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INNOVATIVE TECHNOLOGIES FOR THE DISPOSAL OF SEDIMENTS FORMED AT TREATMENT PLANTS IN UKRAINE AND POLAND

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Abstract. *Continuously growing human economic activity has gained such strength that at the present stage it is ~ 10% of the productivity of the entire biosphere of the Earth and covers 61% of the earth's surface. As a result of human economic activity, a large amount of waste enters the environment. Most often, such waste is stored in specially designated areas, but over the decades, such storage sites have become overcrowded, and therefore began to negatively affect people and the environment. In recent decades, scientists, not only in Ukraine but also in the world, have attracted special attention to the problem of rapid growth of sewage sludge (ERU), which is a large tonnage of biological wastewater treatment, so this work is very relevant.*

The purpose of this work is to establish the possibility of using for biological reclamation of the substrate based on sewage sludge.

To achieve this goal it is necessary to perform the following tasks:

- to determine the sanitary-microbiological and ecological-chemical characteristics of the accumulated SS;*
- determine the quality of fresh SS;*
- to conduct bioindication of substrates on the basis of settled and fresh SS;*
- to study the influence of different types of substrate on the germination, growth and development of bioindicator plants;*
- to establish the dependence of changes in growth and development of plants depending on different types of substrate;*
- to determine the optimal composition of the substrate for biological reclamation.*

Keywords: *sewage sludge, biological reclamation, substrate, sanitary-microbiological and ecological-chemical characteristics, bioindication.*

I. FORMULATION OF THE PROBLEM

Sewage sludge is a by-product of wastewater treatment technology. It contains more than half of the pollutants inflowing to the treatment plant with raw sewage [Bauman-Kaszubska and Sikorski, 2008]. According to polish legal acts municipal sewage sludge is defined as sludge from fermentation chambers and other installations used for treating sewage [Act of 14 December 2012 on Waste]. Wastewater treatment is always accompanied by the generation of sludge, which is defined as organic-mineral solid phase separated from wastewater. Sludge is also defined as a mixture of water and solids separated from various types of sewage by natural or artificial processes. In specialized literature municipal sewage sludge is defined as sludge

resulting from the treatment of municipal wastewater. Raw sludge is defined as untreated sludge coming directly from wastewater treatment processes (this sludge rots easily and gives off unpleasant odours).

Until recently, the main methods of wastewater disposal were dumping and storage on sludge sites (landfill), but such methods of disposal are expensive and environmentally friendly, so in recent decades, actively began to use other methods of wastewater disposal: incineration, use as fertilizer in agriculture, etc. Important in the disposal of sewage sludge are the processes of pre-treatment of sludge, which include stabilization by adding lime, composting, aerobic or anaerobic conversion, as well as dehydration and drying processes.

Initial sludge is produced by sedimentation of easily settable suspended solids (organic and mineral - not kept in grit chambers) in preliminary settling tanks. These sludges are unmixed with other recirculated sludges. Secondary sludge is separated in secondary settling tanks after biological wastewater treatment in activated sludge flow devices or in biological beds. Secondary sludge, when returned to the biological reactor, is called recirculated sludge, whereas sludge removed from the wastewater treatment system due to biomass growth forms excessive sludge. Mixed sludge is usually obtained by mixing primary and secondary sludge. Different types of waste and sewage sludge generated at wastewater treatment plants are depicted in the Figure 1.

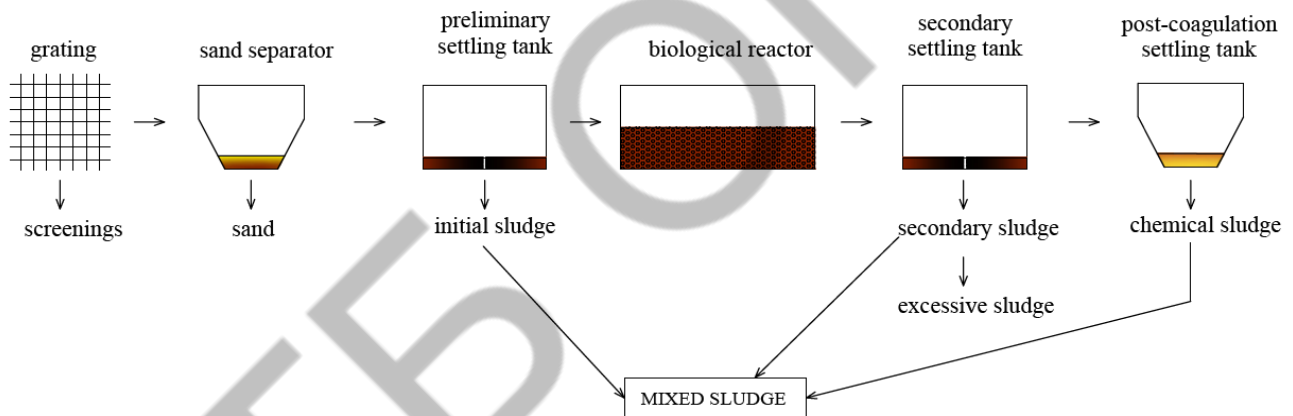


Fig.1. Types of waste and sewage sludge generated at the wastewater treatment plant

It is estimated that sewage sludge generated after wastewater treatment constitute about 1-5 % of wastewater volume that flows into the treatment plant. Sewage sludge is characterised by high hydration level (up to 95-99%) which is connected with its liquid consistency and poor drainability. Moreover, it shows significant content of easily decomposable organic matter which causes its high tendency to decay. Sewage sludge contains many compounds that are harmful to the environment, but also a lot of nutrients and organic substances valuable for agriculture, such as nitrogen and phosphorus. Sometimes industrial sewage sludge can also include some so called new-generation pollutants- pharmaceuticals, personal care products, plasticizers, specific or toxic pollutants such as: heavy metals, dioxins, furans, pesticides and others, depending on the type of industry.

In the European Union, the most common methods of pre-treatment of SS are aerobic and anaerobic conversion. Studies have shown that in the case of aerobic

conversion in sewage sludge in large quantities of humic acids are formed, and as a result of anaerobic digestion the main components that are formed are proteins and aromatic amino acids, which allows the use of SS in agriculture.

RESEARCH OF WAYS OF DISPOSAL OF WASTE ACTIVE MUD IN UKRAINE

For research in this work were used sewage sludge treatment plants (WWTP) of Lviv. selected at the Lviv CBS contain sufficient amounts of phosphorus, potassium and nitrogen, and heavy metals do not exceed the maximum allowable concentration (MPC). At the time of sampling (June 2019), sludge sludge from sewage treatment plants was finely dispersed, and in some places water-saturated sludge.

Sampling of the accumulated sediments was performed using a metal cylindrical tube, such as a chute, with a lower valve. The diameter of the sampler was 128 mm, length 1 m. A pipe was screwed to the upper part of the sampler, the length of which was increased by means of couplings.

The thickness of the sludge was 3 m or more. Samples were taken in the range of depths 0-0.2 m; 1.4-1.6 m Length; 2.8-3 m. Such intervals were chosen in order to investigate the ecological-biogeochemical and parasitological characteristics of silt in the near-surface, medium-depth and bottom conditions of their stay. The volume of the sample was 2.5 dm³. The selected sediment samples were packed in double plastic bags. Each sample was assigned a serial number. Sample numbers were recorded in the sampling log. The coordinates of the sampling points were measured and tied to the area with the help of geodetic instruments. Fresh sediments were collected immediately after unloading from the centrifuges. The selected sediment samples were packed in a plastic bag.

To study the quality of the growth substrate (bioindication), two species of plants were selected, which belong to one of the categories. Category 1 - monocotyledonous plants: rye, ryegrass, rice, oats, wheat, barley, sorghum, corn. Category 2 - dicotyledons: white mustard, canola, radish and wild turnip, Chinese cabbage, watercress, tomato, bean. Before using the seeds of each crop, analysis was performed and the energy of their germination was determined. In each of the vessels were planted 10 identical seeds of the selected species. For each replicate in each embodiment, the percentage of seed germination relative to the average germination in the control vessels was calculated. The length of the longest roots of each plant was measured and the average length of the longest root for each investigated growth substrate was determined. Statistical analysis was used to determine the smallest significant discrepancies between controls and test concentrations.

For the study, in accordance with this method, we used different types of substrate based on soil, SS and natural sorbents, which were compared according to the control soil.

To determine the quality of the growth substrate from the above plants used: barley (*Hordeum vulgare*), white mustard (*Sinapis alba*), watercress (*Lepidium sativum*) and ryegrass (*Lolium perenne*).

Since, in recent years in Ukraine there is a growing need for biological reclamation of spent man-made objects (landfills, dumps, quarries, etc.), and this

process requires significant resource and energy costs, finding ways to reduce its cost and preserve natural resources. resources is extremely important and promising. Therefore, great attention in solving this problem should be paid to the possibility of using in the biological reclamation of man-made waste, such as SS. As a result, it is possible to simultaneously address two extremely common environmental problems and offer a technological solution for the use of nutrients from SS and provide them with the process of biological reclamation.

The first stage of research was carried out with dark gray podzolic soil, to which was added settled sewage sludge (for this fresh selected sludge was stored without access of oxygen for 6 months to simulate the conditions of accumulation of sludge on sludge sites) in the ratio (%): 100: 0; 80:20; 60:40; 40:60; 20:80; 0: 100. The created substrate was placed in Petri dishes and 10 seeds of common barley (*Hordeum vulgare*), white mustard (*Sinapis alba*) and watercress (*Lepidium sativum*) were planted in it. For the reliability of the studies, the experiments were performed in quadruplicate. In fig. Figure 2 shows the general appearance of bioindicator plants (white mustard) in the experimental substrates.

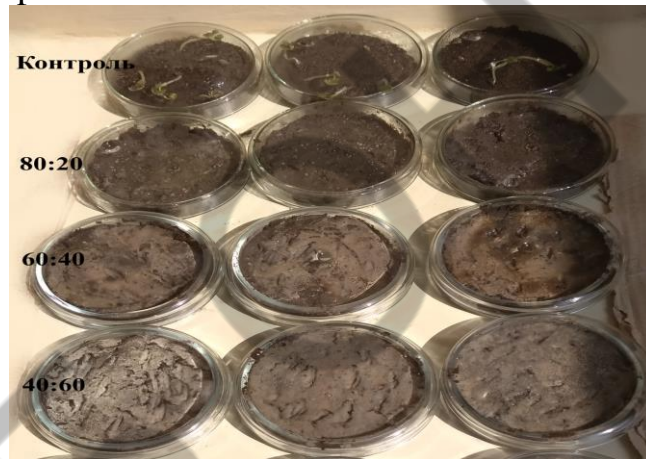


Fig.2. General appearance of white mustard in experimental samples on day 10

As can be seen from Fig. 2 germination of white mustard is not observed in any sample except the control sample. According to the results of the first experiment, we found that even a small proportion of sewage sludge (20%) in the substrate, with this type of storage has a very negative effect on the germination of all plant species. And in samples with a sediment content of more than 40%, the development of dangerous fungi and mold is observed.

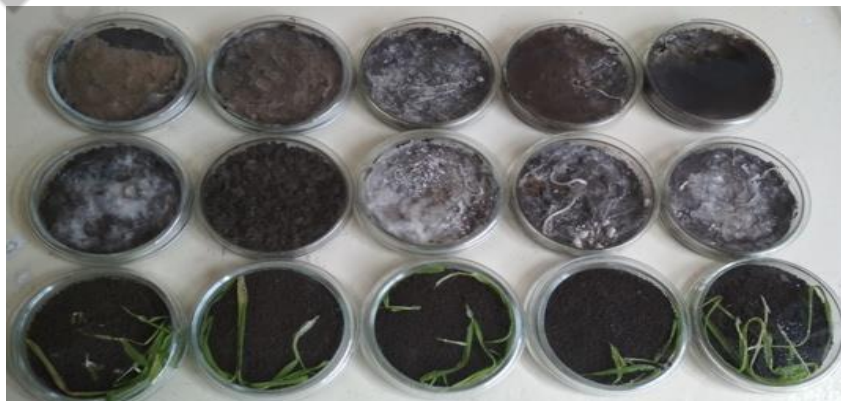


Fig. 3. The appearance of fungi and mold in the studied samples

In parallel, at the same stage, an experiment was set up in which dark gray soil, settled sediment and heat-treated settled sediment (dried in a drying chamber for 2 hours at a temperature of 105 °C) were used, which were mixed in the ratio (%): 60:40 ; 20:80; 0: 100. To determine the quality of the growth substrate in Petri dishes were planted 10 seeds of barley in the substrate with heat-treated sediments and 10 seeds of barley, which were etched with a disinfectant Vitvax 200 FF, v.s.k. (consumption rate of 3 l / t of seeds). The experiments were performed in triplicate. The results of the second experiment are presented in Fig. 4.



Fig. 4. The appearance of pathogenic microflora in the sample with heat-treated sludge

As can be seen from Fig. 3, in the case of using heat-treated sludge, it is possible to observe the development of pathogenic microorganisms that are dangerous not only for plants but also for the soil. Also, it should be noted that the use of pickled seeds did not give results, plant germination was not observed in any sample other than control.

Therefore, based on the results of the first stage of research, it can be concluded that the main problem for the use of sediments is their disinfection, because this method of storage develops a significant number of fungi and pathogenic microflora.

The second stage of research was carried out with dark gray podzolic soil, to which fresh sediments were added in the ratio (%): 100: 0; 80:20; 60:40; 40:60; 20:80; 0: 100. Bioindication was performed in Petri dishes by planting 10 seeds of pickled (Vitivax 200 FF) barley (germination 95-97%), barley (germination 95-97%) unfermented and watercress (germination 92-95%). To ensure the reliability of the research, the experiments were performed in quadruplicate. Upon completion of the study, the length and weight of the aboveground part and roots were measured. The results of the bioindication on the experimental substrates are presented in Fig. 5.



Fig.5.General view of common barley in the studied substrates on day 10

On the 10th day of the study, the number of seedlings of bioindicator plants did not differ much from control samples (pickled barley - 17.5%, watercress - 15%, and in untreated barley even exceeded them by 2.5%). With a content of 40% of sediments in the substrate in samples with pickled barley, there was a much greater impact on plant growth and development, namely: total plant weight \approx 18.5%, height of the ground from -25.8 to -54.6%, and for roots from -65.1 to -87.8%.

Therefore, as a result of the analysis of the results of the second stage of research it was found that fresh sewage sludge according to the results of laboratory studies contains a significant proportion of nutrients, and therefore can be used in the mixture to create a substrate. In addition, in the case of adding 20% of ERUs to the substrate, there is a positive effect on the growth of the aboveground part (stem) of barley.

After analyzing previous studies in the third stage, it was decided to add to the substrate sorbents of natural origin, to improve its quality and binding of mobile forms of hazardous compounds.

At this stage of the research, fresh sediments were added to the dark gray podzolic soil in the amount (%): 0; 20; 25; 30; 35; 40. In the same substrate in the amount (%): 0; 5; 7.5; 10 added natural zeolite. For the reliability of the experiments were performed in triplicate.

Bioindication was performed in Petri dishes by planting on the created substrate 10 seeds of barley (germination 95-97%). Upon completion of the study, the length and weight of the aboveground part and roots were measured.

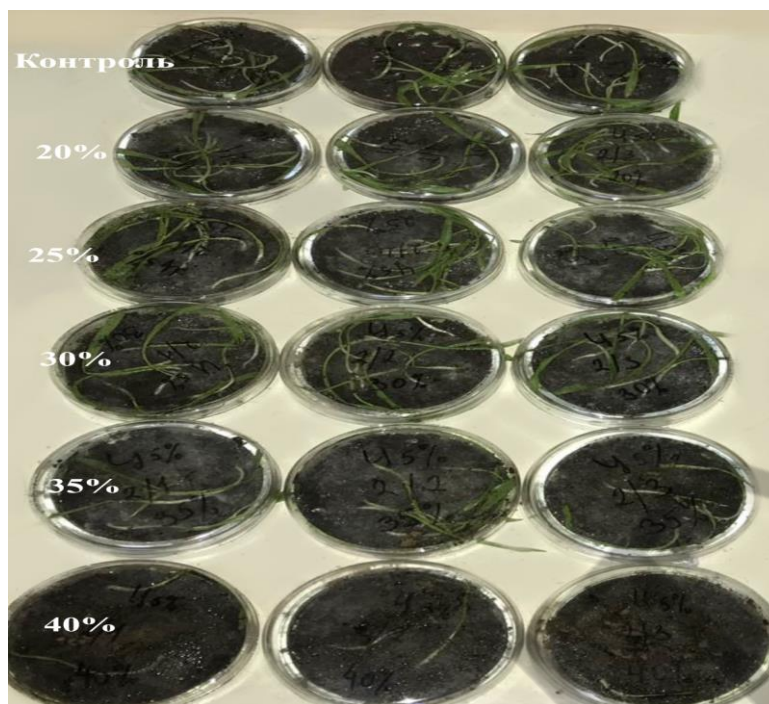


Fig.6. Germination of common barley in samples with a zeolite content of 5% per 10 days

According to the obtained data, the best growth rate of the terrestrial part of the plant is observed in the substrate with a ERU content of 35% and a zeolite content of 7.5%.

After analyzing previous studies in the fourth stage, it was decided to conduct studies with two types of natural sorbents.

At this stage, the study was performed with two types of substrate: the first added dark gray podzolic soil, fresh ERUs and zeolite, the second - dark gray podzolic soil, fresh ERUs and glauconite in the ratio (%): 50:40:10. Comparisons were performed with the control sample (soil). Bioindication was performed in plastic cups (volume 500 ml) by planting 10 seeds of barley (germination 95-97%) and 30 seeds of ryegrass (germination 90-93%). To ensure the reliability of the data, the experiments were performed in triplicate.

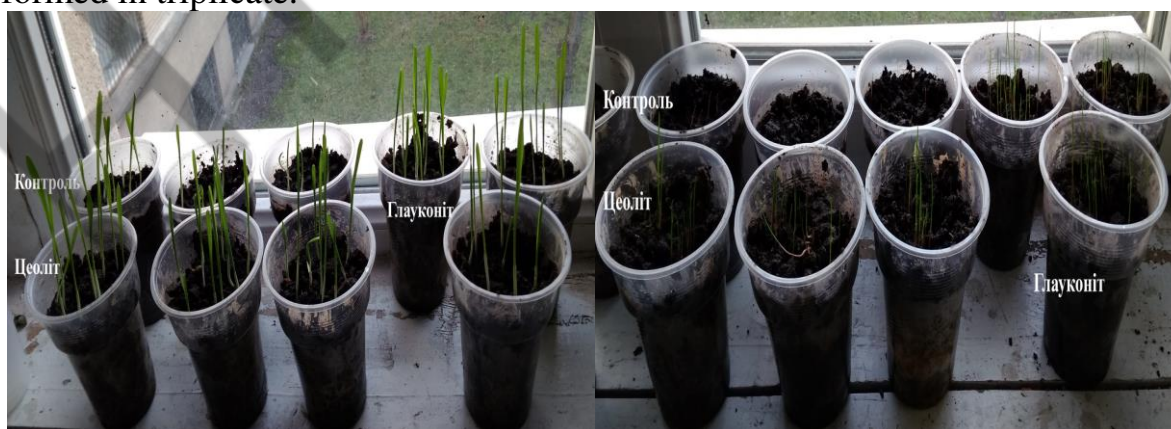


Fig. 7. General appearance of plants for 10 days

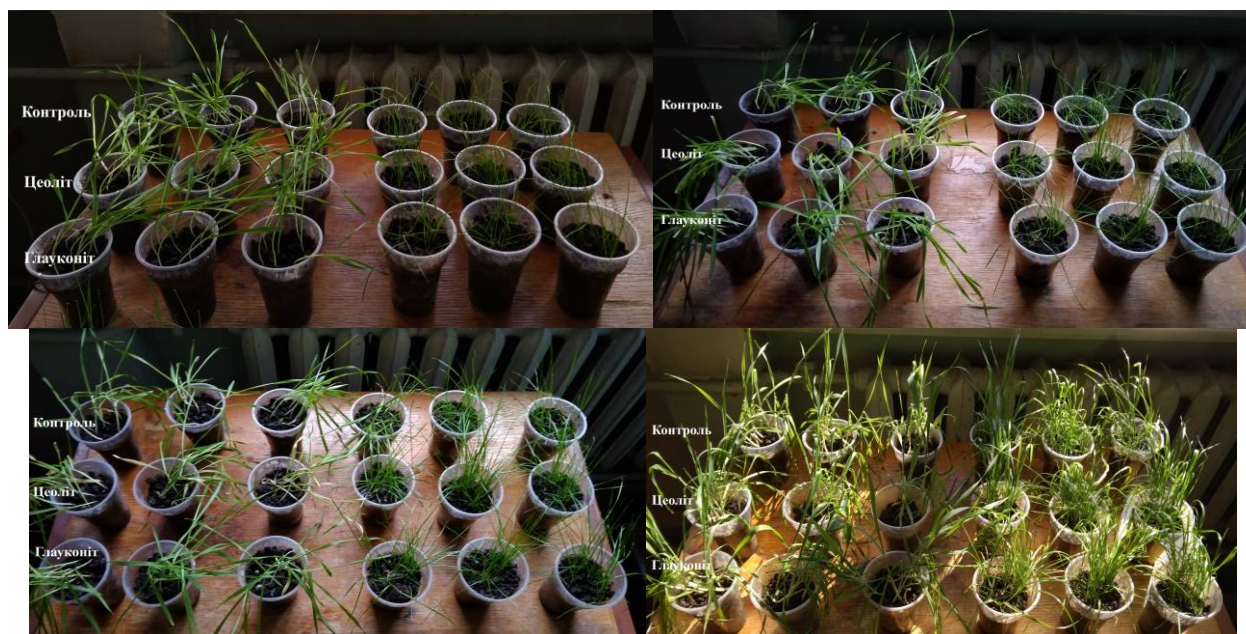


Fig. 8. General appearance of plants for 20,30,40,60 days

Thus, based on the results, we can conclude that in the case of adding two different types of natural sorbents (zeolite and glauconite) to the substrate, there are positive changes in germination, growth and development of bioindicator plants (barley and ryegrass). In addition, it should be noted that this composition of the substrate has a positive effect on the growth of ryegrass, which is an energy plant.

PROBLEMS OF DISPOSAL OF WASTE ACTIVE MUD IN POLAND

In Poland the basic legal act concerning sewage sludge is the Act of 14 December 2012 on Waste. According to it, every waste is identified by its own numerical code and thus 19 08 05 is the waste code of "stabilized municipal sewage sludge". Stabilization means the process by which organic substances from sewage sludge are transformed into inorganic substances or very poorly degradable material. The same deed states that the use of municipal sewage sludge is possible, when it is stabilized (i.e. with significantly reduced susceptibility to rotting, in which the organic matter content has been reduced by at least 38%) and after being prepared appropriately for the purpose and manner of its use.

Sewage sludge can be either treated within the installation of the wastewater treatment plant or it can be subjected to neutralisation or recovery outside it, in specialised processing plants. Sewage sludge disposal processes include storage of thermally treated or stabilized waste at hazardous waste landfills. On the other hand, in strong accordance with polish regulations, sewage sludge can be also recovered by being used as biomass, for industrial purposes, for agricultural use, for land reclamation or for composting. National Waste Management Plan 2022 and Strategy for dealing with municipal sewage sludge for 2019-2022 are another polish legal acts concerning waste management. According to them in 2016 the most common way to manage municipal sewage sludge was to use it in agriculture. Detailed information on different ways of municipal sewage sludge management in 2016 is presented in the Figure 9.

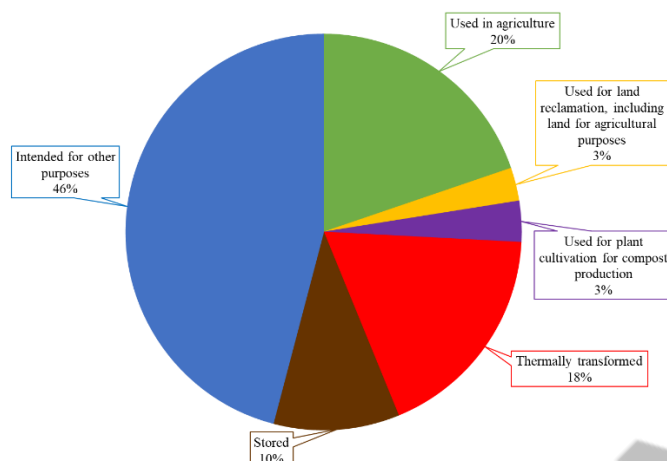


Fig.9. Ways of municipal sewage sludge management in 2016 [CSO 2016]

In recent years there can be observed an increased interest in the issue of sewage sludge management, useful components are recovered and simultaneously soils and waters are protected from contamination with heavy metals or pathogens contained in sewage sludge. Different physical, chemical and filtration properties of sewage sludge means that its processing and final treatment (disposal) requires an individual approach in each case. The main purpose of sludge treatment is to change its physical-chemical composition, reduce its volume, hydration and the concentration of organic matter, eliminate parasites and pathogenic bacteria and prepare them in such a way that it can be ultimately utilised. The fundamental problem with sewage sludge management is that there is no "typical" sewage sludge. Consequently, there is no one right solution for all wastewater treatment plants. Moreover, the amount of sewage sludge generated depends on the content of organic and mineral pollutants in wastewater, wastewater treatment technology, method of sludge stabilization or reagents used in wastewater treatment and sludge treatment. Other amounts of sludge are generated at household wastewater treatment plants and others in collective facilities.

NON-TRADITIONAL METHODS OF SEWERAGE MUD DISPOSAL IN POLAND

Conventional methods of sludge dewatering and stabilization are costly and energy-consuming. This is a very important especially for small wastewater treatment plants (serving up to 2 000 P.E.), which have very limited budgets. At present, sludge produced in household wastewater treatment plants are usually transported by septic trucks to collective facilities which is very inconvenient and expensive for the user of an object. Therefore, sludge is sometimes (although this is unacceptable) discharged in an unstabilized state into the natural environment, which may cause its pollution and degradation.

There is a strong need to find different low-cost solutions for solving the problem of sewage sludge treatment and disposal on a local scale. One of them is a method that simulates processes occurring in natural marsh ecosystems, called the constructed wetland method. This involves the use of specially constructed ground and plant beds planted with water-loving plants such as: water club, rush, calamus, wicker and the most often - common reed (*Phragmites Australis*). The presence of such plants allows

faster drainage of sludge and development of heterotrophic microorganisms. Thanks to its porous tissue called arenechyma, common reed has the ability to absorb water from sewage sludge and then release it to the atmosphere through evapotranspiration. Another phenomenon affecting sludge dewatering in reed beds method is water leaching, which occurs due to gravitational forces. In turn, transport of oxygen through leaves and stems from the atmosphere to the underground system of rhizomes and roots allows the formation of oxygen micro-zones there. Dewatered sludge in reed beds is also subjected to stabilization as a result of biochemical transformations occurring in the vicinity of reed roots. Constructed wetland systems with common reed for sewage sludge utilization are simple to build and inexpensive to operate, moreover their natural appearance allows them to be easily incorporated into the existing landscape. Sewage sludge brought to the reed beds is not removed for a long time, even for 10-15 years. The Figure 10 shows a scheme of an installation for sewage sludge dewatering.

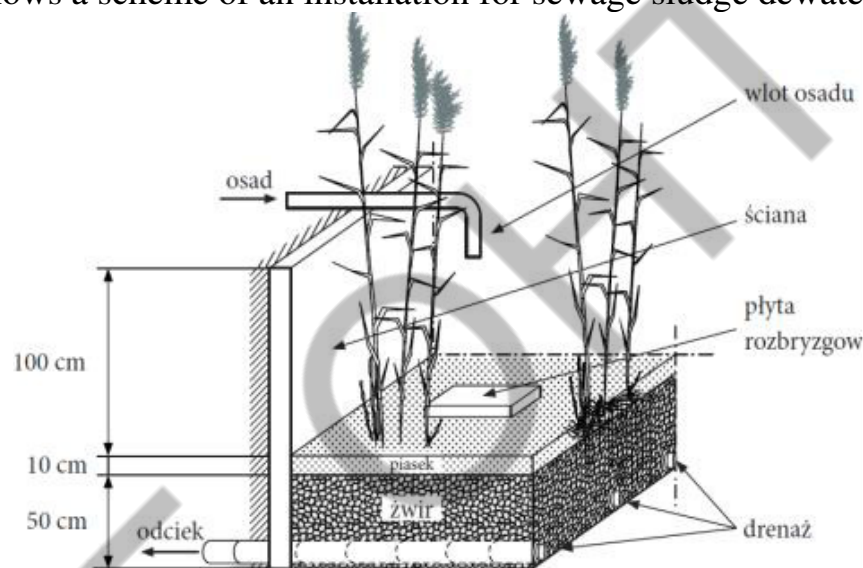


Fig.10. A scheme of an installation for sewage sludge dewatering

The method of reed bed systems for sewage sludge utilization has been known and used since the late 1980s in many European countries, including France, Denmark. In Poland, reed bed facilities are in operation, among others, at a household constructed wetland wastewater treatment plant in small Dąbrowica village near Lublin or at a big constructed wetland system near the Bialskie Lake in Dębowa Kłoda village (Figure 11).



Fig.11. Constructed wetland system with common reed for sewage sludge dewatering in Dąbrowica

The primary task of reed bed systems is to ensure the proper course of processes of dewatering and stabilization of the delivered sewage sludge. Stabilization processes reduce the intensity of unpleasant odours. Progressive stabilization is indicated by a decrease in organic matter concentration. During the dewatering process, the initially liquid sludge (99% of hydration) is transformed into a solid form. This contributes to a significant reduction in its volume. Increase of dry matter concentration of sewage sludge by 7% results in an 87% reduction of its initial volume. The efficiency of sludge dewatering in reed bed systems is comparable or higher than the efficiency of mechanical facilities. The advantage of constructed wetland systems compared to mechanical facilities is that they require significantly less electrical energy than mechanical.

Another type of promising technology is the application of an innovative installation for dewatering and disposal of sewage sludge produced in household wastewater treatment plants, constructed according to the Patent No. 218897 for the invention “Installation for sludge dewatering” of 19.06.2015. A technological scheme of the installation for dewatering and disposal of sewage sludge from the settling tank of the household wastewater treatment plant is shown in the Figure 6.

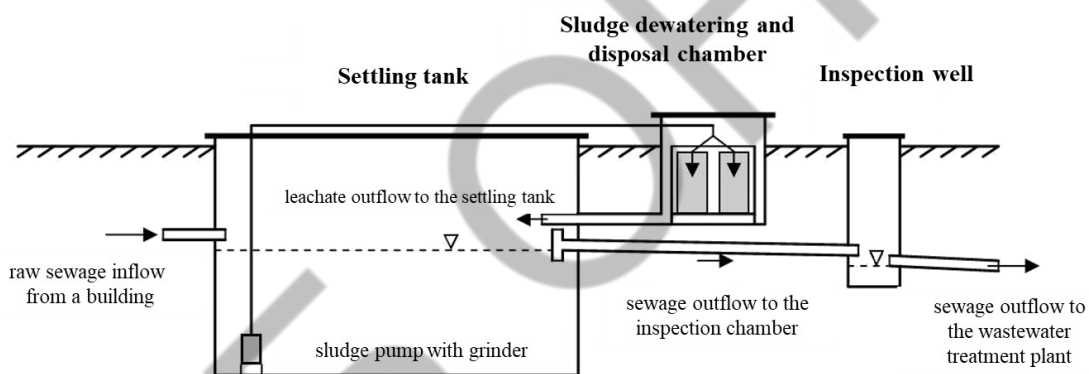


Fig.12. Technological scheme of the installation for dewatering and disposal of sewage sludge from the settling tank of the household wastewater treatment plant

The chamber for sludge dewatering and disposal is made of concrete circles in which a filter element in the form of water-repellent fabric bags is detachably mounted. In order to dewater sludge, the sewage sludge pump with grinder periodically switches on and sludge is pumped from the settling tank to the filtration unit where sludge is collected, while drained wastewater returns to the settling tank through the drain pipe. At the same time, from a special dosing device some substance is fed to the filtration unit, which hygienises the sludge and accelerates its transformation into compost, for example a complex bacterial preparation. After pumping is completed and the sludge is drained, the filter element is removed together with its contents and can be prepared for use as a fertilizer for agriculture. Numerous practical applications show that the use of some microbiological preparation can effectively support the process of dewatering and disposal of sewage sludge from wastewater treatment plants.

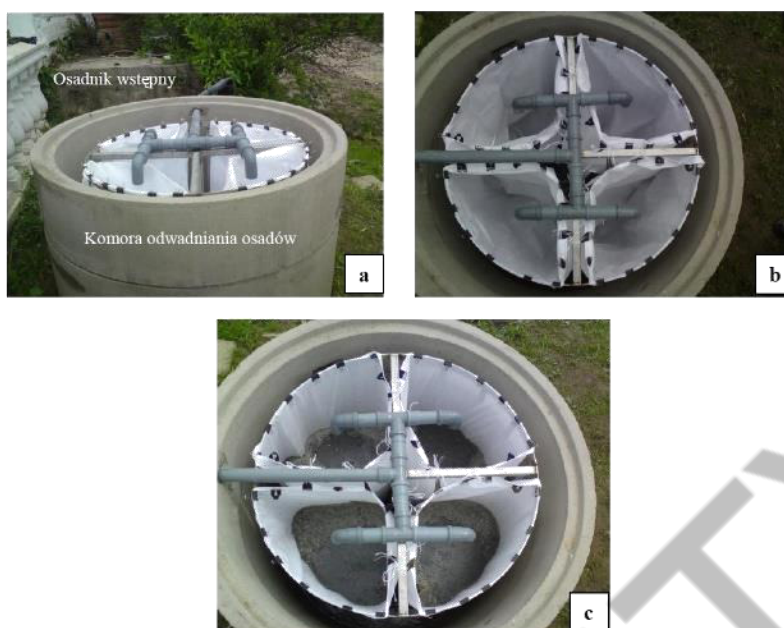


Fig.13. Installation for dewatering and disposal of sewage sludge produced in household wastewater treatment plants.



Fig. 14. Installation for dewatering and disposal of sewage sludge. a- in Florianka in the Roztocze National Park, b- in Stare Załucze in the Polesie National Park

The innovative installation for dewatering and disposal of sewage sludge has been already implemented in some household wastewater treatment plants in Poland, for example in Florianka in the Roztocze National Park or in Stare Załucze within the area of the Polesie National Park. Moreover, it is not necessary to transport later the disposed sludge to its destination.

CONCLUSIONS

According to the obtained research results, it can be concluded that: in case of addition of settled sediments to the substrate, inhibition of growth and development of bioindicator plants is observed due to the content of pathogenic microflora, fungi and mold in them; in the case of adding fresh sediments to the substrate, plant germination occurs only in samples where the sediment content does not exceed 40%; in the case of adding an additional component (natural zeolite) to the substrate, there is a positive effect on the germination of bioindicator plants. The best germination rates are observed in samples with a sediment content of 40% and a zeolite content of 7.5 and 10%, respectively.

Sewage sludge management is an integral part of wastewater treatment. The main purpose of sludge treatment is to change its physical-chemical composition, reduce its volume, hydration and the concentration of organic matter, eliminate parasites and pathogenic bacteria and prepare them in such a way that it can be ultimately utilised.

There are many different ways of sewage sludge disposal. Different physical, chemical and filtration properties of sewage sludge means that its processing and final treatment (disposal) requires an individual approach in each case.

Constructed wetland systems with common reed for sewage sludge utilization are simple to build and inexpensive to operate, moreover their natural appearance allows them to be easily incorporated into the existing landscape. The efficiency of sludge dewatering in reed bed systems is comparable or higher than the efficiency of mechanical facilities.

An innovative installation for dewatering and disposal of sewage sludge constructed according to the Patent No. 218897 for the invention "Installation for sludge dewatering" is a compact solution that enables the disposal of sewage sludge produced in household wastewater treatment plants.

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