Наведені результати експериментальних досліджень зневоднення надлишкового активного мулу з комунальних очисних споруд на камерно-мембранних фільтр-пресах. Для кондиціонування осаду було здійснено додавання золи виносу теплової електростанції у якості мінеральної добавки. Експериментальні дослідження показали високу ефективність зневоднення надлишкового активного мулу з додавання золи виносу. Збільшення дози золи виносу приводить до загального збільшення продуктивності фільтрування та зниженню вологості фільтраційного осаду (кеку). Було встановлено, що у разі додавання золи виносу у кількості 2 % від маси вихідного осаду ефективність зневоднення збільшується не суттєво. У цьому випадку тривалість фільтрування зменшується тільки на 15 %, а питома продуктивність збільшується на 12 %. У разі збільшення долі золи виносу до 6 % від маси вихідного осаду спостерігається більш інтенсивне прискорення процесу. Тривалість фільтрування скоротилася з 100 до 10 хвилин, питома тривалість збільшується з 87 до 400 літрів з квадратного метру за годину. Проведені експериментальні дослідження показали, що додавання золи виносу до осадів комунальних очисних споруд водовідведення в якості мінеральної складової забезпечує можливість зневоднення отриманих суспензій за допомогою камерно-мембранного фільтр-преса. При оптимальних дозах 4–5 % від маси вихідного осаду, прогнозована продуктивність очікується на рівні 350–400 л/м^2 на годину. Одержаний фільтраційний осад має власну вологість близько 60 %, щільну, суху структуру, що забезпечує можливість його транспортування в насипному вигляді

***Ключові слова:** камерно-мембранний фільтр-прес, кондиціонування, зола виносу, зневоднення, тривалість фільтрування, активний мул*

UDC 628.4
DOI: 10.15587/1729-4061.2019.170200

USE OF FLY ASH FOR CONDITIONING THE EXCESS ACTIVATED SLUDGE DURING DELIQUEFACTION AT CHAMBER-MEMBRANE FILTER PRESSES

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1. Introduction

Formation of sediments is inevitable in treatment of domestic wastewater at urban wastewater treatment plants. Such sediments include domestic waste from grates, mineral sediment collected in sand traps, moist sediment from primary settlers and excess activated sludge from secondary settlers.

Moist sludge, excess activated sludge or their mixtures are the most difficult in terms of their treatment and disposal. The main difficulties in processing sediments of above types are associated with large amounts of sediment and high moisture content (94–96 % for moist sludge, 98–99 % for excess activated sludge). Ability of household sewage sludge to rot, bacterial contamination and its property of moisture retention during deliquefaction also complicate sludge treatment [1].

High moisture content in sewage sludge leads to its accumulation in large volumes and creates significant problems with its transportation and further disposal. Since high moisture content of the fresh sewage sludge creates significant costs for the water treatment plants, it is important to ensure effective deliquefaction. To improve deliquefaction of sewage sludge, conditioning with the use of various materials is used [2].

The sewage sludge is conditioned by the following methods:

– chemical method: the use of organic (polyelectrolytes) and inorganic (salts of aluminum, iron) reagents;

– physical methods: mechanical (adding coal, ash, sawdust); thermal (heating, cooling); water washing, ultrasonic and electromagnetic treatment.

Chemical conditioning with the use of organic polymers is used at sewage treatment plants more often than other methods. Addition of chemical reagents enhances the ability to dewater sewage sludge by forming larger flocks than in untreated sludge. Main disadvantages of chemical conditioning consist in high doses of polyelectrolytes and the cost of these substances. Because of the high operating costs of sludge conditioning with organic flocculants, physical conditioning with various substances is considered.

Therefore, studies aimed at assessment of other, alternative methods of conditioning sewage sludge will be relevant and useful in solving a number of problems. The most difficult problem is the use of high doses of reagents in

Received date: 20.05.2019 Accepted date: 06.06.2019 Published date: 28.06.2019

treatment of sediments and their further deliquefaction as well as their impact on operating costs of wastewater treatment facilities.

2. Literature review and problem statement

Control of sediments formed at wastewater treatment plants has become a key issue. After thickening, removal of the remaining water by means of mechanical deliquefaction and/or thermal drying is necessary before disposal of any type. Polymers are used commonly at the conditioning stage to promote aggregation of particles and improve deliquefaction. Effect of dose and type of polymer on deliquefaction during convective drying of sediments is shown in [3]. The results clearly show the effect of conditioning on deliquefaction characteristics. However, it should be noted that only flocculants were considered in this study without comparing with effectiveness of sediment conditioning using mineral coagulants.

The studies presented in [4] are devoted to analyzing the effect of conditioning the sewage sludge using lime on the content of heavy metals. The authors found that this effect is ambiguous. Mixing sludge with lime often leads to a decrease in copper content along with increase in cadmium content. Mobility of metals also rises slightly. After lime treatment, the sewage sludge can be used as a fertilizer, however, it is necessary to remember about adequacy of the content of ammonium nitrogen in this sediment. This method has a drawback: addition of lime leads to a significant increase in pH of the sediment from 5.92 to 11.9. This can have negative consequences for soils in which the sediment will be introduced as a fertilizer.

Conditioning with mineral components, primarily lime in the form of lime milk, is optimal. However, it should be borne in mind that addition of any inorganic components increases percentage of solids in the dewatered sludge because of its own weight. At the same time, the filtration sediment acquires denser, drier structure, becomes suitable for transportation in bulk. However, in the cases where it is not the moisture content of the sediment that is important but the absolute content of liquid phase in the dehydrated sediment, it is necessary to calculate the material balance taking into account mass of the introduced solid phase.

The authors of [5] studied the effect of various methods for conditioning sewage sludge on its further composting and bioavailability of sediments. Five methods of sludge conditioning were investigated: chemical acidification, biological leaching, chemical conditioning with iron salts and lime and chemical conditioning using aluminum polychloride or polyacrylamide. The results showed that the bioavailable proportion of pyrene increased from 59.1 % in untreated sludge to 68.7 % in chemically acidified sludge and to 79.3 % in biologically leached sludge. However, the other three approaches to conditioning did not significantly change bioavailability of pyrene. The authors did not compare these methods of sediment conditioning with application of physical methods, such as adding ash or coal.

Effect of various types of polymers on the sediment deformation and microscopic properties was studied in [6]. Polymer dose has appeared to be the main parameter controlling these properties. However, it is necessary to identify effect of various types of flocculants on moisture loss properties of sediments upon their further deliquefaction.

Article [7] presents the results obtained in the study of effect of sludge conditioning on rheological parameters (deformation and fluidity). It was found that regardless of presence of anaerobic fermentation, all samples of sludge had a qualitatively identical rheological behavior while sediments had different quantitative behavior. It was also proven that concentration of suspended solids and temperature influence the sediment rheology. These studies were devoted to assessment of influence of physical conditioning methods on sediment properties. It is important to study the experimental data when using mineral coagulants or combined conditioning methods.

Various conditioning methods were studied in [8] for deliquefaction of sewage sludge in a plate filter press: use of ultrasound, acid hydrolysis with various acids and alkaline hydrolysis with NaOH. It was found at the stage of sludge conditioning that ultrasonic treatment resulted in about 6.5 % decrease of suspended solid concentration but did not have a significant destruction effect on suspended mineral and organic substances. It was also found that ultrasonic treatment increases the chemical oxygen demand (COD) by 40.35 %. When using HNO_3 for acid hydrolysis, an increase in COD by 81.82 % was obtained. It was also observed that alkaline hydrolysis using NaOH resulted in poor filter press capacity in sludge deliquefaction. As a result of combination of hydrolysis and electric deliquefaction, it was found that moisture content in sediment can be reduced to 71.88 %. However, the use of these conditioning methods is resource and energy-consuming leading to an increase in the cost of treatment and further disposal of sewage sludge. Other materials and reagents for sediment conditioning which would reduce operating costs should be considered.

The effect of conditioning of sewage sludge by bio-oxidation caused by Acidithiobacillus ferrooxidans LX5 bacterium was studied in [9]. The effect on the rate and degree of deliquefaction of sewage sludge by compression was studied. The results showed that bio-oxidation of sludge by Acidithiobacillus ferrooxidans LX5 simultaneously improved both the rate and the degree of sludge deliquefaction which was not achieved using other methods. Decrease in sludge pH caused damage to the microbial cell structures of the sludge during sludge bio-oxidation which increased the degree of sludge deliquefaction. Addition of Fe^{2+} and its subsequent bio-oxidation to Fe^{3+} has made it possible to flocculate effectively the damaged sludge flakes and improve deliquefaction. In the process of deliquefaction by compression consisting of filtration and expression stages, a high degree of moisture removal and a short deliquefaction time during the filtration stage were achieved. In addition, it was found that high efficiency of biological acidification by A. ferrooxidans LX5 bacteria during deliquefaction of sewage sludge cannot be achieved by means of chemical treatment of the sludge by modifying pH and adding Fe^{3+}. The method of bio-oxidation of sewage sludge requires further study since it is necessary to establish optimal environmental parameters to ensure high productivity and vital activity of bacteria A. ferrooxidans LX5.

Analysis of efficiency of sewage sludge conditioning using biomass ash (after burning straw and willow tree) with a dosage of ash in the range of 5–30 g/dm^3 was made in [10]. The results confirmed different efficiency of the use of ash in deliquefaction of sewage sludge depending on the type of biomass ash. The greatest efficiency in deliquefaction of sewage sludge was shown by willow ash with a dosage of 30 g/dm^3. Small doses of biomass ash (5 and 7.5 g/dm^3) slightly affect moisture content in the wastewater. Therefore, the use of biomass ash in conditioning of sewage sludge is an alternative solution for sludge deliquefaction. However, it should be pointed out that to obtain biomass ash from straw and willow requires additional energy inputs. The latter will lead to an increase in the cost of treatment and disposal of sewage sludge.

It is well known that sediments of municipal wastewater treatment facilities belong to suspensions difficult to filter. Attempts to filter them using high pressure lead to a rapid formation of a «barrier» layer on the filter compartment caused by the high degree of compressibility of organic components of the solid phase. Nevertheless, the use of synthetic flocculants which give a certain positive effect on deliquefaction when using band filter presses or dehydrators of various designs does not lead to a sharp intensification of deliquefaction. In the case of a chamber-membrane filter press, the filter cake has a gel-like, almost pseudoplastic structure, even after pressing with high-pressure membranes. Various types of additives can be used as inorganic constituents, for example, wastes of various nature, in particular fly ash.

The author of [11] has found that it is advisable to process sewage sludge from pulp and paper plants in a mixture with the heat power plant ash. Ash was introduced into sediments before the stage of their compaction. When dosing ash from 30 to 50 % of dry matter, duration of the activated sludge compaction was reduced 2 times and concentration of dry matter increased 1.5 times at a conventional duration of compaction. It was found that with the additional introduction of cationic flocculant in an amount of up to 0.6 kg/ton of dry matter, sediment compaction is intensified and the ash dosage is reduced to 20–30 %. Joint compaction of sludge-containing sediments with ash and flocculants leads to an improvement in quality of the supernatant liquid. Its clarity increases 1.4–4 times and the content of suspended solids decreases 1.2–7 times. Deliquefaction of sediment mixtures with ash reduces the cake moisture by 3.5–14.0 %. At the same time, specific filtration capacity increases 1.2–1.7 times (without taking into account the dry substances of ash). A sharp improvement in sedimentation and filtration properties of these sediments is observed as well. However, it must be pointed out that when thermal power station ash is added at the stage of compaction of activated sludge, significant dosage of ash (up to 50 %) is required. Addition of cationic flocculants will lead to an increase in operating costs when deliquefaction of the mentioned sediments is conducted.

Conditioning of sewage sludge is one of important stages in their mechanical deliquefaction. Effectiveness and speed of the process of preparing sediment for deliquefaction depends on the chosen method of conditioning. However, it is necessary to take into account economic and environmental feasibility of the chosen method since composition and structure of the resulting product (dehydrated sludge) depends on this point. Further usability and environmental safety of the resulting product directly depend on the chosen method of conditioning and treatment of sewage sludge. Therefore, the study of usability of fly ash taken from thermal power plants for conditioning excess activated sludge during deliquefaction in chamber-membrane filter presses is a pressing issue. Fly ash of thermal power plants is one of the waste products piled up in dozens of tons on the territory of these enterprises. The use of this type of waste for conditioning of sewage sludge during its deliquefaction will reduce its piling. Also, advantage of fly ash compared with chemical reagents consists in its environmental safety when added to sewage sludge. Deliquefaction of sediments using band filter presses or dehydrators of various designs and mineral and organic additives does not make it possible to intensify the process sharply. When working namely with chamber-membrane filter presses, introduction of mineral additives enables change of structure of the sediment built up in the chamber space. This affects not only moisture content in the final sediment but also the rate of its formation resulting in a sharp increase in productivity.

3. The aim and objectives of the study

The study objective is to elucidate effectiveness of the use of wastage from thermal power plants, that is, fly ash, for conditioning excess activated sludge during its deliquefaction in chamber-membrane filter presses.

To achieve the objective, the following tasks were set:

– determine parameters of filtering sediments of municipal wastewater treatment plants when adding fly ash in chamber-membrane filter presses;

– study dependence of filtering duration and moisture content in the sediment resulting from addition of a dose of fly ash;

– establish the effect of introduction of fly ash in excess activated sludge on performance of the chamber-membrane filter press.

4. The materials and methods applied in establishing parameters of filtering the activated sludge using fly ash

A laboratory model of a chamber-membrane filter press was used as test equipment (Fig. 1). Confirmation of laboratory data was carried out on a pilot chamber-membrane filter press of BM-16.4.30.S model with 470×470 mm plates (Fig. 2). Maximum pressure: 16 bar, surface area: 4 m^2, maximum deposit thickness: 30 mm.

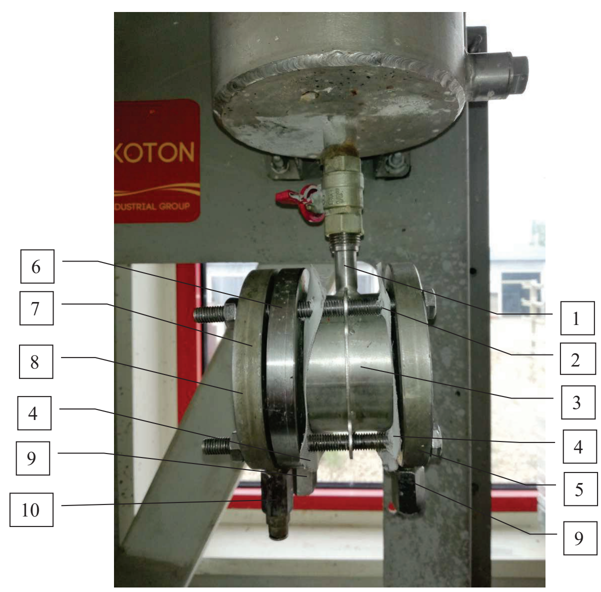

Fig. 1. General view of the laboratory model of a chamber-membrane filter press: suspension inlet (1); ties (2); filtering chamber (3); filter cloth (4); drainage surface (5); movable membrane with drainage surface (6); squeezing membrane (7); submembrane chamber (8); filtrate outlet (9); feed under the membrane (10)

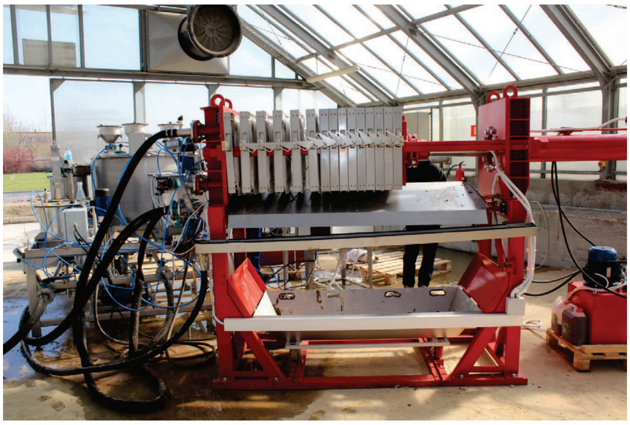

Fig. 2. General view of the pilot chamber-membrane filter press, BM-16.4.30.S model

The laboratory model is a chamber 3 with feed into the upper end 1. The chamber is confined with a flat stationary drainage surface 5 at one end and with a movable membrane with a drainage surface 6 at the other end. Suspension is fed through its forcing off the montejus by compressed air at pressure up to 6 bar. Compressed air at pressure up to 16 bar is used for the membrane operation. The model includes a set of chambers of various thicknesses from 15 to 50 mm.

In first experiments, the suspension volume sufficient for formation of 10 mm thick sediment layer which corresponds to 20 mm thick sediment layer when filtering in a real filter press (the BM-16.4.30.S pilot filter press) was determined. Subsequently, duration of filtration, mass and moisture content in the filter cake were measured in each individual experiment and specific filtration capacity was calculated. When filtering by means of the filter press model, dosages of fly ash were determined for addition to the sludge. The dose at which duration of filtration was reduced to 5 minutes was taken as the maximum dose for adding. A further increase in the dose of fly ash does not make practical sense when working with a real filter press. When working with a pilot filter press of BM–16.4.30.S model, steps of pressing with membrane and/or purging the sludge with compressed air were used as auxiliary steps.

When conducting studies, the following parameters were determined for filtering sediments of municipal wastewater treatment facilities when adding fly ash in the chamber-membrane filter presses:

– filtration pressure: 6 bar;
– membrane squeezing pressure: 16 bar;
– membrane squeezing duration: 3 min.;
– sediment purging pressure: 6 bar;
– sediment purging duration: 2 min.;
– duration of auxiliary operations: 10 min.

Fly ash of a thermal power plant was chosen as a mineral additive for conditioning the sludge of municipal wastewater treatment facilities. Fly ash is a fine dispersed material with particle size less than 0.315 mm formed from the mineral component of solid fuel combusted in a dust-like state and captured by ash collecting devices from the flue gases of thermal power plants.

Table 1 shows data on the main initial parameters of suspension (of the excess activated sludge) and fly ash during sludge deliquefaction in the laboratory chamber-membrane filter press.

The sediment obtained after deliquefaction in a laboratory chamber-membrane filter press with addition of fly ash is shown in Fig. 3.

Table 1

Parameters of suspensions (of the excess activated sludge and fly ash) during deliquefaction in a laboratory chamber-membrane filter press

Sample 1. Pure ash diluted in water			
No.	Name	Parameter	Note
1	Type of suspension for filtering	Ash	–
2	Sample volume, ml	350	water: 350 ml, ash: 50 g
3	Pressure, bar	2	–
4	Drying time, min	1	–
5	Filtration time, min	5	–
6	Sediment thickness, mm	30	–
7	Cake mass, g	50	–
Sample 2. Pure excess activated sludge			
1	Type of suspension for filtering	Excess activated sludge	–
2	Sample volume, ml	100	–
3	Pressure, bar	5	–
4	Drying time, min	1	–
5	Filtration time, min	11	–
6	Sediment thickness, mm	2	–
7	Cake mass, g	3	–
8	Moisture content in initial sediment, %	99.3	0.7
9	Reagent dose	no	–
Sample 3. Pure excess activated sludge			
1	Type of suspension for filtering	Excess activated sludge	–
2	Sample volume, ml	300	–
3	Pressure, bar	6	–
4	Drying time, min	1	–
5	Filtration time, min	98	12.51–14.29
6	Sediment thickness, mm	10	–
7	Cake mass, g	no	–
8	Moisture content in initial sediment, %	99.3	0.7
9	Reagent dose	no	–

Fig. 3. Sediment after deliquefaction in a laboratory chamber-membrane filter press with addition of fly ash

When determining parameters of filtering in a chamber-membrane filter press, it is necessary to consider additionally the periodic nature of this press operation. When operating the equipment, it is necessary to take into account presence of the so-called «non-productive» operations in the cyclogram during which suspension is not taken away. Therefore, the specific filtration performance is determined not only by the filtration rate during actual filtration but also by the proportion of «non-productive» operations during the operation cycle time. The use of chambers with the lowest possible depth is obvious for slowly filtered suspensions but on the contrary, it is advisable to stretch filtration time to a greater sediment thickness (40–50 mm) for short filtration cycles (up to 30–40 min).

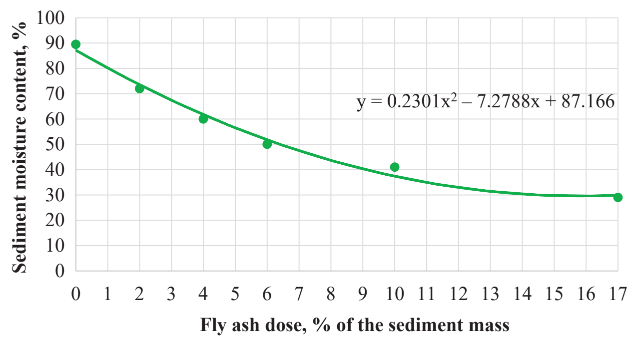

Fig. 5. Influence of ash dose on moisture content in the filter cake

5. The results of determining performance of chamber-membrane filter presses for deliquefaction of activated sludge with fly ash

Results of the experiment with the pilot filter press, BM-16.4.30.S model, with filtration pressure of 6 bar are presented in Table 2 and Fig. 4, 5. The data obtained make it possible to study dependence of filtration time and the moisture content in the resulting sediment on the introduced dose of fly ash. Also, the experimental results allow us to establish effect of introduction of fly ash in the excess activated sludge on capacity of the chamber-membrane filter press.

Table 2

Dependence of filtering duration, moisture content in the sediment and capacity of the chamber-membrane filter press on the dose of ash

Ash dose, % of the sediment mass	Filtering time, min.	Moisture content in the resulting sediment, %	Filtering capacity, $l/m^2 \cdot hr$	
			average during filtration	specific during the entire cycle
0	100	89.5	100	87
2	85	72	115	98
4	35	60	290	200
6	10	50	1,000	400
10	7 (10)	41	1,450	400
17	5 (10)	29	2,000	400

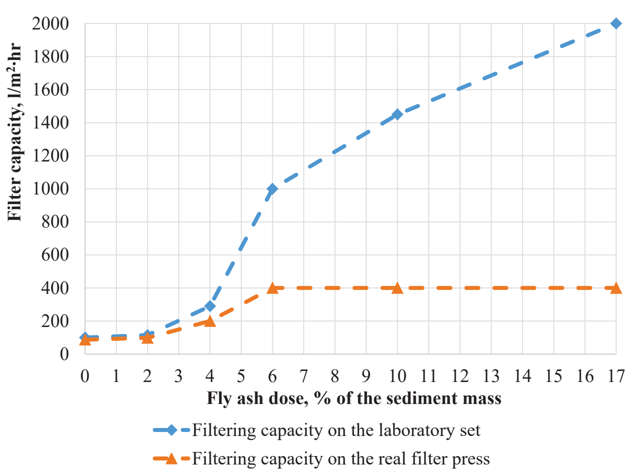

Fig. 4. Possible patterns of influence of ash dose on filtering capacity

As noted earlier, a decrease in the relative moisture content in the sludge when adding mineral additives may not lead to a decrease in absolute content of the liquid phase in the sludge. Fig. 6 shows dependence of the absolute mass content of water in the sediments obtained by filtering 1 kg of suspension.

Analysis of Fig. 4 shows that the potential filtration capacity of the filter press increases with the dose of introduced ash. It can also be seen that moisture content in the resulting sediment decreases with an increase in doses of fly ash (Fig. 5).

A decrease in the relative moisture content in the sediment upon addition of mineral additives can be achieved both by increasing mass of the solid phase and improvement in the moisture loss indicator of the initial suspension. The latter can be achieved by forming a more favorable pore structure with introduction of a mineral additive. Fig. 6 shows dependence of mass distribution of the solid phase of activated sludge, water and fly ash in the filter cake obtained by filtering a suspension prepared from 1 kg of activated sludge on the percentage of fly ash.

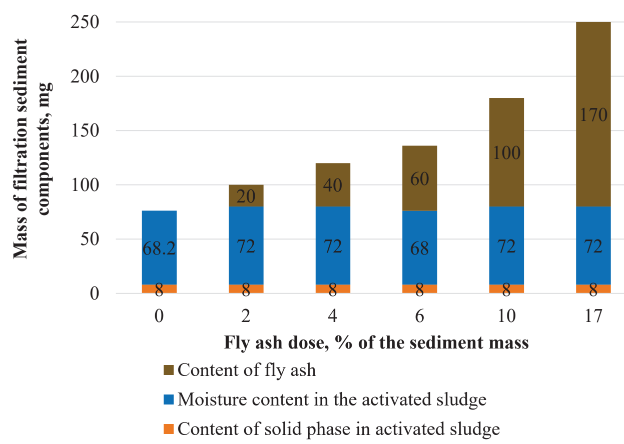

Fig. 6. The mass of components (dry activated sludge, water, fly ash) in the filter cake

When analyzing Fig. 6, it can be noted that the absolute solids content in the sludge and moisture does not change. The relative content (moisture content) changes due to an increase in share of the solid phase from addition of fly ash.

Proceeding from Fig. 6, it follows that increase in the dose of fly ash in the volume of excess activated sludge during its deliquefaction does not result in an increase in moisture separation.

6. Discussion of the results of operation of the chamber-membrane filter press during deliquefaction of activated sludge with fly ash

As can be seen from the data in Table. 2 and Fig. 4, 5, increase in the dose of fly ash in suspension naturally leads to an overall increase in filtration capacity and a decrease in moisture content in the filter cake. However, the observed increase in efficiency of deliquefaction is non-linear. When adding fly ash in an amount of 2 wt. % of the initial sludge, efficiency of deliquefaction increases slightly: filtering time is reduced by only 15 % while specific capacity increases by 12 %.

With the growth of fly ash share to 6 wt. % of the initial sludge, a more intensive acceleration of the process is observed. In this case, filtering duration is reduced from 100 to 10 min, specific capacity increases from 87 to 400 l/m^2·hr. Regularities of the processes of suspension filtering through porous partitions have been repeatedly considered by many authors [12–14]. Virtually all such works consider the Darcy law as applied to incompressible sediments which, when going to real suspensions, is supplemented with various modifications in the form of variations of averaged specific parameters.

At the same time, the main principle based primarily on the analysis of experimental data remains unchanged: an increase in the pressure difference on both sides of the filter partition leads to an increase in filtration rate. At the same time, filtration resistance increases because of a decrease in permeability of the sediment layer.

Taking into account the natural increase in sediment resistance with an increase in its thickness during the process, the resulting filtration kinetics can be expressed by an equation of the form:

$$u = \alpha \frac{P \cdot \left(\frac{a \cdot n_0}{e^{cP}} + b \right)}{h}, \qquad (1)$$

where u is the filtration rate, α; a, b, c are coefficients; P is the overpressure, n_0 is the sediment porosity without pressure; h is the sediment thickness.

For the purposes of this study, three generalizations arising from analysis of experimental data and this equation are important:

1. Filtration rate can be increased by increasing pressure but only to a certain value above which the increase in filtration rate slows down significantly.

2. A certain «boundary» sediment thickness can be distinguished above which filtration rate also slows down significantly.

3. Filtration can be accelerated by reducing specific compressibility of particles in the solid phase.

A further increase in the share of fly ash is no longer as effective, especially in the context of operation of a real filter press: an increase in this share to 17 % leads to an increase in the specific productivity up to 500 l/m^2·hr. Additionally, filtering duration about 5 min easily obtained with the help of montejus under laboratory conditions is difficult to achieve under conditions of pumping the suspension to a real filter press. With such short filtering durations, it is already necessary to take into account time of filling of the filter press, instantaneous feed rate of suspension at the start of filtration, throughput of supply lines and possible energy loss for operation of a high-performance pump. In the framework of this work, we have taken minimum filtering duration in a real filter press within 10 minutes.

It was established that at the maximum studied dose of fly ash, numerical value of relative moisture content in the filter cake decreases to 30 %.

However, the data presented in Fig. 6 indicate that the effect is almost completely achievable by adding a mass of fly ash to the mass of solid phase of initial suspension. Therefore, further addition of fly ash does not lead to an increase in dehumidification.

In order to implement and develop this technology for conditioning sediments of municipal wastewater treatment plants, several factors must be taken into account. These factors include the cost of transportation of the ash to the place where sludge deliquefaction will take place with addition of fly ash. Feasibility study on the use of fly ash from thermal power plants during deliquefaction of sludge from municipal wastewater treatment plants should be performed for concrete projects.

However, a positive environmental effect should be noted: cleaning of land resources from ash dumps and sludge sites, reducing the volume of and moisture content in the resulting suspensions.

Further use of the dry mixture (activated sludge and fly ash) is possible: burning. Sediment burning is possible due to the content of organic part in the activated sludge. The ash resulting from combustion can be returned later to the cycle of mechanical deliquefaction of new sediment portions. It is also possible to use sludge after its combustion as a filler for production of building materials, a basis for pavement or a fuel for thermal power stations.

7. Conclusions

1. Experimental studies have shown that addition of fly ash to sediments of municipal sewage treatment plants as a mineral component provides the possibility of deliquefaction of the suspensions obtained using a chamber-membrane filter press. With optimal doses of 4–5 % of the mass of the initial sludge, the projected performance is expected to be 350–400 l/mm^2·hr. The resulting filter cake has its own moisture content of about 60 %, dense dry structure providing the possibility of its transportation in bulk.

2. Increase in the dose of fly ash in suspension naturally leads to an overall increase in filtration capacity and a decrease in moisture content in the filter cake. However, the observed increase in efficiency of deliquefaction is non-linear. When adding fly ash within 2 wt. % of the initial sludge, efficiency of deliquefaction increases slightly: filtering time is reduced by only 15 % while specific capacity increases by 12 %.

With the growth of the share of fly ash to 6 wt.% of the initial sludge, a more intensive acceleration of the process is observed. Then, filtering time is reduced from 100 to 10 minutes, specific productivity increases from 87 to 400 l/m^2·hr.

3. Increase in share of fly ash is no longer as effective, especially in the context of a real filter press operation: an increase in the share to 17 % leads to an increase in specific capacity of up to 500 l/m^2·hr.

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