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Wastewater Sludge Conditioning with Diatomite Used for Beer Breaking

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Abstract

This paper presents the results of an experiment on the use of diatomite from beer breaking, as a filtration agent in wastewater sludge dewatering. Results of the study have allowed us to conclude that it may be one of the practical ways to dispose of this troublesome waste product.

Keywords: dewatering, condition sludge, diatomite, yeast cells, wastewater sludge

Introduction

Conditioning is indispensable in sludge dewatering as sludge has the ability to hold water and thereby impede filtration. Conditioning prepares sludge for mechanical dewatering by the change of its structure and physico-chemical properties. As a result, sludge particles increase their size, the force bonding water onto their surface decreases and water can be more easily separated from the sludge.

For conditioning, the following agents can be used: organic flocculent - polyelectrolytes, and inorganic chemicals such as ir.on and aluminium salts, or lime. Diatomite has also been reported as a filtration agent [1].

Diatomite originates from the Tertiary and Pleistocene periods, when it was formed from the shells of dead diatoms that had sunk to the bottom of water reservoirs. It is widely used in many industries. Very high porosity makes it a perfect adsorbent, used in the food and chemical industies to filtrate (break) drinks. For instance, in beer breaking diatomite is used to hold-up yeast cells. However, over the course of time the sorption capacity of diatomite ceases and it becomes a useless and troublesome (due to quantity) waste.

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The objective of this study was to determine the influence of diatomite polluted by yeast cells on the conditioning process of the wastewater sludge. The authors' intention was to find out whether waste diatomite would improve the sludge structure in the same way as pure diatomite, and whether the initial increase of solids concentration, resulting from the addition of diatomite, would improve the effectiveness of the sludge dewatering.

Materials and Methods

In the tests, stabilised wastewater sludge from an Imhoff tank in a small domestic wastewater treatment plant was used. After gravitational thickening, the sludge hydration ranged from 92.65 to 96.02%, therefore the sludge was classified as "watery". Dry solids concentration in the dewatered sludge varied between 39.8 and 73.5 g/dm^3, out of which 18.6 to 30.4 g/dm^3 comprised the mineral residue. The values were similar for all samples used in the given experiment run.

For sludge conditioning the following agents were used: dried diatomite polluted by beer yeast - DY (run 1), dried diatomite containing yeast and quicklime CaO (run 2), and finally, a mixture of diatomite and lime pre-

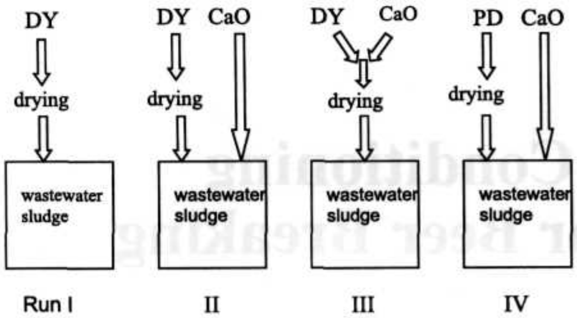

Fig. 1. Scheme of the experiment.

pared without DY drying but dried after mixing (run 3). As a reference, the tests were carried out using pure diatomite and quicklime CaO (run 4) (Fig. 1).

The experiments on laboratory scale were carried out by the vacuum filtration method. Sludge dewatering tests were performed in a vacuum filter model (a Biichner funnel, connected with the vacuum pump) in accordance with the commonly practised method [2, 3]. Filtrate was collected in a beaker of 30 ml volume. Filter paper played the role of the filtering medium.

The conditioning chemicals were dried at 105°C and added to the sludge in the amounts of 5, 10 and 20% of dry solids. Sludge samples of defined volume were mixed with the filtration agents for 5 min by a magnetic stirrer at constant speed, in order to obtain a homogenous solution. A Buchner funnel with filter was dosed with 40 ml of the sludge. When the first drop of filtrate was collected, the vacuum pump was switched on (negative pressure 0.6 Pa), and the volume of filtrate was measured in defined time intervals. Filtration continued until 30 ml of the filtrate was collected.

To determine whether the sludge was amenable to dewatering, filtration rate, (filtrate volume in a time function V = f(t)), specific resistance of filtration (r) and dewatering rate were measured.

Rate of the mechanical dewatering of sludge depends on specific resistance of filtration: the lower the resistance, the more effective and quicker the dewatering.

Specific resistance of filtration depends on the type and moisture content of the sludge. This parameter comprised of the sludge resistance and the filtration medium resistance. Because in the whole experiment the same filtration medium was used, changes of the specific resistance of filtration resulted from changes in sludge resistance.

$$r = \frac{2 \cdot b \cdot P \cdot S^2}{\mu \cdot c} \qquad [\text{cm/g}]$$

b - tangent of a line slope in a coordinate system t/V = f(V) (t - filtration time, V - filtrate volume) [s/cm^3]
P - used negative pressure [Pa]
S - filtration surface [cm^2]
μ - coefficient of dynamic viscosity [= 0.01 Pa·s]
c - solids concentration in filtrate unit [kg/m^3]

Acidity, alkalinity and pH-value of the filtrate were examined to determine the influence of the type and dosage of conditioning agent on the pH-value of the filtrate.

Results and Discussion

In the first run of the study, in which the sludge was conditioned with diatomite containing yeast (DY), filtration rate - compared to dewatering rate of the unconditioned sludge - grew faster only when the maximum DY dosage was added, i.e. 20% of dry solids. At lower dosages the rate even decreased (Fig. 2).

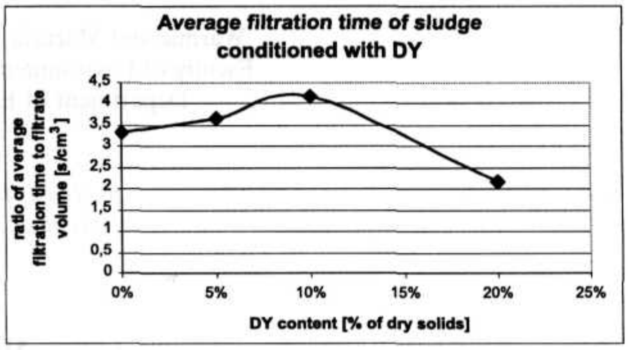

Fig. 2. Impact of the sludge conditioning with diatomite containing yeast on the filtration time.

The specific resistance of filtration, having an impact on this parameter, decreased markedly (by about 30%) also at maximum DY dosage, and equalled 2.1·10^{-14} m/kg (Fig. 3). Lower dosages of diatomite containing yeast did not cause a decrease in specific resistance of filtration.

The maximum quantity of DY also caused a few percent decrease in sludge hydration after filtration (Fig. 4).

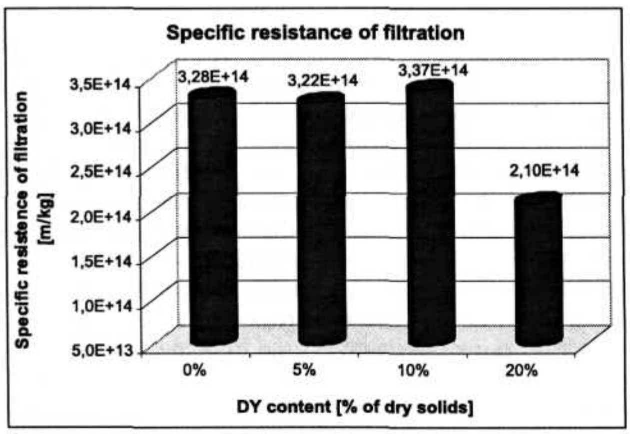

Fig. 3. Changes of the specific resistance of filtration, caused by conditioning with diatomite containing yeast.

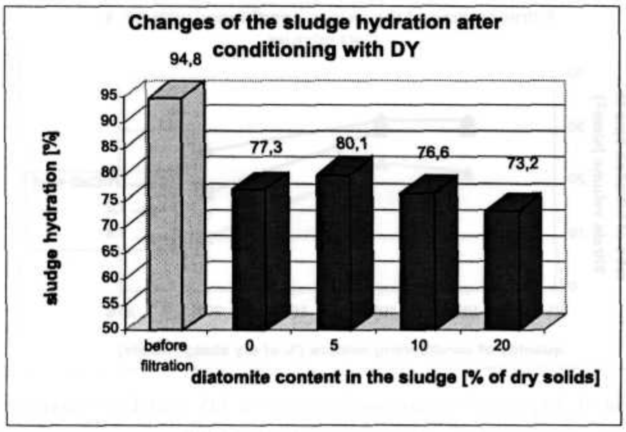

Fig. 4. Influence of wastewater sludge conditioning with diatomite containing yeast on sludge hydration after filtration.

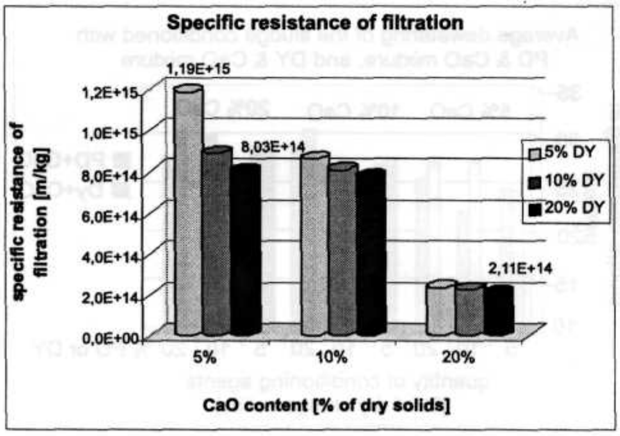

Fig. 6. Changes of the specific resistance of filtration caused by various quantities of dried diatomite containing yeast and lime, added to the sludge before filtration.

After filtration it equalled 73-80% and therefore the sludge was characterised as "doughy" [4]. pH (close to neutral) and alkalinity were not changing, whereas acidity grew as DY quantity increased.

In the second run, dewatering of the sludge conditioned with the mixture of diatomite containing yeast with CaO (prepared after DY drying) was tested. It was observed that filtration rate increased considerably with an increase of CaO dosage. Sludge hydration after filtration decreased, although at the higher CaO dosage a better effect was observed. It ranged from 64.5-72% ("soggy soil" or "doughy" consistence of the sludge [4]) which, taking into consideration initial hydration (i.e. before filtration) of 92.7%, resulted in the average dewatering (percent decrease of the hydration, as compared to the initial hydration assumed as 100%) higher than in the case of only DY application (Fig. 5). For instance, when diatomite dosage of 10% of dry solids was applied, sludge hydration decreased by 19.2%, whereas at 5% diatomite and 5% lime dosage (% of dry solids) hydration decreased by 24.7%.

The specific resistance of filtration was decreasing when dosage of the conditioning agents increased, although in this case a better effect of lime dosage increase than of DY was also observed; however, at 5% CaO dosage the increasing DY quantity reduced the specific resistance by about 1/3 (Fig. 6). The best result was observed at 20% DY and 20% lime dosage when the specific resistance of filtration equalled $2.11 \cdot 10^{14}$ m kg^{-1}, and it was over 5.5 times lower than the specific resistance measured at 5% dosages of diatomite and lime.

The pH-value of the filtrate rose with an increase of lime quantity, from the value of 8.5 up to 12.3 pH. So was alkalinity of the filtrate (Fig. 7).

Dewatering results of the sludge conditioned with a mixture of pure diatomite with lime revealed that the filtration rate decreased considerably with an increase of both lime and diatomite dosage; however, lime dosage increase was more effective. It was also observed that the low diatomite dosage of 5% had a minor effect. The results of dewatering were very similar to those obtained when the "polluted" diatomite was used (Fig. 8). At the

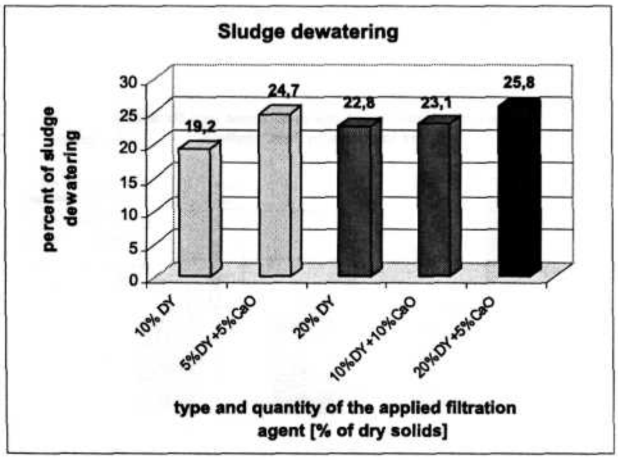

Fig. 5. Comparison between the dewatering effectiveness of waste diatomite and waste diatomite with lime (selected dosages).

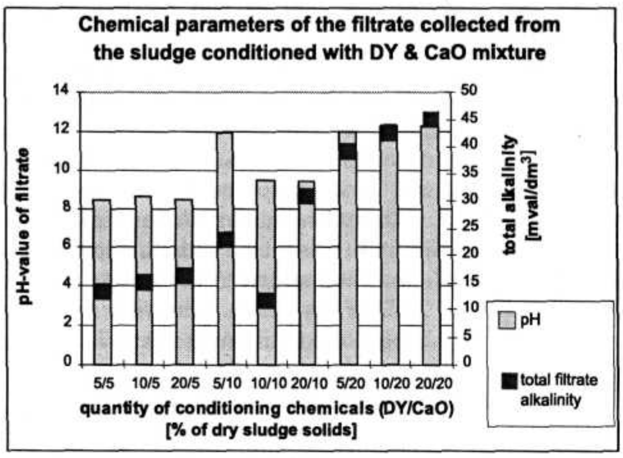

Fig. 7. Changes of pH-value and alkalinity of the filtrate, caused by sludge conditioning with diatomite containing yeast and lime.

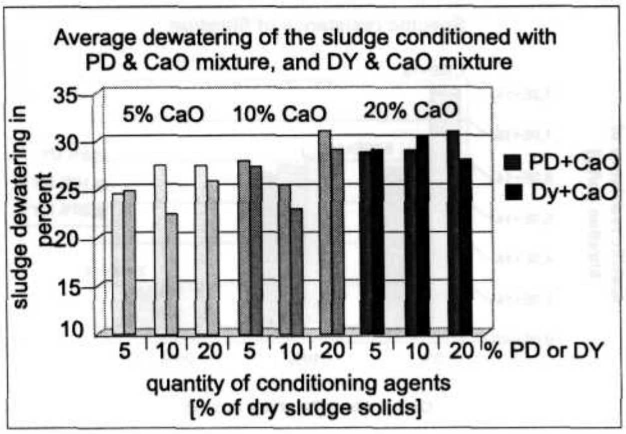

Fig. 8. Comparison between average dewatering of the sludge conditioned with pure diatomite with lime, and diatomite containing yeast and lime (percent of dewatering is the percent of hydration decrease as compared to initial hydration, assumed as 100%).

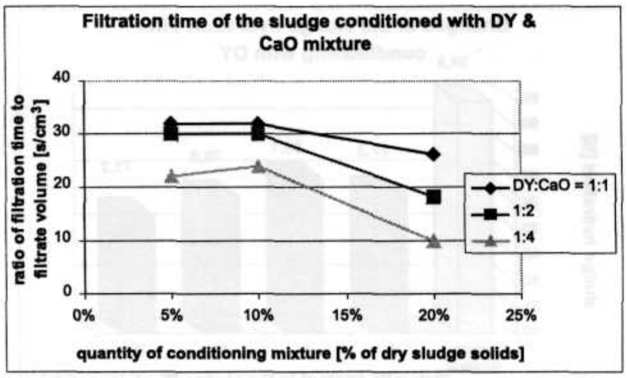

Fig. 9. Impact of sludge conditioning by DY and CaO mixture (prepared by "wet" method) on filtration time.

same time, it was observed that the increase of dewatering rate simultaneous with an increase of diatomite dosage was higher in the case of pure diatomite (PD).

Also in the case of specific resistance of filtration, the differences between conditioning with pure diatomite (PD) and diatomite containing yeast (DY) were of small importance. Specific resistance was decreasing with an increase of diatomite and lime quantity (as in the case of "polluted" diatomite, effect of lime quantity increase was bigger than of diatomite) and reached the minimum value at 20% dosages of both agents.

The small differences between the effectiveness of pure diatomite and diatomite containing filtered yeast cells can be caused by the presence of protein in the latter, due to its waste origin. High protein content in the sludge enhances its specific resistance. As reported by Coackley, the digested sludge with high protein content from the wastewater treatment plant at Colombez (Paris), had a specific resistance of $1.45 \cdot 10^{14}$ m/kg, whereas digested sludge from the treatment plant at Achares (Paris), with lower protein content, had lower resistance of $0.94 \cdot 10^{14}$ m/kg[5].

pH-value and alkalinity of the filtrate grew with increasing lime quantity, to the same degree as in the case of diatomite containing yeast with lime.

The conditioning ability of the mixture of diatomite containing yeast and lime, prepared by the so-called "wet" method (i.e. without preliminary diatomite drying) was also tested. Diatomite was mixed with lime in various proportions, dried, and then added to the sludge at dosages of 5, 10 and 20% of dry solids. Filtration rate was growing with an increase of conditioning mixture dosage, and additionally with an increase of the lime fraction in it. Filtration time measured at maximum dosage (20% of dry solids) was shorter by 19-55% than at minimum dosage (5% of dry solids), depending on the ratio of both agents (Fig. 9). When equal parts of diatomite and lime were used, the maximum dosage of the mixture was needed to shorten filtration time by 20%. At the higher lime quantity, in relation to DY (1:2, 1:4), filtration time was shortened by over 40%.

Analysis of the sludge dewatering by filtration has revealed that the increase in CaO ratio in relation to DY, at the minimum dosage of 5%, had no effect on the dewatering effectiveness (Fig. 10). As in the prior runs, only the 20% dosage had a distinct effect, whereas the difference in hydration after filtration between 5% and 10% dosages was minor (0.1-1.8%). Noteworthy is also the fact that the difference in hydration after filtration between the DY:CaO ratios of 1:1 and 1:4 (thus 4 times more lime) was only 1.5% at the 20% dosage (1.1% at 10%, and 0.1% at 5%). The difference between the conditioning ability of both mixtures was minimal, although the second mixture contained 4 times more lime. Therefore, the quantity of the mixture seems to be more important than its composition.

Similar results of sludge hydration after filtration to those mentioned above, were obtained by vacuum filtration of the digested sludge from wastewater treatment plants in the USA (65-75%), where the sludges were conditioned with lime (dosage: between ten and twenty % of dry solids) and ferric chloride (few % of dry solids) [4]. A decrease in specific resistance was also not observed

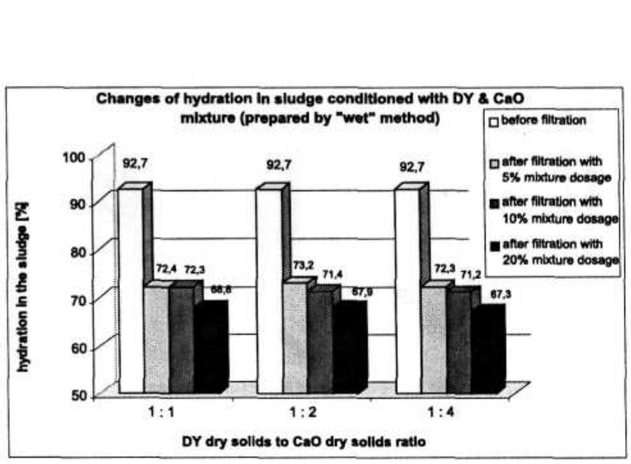

Fig. 10. Changes in sludge hydration caused by conditioning with dried mixture of wet diatomite and lime.

until the maximum dosage of 20% was applied (Fig. 11). Increase of lime fraction in relation to DY caused a decrease in specific resistance of filtration. However, it could also be seen that more important was an increase of the conditioning mixture quantity (i.e. from 5 to 20%) than of the lime to diatomite ratio. The specific resistance of filtration of the sludge conditioned with DY and lime, mixed at 1:1 ratio, at 20% dosage was the same as of the sludge conditioned with DY and CaO at 1:4 ratio, at 5% dosage.

The pH-value of the filtrate increased from 8.3 to 11.6 pH, and so did alkalinity [Fig. 12].

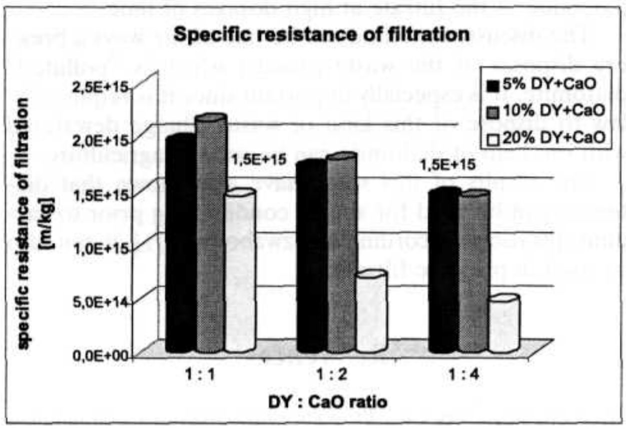

Fig. 11. Changes in the specific resistance of filtration caused by various quantities and ratios of the mixture of diatomite with yeast and lime (prepared by "wet" method).

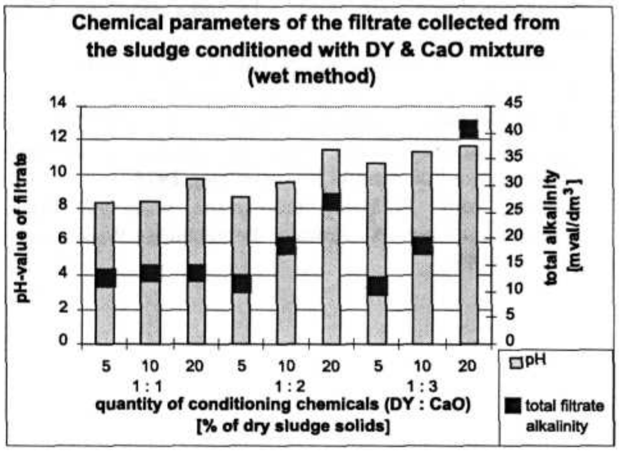

Fig. 12. Changes in the pH-value of the filtrate and alkalinity, caused by sludge conditioning with DY & CaO mixture (wet method).

After comparison of both runs of the experiment when diatomite containing yeast and lime was applied, we can conclude that the preparation of the conditioning mixture without DY drying had no major effect on the effectiveness of dewatering.

Average filtration time varied in the individual runs of the experiment. Besides the various conditioning methods, it was due to different initial hydration of the sludge.

Also, the specific resistance of filtration depends on sludge hydration. Therefore, it is hard to compare the results of the specific resistance measurements obtained in the individual runs because the initial hydration of the sludge varied. Even more difficult is to compare these results with the results of other studies or from other wastewater treatment plants, because specific resistance also depends on sludge type, measurement conditions, and applied pressure. Finally, even if the experiments are carried out in similar conditions their results reveal big discrepancies due to various sources.

Moisture content of the examined sludge after filtration was similar to the results obtained by the vacuum filtration method (i.e. 75-80% for digested primary--sludge and activated waste-sludge; 60-75% for digested primary-sludge [4]).

When the maximum dosage of diatomite polluted by yeast (DY) was used, dewatering equalled 22.8% (assuming 100% hydration before filtration). Lower dosages of DY did not considerably improve the dewatering characteristics of the tested sludges. Presumably, the dosages were too low. According to Szwabkowska [1], the ratio of inorganic agents (fly ashes, diatomite) added to improve the dewatering characteristics of a sludge, to the sludge dry solids content is usually contained in the range from 0.5:1 to 3:1, which is higher than in the experiment.

The addition of lime to diatomite increased the effectiveness of dewatering. Sludge hydration after filtration decreased from 92.7 to 64.6-67.3%, which is equal to the dewatering of 27.4-30.3%, and about six-fold volume reduction [6].

No major differences were observed between the effectiveness of dried diatomite added to the sludge with lime, and DY mixed with CaO and dried afterwards. The specific resistance of filtration of the sludge conditioned with 10% lime dosage, and with DY in the same quantity, was lower by 1/3 as compared to the specific resistance of the sludge dosed with 5% dosages of both agents. Likewise, in the third run specific resistance decreased by 1/3 after the addition of DY with the CaO mixture in 1:1 ratio at 20% dosage, compared to the 10% dosage of the same mixture. Therefore, irrespective of the drying of diatomite containing yeast, or thereof mixture with lime (at the same dosages of both), the obtained results were similar. Hence, it seems more important to make an analysis of the drying costs of the conditioning agents.

Alkalinity, acidity and pH-value measured in the filtrate revealed a dependence between various dosages of lime and diatomite. The sludge conditioned with the mixture of lime and diatomite (pure, as well as polluted) resulted in an increase of the filtrate pH with the increase of CaO quantity, up to the value of 11.6-12.3 pH. If the filtrate were to be returned to the wastewater for treatment, too high pH would have had a negative impact on treatment processes. On the other hand, filtrate disposed directly to a recipient would have had a negative impact on its ecosystem. Moreover, an increase of pH-value of water enhances its corrosive properties. An increase of total alkalinity, occurring simultaneously with an increase of lime dosage (from 10 to 45.3 mval litre^{1}) indicates that the buffering capacity of water has been exceeded and the quantity of hydrocarbons related to the quantity of carbonic acid has increased. Thus, it is advantageous to increase the fraction of diatomite in the sludge in relation to lime, at a cost of minor reduction of the dewatering effectiveness. Diatomite added to the sludge in the experiment did not increase the pH-value of the filtrate, nor its alkalinity. In the case of sludge conditioning with diatomite containing yeast, some increase of acidity was observed.

Conclusions

Conditioning of wastewater sludges with inorganic agents enhances the efficiency of dewatering and increases mechanical resistance of a sludge which is important in the subsequent process of pressure dewatering.

In the experiment, common wastewater sludges were tested. Hydration of the sludge (after thickening) was typical for digested wastewater sludge. The measured specific resistance of filtration was similar to the values reported for digested sludges from other wastewater treatment plants in Poland and abroad [1, 4]. It has been reported that if $r > 10\cdot10^8$ s^2/g (which is equal to $r > 10\cdot10^{12}$ m/kg), the sludge is not amenable to dewatering and must be conditioned prior to it [6].

Results of the study have revealed that the use of inorganic agents for sludge conditioning before mechanical dewatering, helps to reduce the specific resistance of filtration and to shorten the related filtration time, and also to increase dry solids content. The results have also proven that diatomite is an effective agent supporting dewatering, but also that there are no major differences in the conditioning properties of pure diatomite and diatomite polluted by yeast. After their application, filtration rate increased and the specific resistance of filtration and the hydration after filtration decreased. Differences in the sludge dewatering rate after the use of diatomite with CaO, and DY with CaO were minor. Diatomite, even when used in large quantities, did not change the pIT-value of the filtrate considerably. It can therefore be concluded that diatomite being a useless and burdensome waste product from the brewing industry (due to yeast content) can be used for wastewater sludge conditioning.

Conditioning with lime is a frequently applied method to improve the dewatering properties of sludge. Lime is added in quantities from a few to 20% of dry solids. The results of the study have confirmed that the addition of quicklime to diatomite containing yeast improves the properties of the dewatered sludge. The volume of applied dosages will be limited by the possibility to dispose of increased amounts of the sludge and by a high pH-value of the filtrate at high dosages of lime.

The discussed method can be one of the ways a brewery disposes of the waste product which is "polluted" diatomite. It is especially important since it is required by law to dispose of this kind of waste. Sludge dewatered with the help of diatomite can be used in agriculture.

The results of this study have also shown that diatomite can be used for sludge conditioning prior to vacuum filtration. According to Szwabowska [1], it can also be used in pressure filtration.

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