technology is a necessity because of the introduction of the ban on landfilling of sewage sludge from 1 January 2016. Moreover, as a result of sewage sludge processing, the mass of post-process products in landfills is lower.

The analysis also covered the following changes:

– after switching off the devices connected with the container of the Aerobic Sludge Digestion, 20 kWh/24 h of energy was saved, which gives the value of 336 PLN (20 kWh/24 h * 0.56 PLN/kWh = 11.2 PLN/24 h; 11.2 PLN/24 h * 30 days = 336 PLN/month);

1. in BIONOR SLUDGE technology there is no manual grate, thus there are savings of energy connected with the usage of a grate: 3.5 kWh/24 h * 0.56 PLN = 1.96 PLN/24 h; 1.96 PLN/24 h * 30 days = 58.8 PLN/month and the usage of water: 0.5 m^3/24 h * 2.13 PLN = 1.065 PLN/24 h; 1.065 PLN/24 h * 30 days = 31.95 PLN/month. The value of energy and water saved equals: 90.75 PLN /month.

On the basis of the conducted analysis, the costs of monthly operation of BIONOR SLUDGE are lower than the costs of monthly landfilling and utilization of sewage sludge by 1 406.49 PLN (9 000 PLN – 7 593.51 PLN). Finally, taking into account all the calculations, the value is higher by 426.75 PLN/month (336.00 PLN + 90.75 PLN). Thus, the costs of monthly operation of BIONOR SLUDGE technology decreased and equal 7 593.51 PLN – 426.75 PLN = 7 166.76 PLN/month. Taking into consideration the above mentioned, the costs of monthly operation of BIONOR SLUDGE technology are finally lower than the cost of landfilling and utilization of sewage sludge by 1 833.24 PLN (9 000 PLN – 7 166.76 PLN) which means that for potential local governments, the introduction of an innovative Bionor technology is profitable. It is the more essential due to the introduction of the ban on landfilling of sludge from the day of 1 January 2016.

4. Role of sludge management in the local development

Local development depends on the potential presented by community in a particular area. It is a multidimensional term, which is perceived as changes in quantity and quality taking place in the social and economic functioning of local government units (Markowski, 2008: 13-15). On the other hand, Brol (1998: 11) considers local development to be a harmonized and systematic action on the part of local community, a local government and other entities functioning in the community aimed at creating new and correcting the existing functional qualities of the community, providing advantageous conditions for the local economy and establishing the spatial and ecological order. In this article, local development should be understood as a process of quantity and quality changes connected with a particular territory, and concerning the level of life of its citizens and the functioning of business entities.

The aim of social and economic actions taken on the local level is above all an increase in prosperity and improvement of the level and quality of citizens' lives. It is realized mainly through the development of housing, taking proper care of the natural environment, an increase in the amount of elements of technical and social infrastructure, attracting new business investments as well as social and economic activation of citizens. Thus, the processes leading to the development of a unit are formed in the direction which is the most desirable, socially and economically accepted as well as consistent with the requirements of reasonable management of space, natural environment protection and the cultural heritage. If these actions are realized in a proper and consistent way, their effect will probably secure an economic advancement to a local unit (Bański and Czapiewski, 2008: 3).

A multidimensional character of the concept of local development results directly from the multitude of factors forming it. Currently, the main development factor is believed to be the endogenous potential, which if mobilized, provides a permanent dynamics of local development. Infrastructure investments are significant for building the potential on a local level because they constitute a base necessary for the development of activities in a particular area. Such investments, especially the ones connected with the environmental protection, should favour a well-balanced development, while the investment process should be economically and technically justified as well as performed with respect for the natural environment and its protection. For an investment to be technically justified, it has to satisfy the needs, solve problems comprehensively

and use the newest technologies. Economic justification in the case of municipal investments is the undertaking of investments for which it is possible to ensure profitability and durability.

In a dynamically developing economy, an activity used for the management of waste is an important element of the social-economic life structure. Among factors having an influence on the regional/local development, by building its potential, the most important is the infrastructure, which constitutes a base necessary for the development of activities in a particular area. In contemporary conditions, a well-designed infrastructure concerning sludge, particularly technological lines for the separation and utilization of sewage sludge, can be significant for overcoming the problem of sludge management, the peripherality of regions/municipalities and can result in significant benefits in the aspect of satisfying living needs, in the development of enterprises and in an increase in the investment attractiveness of regions and municipalities. Infrastructure investments constitute an important tool supporting the local development – they can become a stimulus for an economic activity of a municipality.

The advantage of small, local installations for the utilization of sewage sludge is the possibility of using it on the site of a wastewater treatment plant or in a close location in relation to the place of sludge formation ("at source"). It limits nuisance and costs of transport, which are a disadvantage from the economic and ecological perspective. Local utilization of sewage sludge takes place directly in the place of its formation. The units operating wastewater treatment plants are offered local solutions within their own supervision, which guarantees a favourable and optimal sludge management. The installation used for the separation and utilization of sewage sludge is based on the utilization of waste with the possibility of their usage as fertilizing biomass or alternative fuel. Its functioning is based on recovery of energy and matter together with reasonable management of resources. One should take into consideration the energy and agricultural potential of sludge, which is a perfect source of phosphorous (its stocks are running out). It can be obtained both from sewage meant for thermal processing and from ash obtained after the combustion of sewage sludge (Wójtowicz, 2014). The described technological line constitutes also a factor of extension of the local technical infrastructure, which increases the assets of a municipality and exerts an influence on its development and the improvement of the level and quality of the lives of citizens. It constitutes a tool of modernizing the economy of a municipality and of building its competitiveness.

The effect of the actions taken for the development of the municipality, realized in a proper and consistent way, will be probably a social-economic advancement of a local unit – a municipality.

5. Conclusion

A significant problem in the sphere of sludge management is the utilization of municipal sewage sludge. It is because of the growing amount of sewage sludge and the legal conditions giving little possibility for its utilization in agriculture and landfilling. Particularly significant in this respect is the fact that beginning with 1 January 2016, landfilling of unprocessed sewage sludge has been prohibited. It increases the necessity of searching for new solutions, including thermal treatment. The advantages of BIONOR SLUDGE technology are:

- a significant reduction of sludge volume in the process of composting and during further combustion;
- no need for storing sludge causing a particular odour nuisance;
- no time limitation of storing and in processes of sludge treatment;
- the use of recovered energy and matter.

In order to meet the requirements within the range of sewage sludge utilization, it is necessary to introduce and test innovative methods aiming at the realization of the energetic and material recycling. In order to meet the challenges concerning the management of wastes, BIONOR Company has developed an innovative concept and introduced BIONOR SLUDGE technological line. This technology is a process innovation on the domestic and international scale. This technology can be used in order to solve the problem of sewage sludge utilization in small, rural wastewater treatment plants.

It should be emphasized that energy and fertilizing potentials of sludge are underestimated and wasted from the perspective of current technical possibilities. The impact of sludge management on the rates of fees for the collective discharging and treatment of sewage can become an effective tool of the influence on the economic offer of local governments and attractiveness of the whole domestic economy. Thus, sludge should be perceived, above all, as a "global chance", not the "local problem" (Wójtowicz 2014).

The result of the comparative analysis is a strong argument for the introduction of a new

concept in companies, making them more competitive and innovative, not only on the regional and local market, but also on the domestic and international scale. The comparative analysis of the operational costs of the BIONOR SLUDGE technological line with the costs of landfilling and utilization of sewage sludge has proved that a monthly cost of BIONOR SLUDGE operation is lower than the cost of landfilling and utilization of sewage sludge by 1 833.24 PLN (9 000 PLN – 7 166.76 PLN). It clearly means that for municipalities the potential introduction of the innovative Bionor technology will prove only too profitable.

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Zarządzanie osadami ściekowymi - studium przypadku

Streszczenie

Aktualnie wciąż narastającym problemem w gospodarce komunalnej jest zagospodarowanie osadów ściekowych. Zgodne z prawem to gmina jest odpowiedzialna za ich zagospodarowanie i na niej ciąży obowiązek doboru optymalnych technologii ich zagospodarowania, pozyskania na ten cel funduszy i przekonania społeczności gminy o konieczności ich realizacji. Przedsiębiorstwo Bionor Sp. z o.o. opracowało nowatorską koncepcję separacji i unieszkodliwiania osadów ściekowych w kompaktowej instalacji BIONOR SLUDGE. Ta innowacyjna technologia jest efektywna z punktu widzenia zmniejszania ilości odpadów. Może być wykorzystana w celu rozwiązania problemu zagospodarowania osadów ściekowych wytwarzanych w małych, wiejskich oczyszczalniach ścieków. Celem artykułu jest scharakteryzowanie innowacyjnej technologii BIONOR SLUDGE, analiza porównawcza kosztów unieszkodliwiania osadów ściekowych różnymi metodami oraz wskazanie znaczenia gospodarki osadowej w rozwoju lokalnym. Dla realizacji celu artykułu wykorzystano metodę deskryptywną – opis linii technologicznej BIONOR SLUDGE oraz metodę studium przypadku – analiza porównawcza kosztów eksploatacji linii technologicznej BIONOR SLUDGE z kosztami składowania i utylizacji osadów ściekowych. Wyniki badań potwierdzają, że miesięczne koszty eksploatacji linii technologicznej BIONOR SLUDGE są niższe od miesięcznych kosztów składowania lub utylizacji. Dla potencjalnych gmin wprowadzenie nowatorskiej technologii firmy Bionor jest opłacalne. Ponadto jej wykorzystanie jest aktualnie konieczne dla wielu gmin ze względu na wprowadzenie od 01.01.2016 roku zakazu składowania tego rodzaju odpadów. Technologia ta może być wykorzystana w celu rozwiązania problemu zagospodarowania osadów ściekowych wytwarzanych w małych, wiejskich oczyszczalniach.

Słowa kluczowe: gospodarka osadowa, rozwój lokalny, technologia BIONOR SLUDGE.