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APPLICATION OF CONSTANT ELECTRIC FIELD IN SIMULTANEOUS INTENSIFICATION OF DEWATERING OF WASTEWATER SLUDGE AND FILTRATE PURIFICATION

Because the application of pressure in electro-dewatering of wastewater sludge (and consequent compression) affects processes of electroosmosis and electrophoresis, the study aimed at determining the effect of vacuum and constant electric field on the specific resistance of sludge and quality of filtrate. It was found that both the current intensity and direction affects the biogen content in sludge dewatering filtrate. An increase in the intensity of the current applied to the filtering barrier was accompanied by an increase in the effectiveness of the removal of ammonium nitrogen (filtering barrier as an anode) and orthophosphates (filtering barrier as a cathode). A constant electric field was shown to considerably affect the specific resistance of sludge filtration.

1. INTRODUCTION

Sludge dewatering in a wastewater treatment plant is one of the most important stages in its processing. However, sludge dewaterability is restricted mainly due to its high organic matter content and sludge particle compressibility [1–3]. Due to the latter quality, a compact layer of sludge, called cake sludge, is formed on the surface of the filtering barrier during the dewatering process, obstructing the water flow from above. It is a layer of low porosity and it results in high specific resistance of filtration, thereby hampering water flow [4–7].

Effectiveness of dewatering is usually improved by applying very high pressure, although this does not improve the process to a satisfactory extent. High pressure usually causes further increase in the thickness of the layer which adheres to the filtering barrier and negatively affects the filtration effectiveness. Electro-dewatering and associated electroosmosis and electrophoresis [8–10] is a new technique applied in sludge processing. Electroosmosis involves movement of the liquid phase of a solution rela-

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tive to the solid phase, caused by the difference of electrical potential in the system. Electroosmotic movement of water has been described both on a microscopic scale and in model systems [11–13]. Electrophoresis, on the other hand, involves the movement of charged colloidal particles relative to the surrounding liquid, caused by an electric field. These two processes may largely improve the effectiveness of dewatering, improving its structure on the way.

Wastewater sludge is a heterogenic system containing large amounts of colloidal matter with a surface charge, which enables the application of an electrical current to make the particles move in a specific direction. When a constant electric field is applied to sludge, the matter particles contained in it may be attracted or repelled by electrodes, depending on the charge. Such actions ultimately result in an increase in the dry matter of sludge, i.e. its better dewatering. Considering the operating costs of such devices, the effects are greater than the outlays and are economically justified [10, 14, 15].

Formation of considerable amounts of filtrate which may contain large amounts of impurities is a problem inseparable from sludge dewatering. Since filtrate is returned to the main process line of wastewater treatment, it may reduce the effectiveness of removal of impurities in the plant. However, the intensification of wastewater treatment processes by removal of nitrogen and phosphorus compounds in recent years has not been accompanied by similar progress in the purification of filtrate.

The experiments presented in this paper were conducted on a device which enables the application of a constant electric field to wastewater sludge, while dewatering it under a vacuum. A constant electric field was used to determine its effect on the value of the specific resistance of sludge filtration and the characteristics of filtrate.

2. MATERIALS AND METHODS

The experiment was conducted in wastewater sludge following anaerobic fermentation, obtained from the "Łyna" Wastewater Treatment Plant in Olsztyn, where community wastewater is treated in a high-performance system which involves removal of carbon, nitrogen and phosphorus compounds. Consequently, the sludge being processed contained large amounts of these compounds. Anaerobic fermentation of wastewater sludge is conducted under mesophilic conditions at 32–36 °C. Table 1 shows the fundamental parameters of the wastewater sludge used in the study.

Sludge filtrate which ran off during the sludge filtration process contained 89.62–138.64 mg $N\text{-}NH_4/dm^3$ and 140.22–504.03 mg PO_4/dm^3. Their specific resistance of filtration was high and ranged from 4.67×10^{12} to 3.21×10^{13} m/kg.

The experiment was carried out with a model of a filtering funnel (Fig. 1) in which electrodes were made of steel, enabling the connection of constant electric field. Filter paper (0.2 mm thick, 80 g/m^2) was used as the filtering barrier. Wastewater sludge was treated with a vacuum at 4.9 N/cm^2 according to the method developed by Coackley and Jones, employing a theoretical model of filtration developed by Carman.

Table 1

Physicochemical characteristics
of the sludge used in the experiment

Parameter	Range of values
pH	6.85–7.59
Moisture [%]	96.04–97.31
Dry matter [% d.m.]	2.69–3.96
Ash [% d.m.]	38.55–41.89
Volatile substances [% d.m.]	61.45–58.11

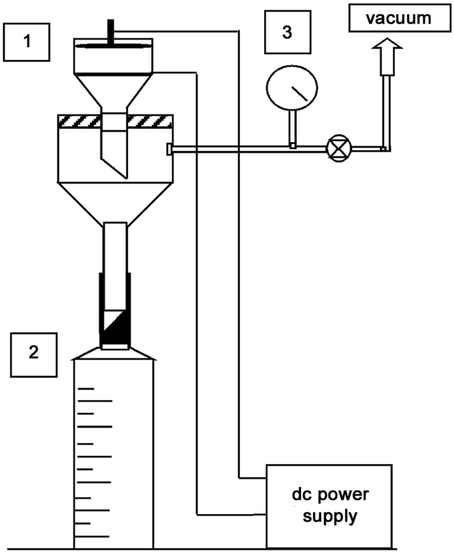

Fig. 1. Apparatus for vacuum electro-dewatering of wastewater sludge: 1 – modified filtering funnel, 2 – measuring cylinder, 3 – vacuum gauge

A current rectifier with adjustable voltage and current intensity was used as a source of direct current. The series of experiments differed in direct voltage (6–48 V), current values (0.05–0.55 A) and its direction. The maximum duration of the sludge dewatering process was 30 min. The pH value of the filtrate was determined with an electrode; other parameters determined included temperature, ammonium nitrogen and orthophosphates. Ammonium nitrogen was determined by distillation according to Kjeldahl, whereas phosphates were determined colorimetrically with ammonium molybdenate and ascorbic acid. Dry matter content, hydration, ash and volatile substances were determined in the sludge according to the methodology given in [16].

3. RESULTS AND DISCUSSION

3.1. EFFECT OF CONSTANT ELECTRIC FIELD ON THE SPECIFIC RESISTANCE OF SLUDGE FILTRATION

Dewatering of wastewater sludge accompanied by electroosmosis and electrophoresis considerably affects fluctuations of the specific resistance of sludge filtration depending on the current direction and the electric field intensity. The effect of current intensity was determined at a constant voltage of 38 V.

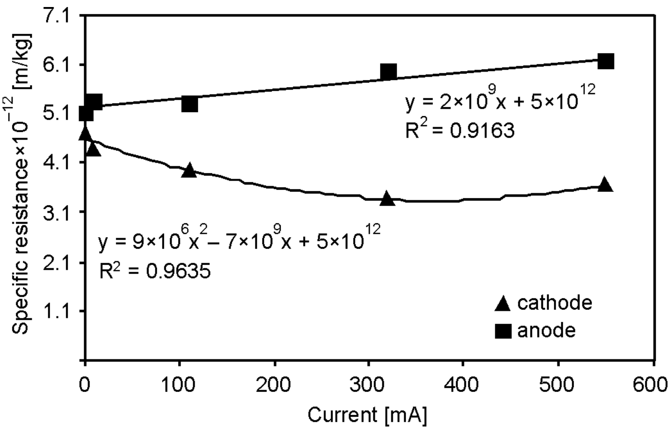

Fig. 2. The effect of current direction on the specific resistance of wastewater sludge ($V = 38$ V)

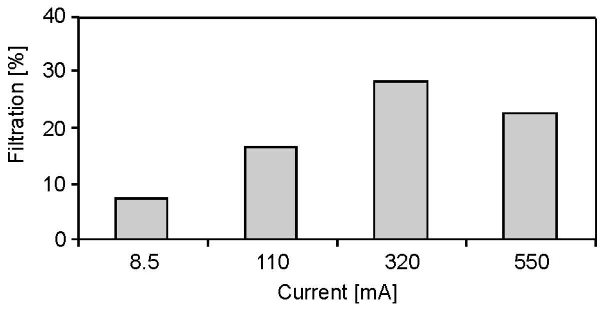

Fig. 3. Effect of electro-dewatering on the specific resistance of sludge filtration. The filtering barrier as a cathode ($V = 38$ V)

The specific resistance of the sludge which was not treated with a constant electric field was equal to 4.73×10^{12} m/kg and 5.13×10^{12} m/kg (Fig. 2). When the filtering barrier was employed as an anode, the specific resistance slightly increased. However, when it was used as a cathode, the specific resistance decreased considerably (Fig. 2) at low values of electric field intensity (8.5 mA). The lowest value of 3.38×10^{12} m/kg was reached at the current intensity of 320 mA. Compared to the sludge dewatering without constant electric field treatment, the value was lower by 28.54% (Fig. 3). The resistance of sludge filtration increased to $3,65\times10^{12}$ m/kg at the current intensity of 550 mA, but it was still lower by 22.83 %. Similar relationships were observed in dry matter content in dewatered sludge. According to reports of other studies, better results can be achieved when high pressure and sludge conditioning is employed in sludge electro-dewatering.

In contrast to conventional methods of dewatering, which yield sludge containing 20–25% of dry matter, electro-dewatering enables an additional increase of dry matter content to over 50% [10, 15]. Much poorer effects of dewatering, such as those presented in this paper, result from the application of low vacuum and from omitting the conditioning process. The effect of high pressure methods is much stronger, leading to increased effectiveness of the process.

3.2. QUALITY OF FILTRATE FROM SLUDGE DEWATERING

Filtrate obtained from sludge dewatering contained variable amounts of ammonium nitrogen and orthophosphates, depending on the direction of the current applied and its intensity.

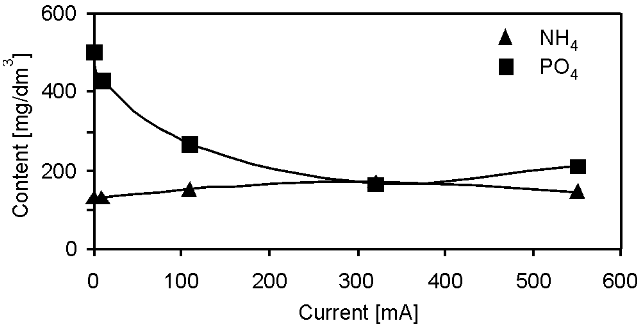

Fig. 4. Ammonium nitrogen and orthophosphate content in the filtrate. Filtering barrier as a cathode

When the filtering barrier was used as the negatively charged electrode (cathode), the ammonium nitrogen content changed slightly (Fig. 4). The concentration of the compound within the current intensity range used in the experiment changed from 133.02 to 172.79 mg $N\text{-}NH_4/dm^3$. The orthophosphate content decreased considerably and its lowest concentration (170.23 mg PO_4/dm^3) was obtained at the direct current intensity of 320 mA. Compared to the initial value in the filtrate, this value was lower by 66.23 % (Fig. 5).

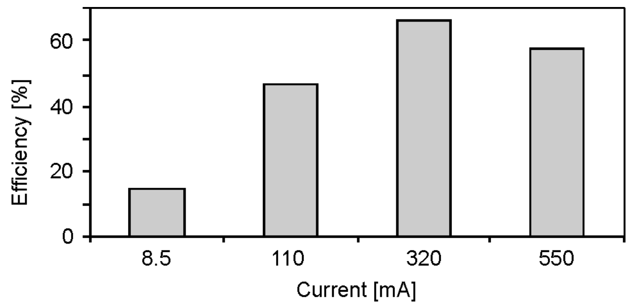

Fig. 5. Effectiveness of orthophosphate removal. Filtering barrier as a cathode

The current of 550 mA produced a slight increase in orthophosphate content, although the effectiveness was still high – 57.82%.

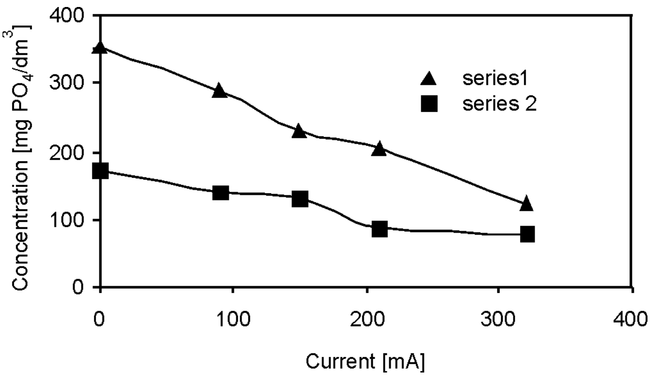

Fig. 6. The effect of electro-dewatering on the orthophosphate content in the filtrate. Filtering barrier as a cathode. Initial concentration: series 1 – 351.86 mg PO_4/dm^3, series 2 – 172.30 mg PO_4/dm^3

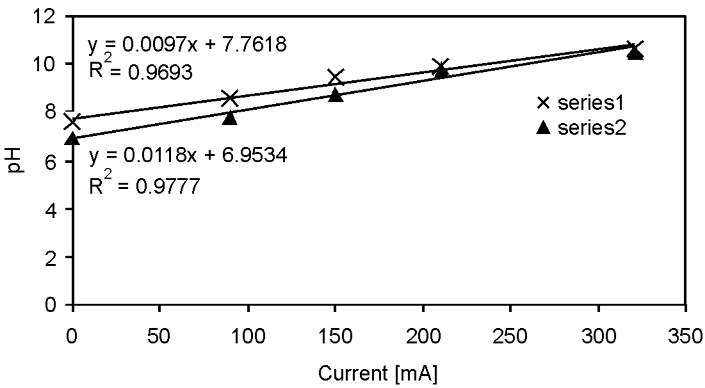

Fig. 7. The effect of electro-dewatering on the filtrate pH. Filtering barrier as a cathode. Initial concentration: series 1 – pH = 7.59, series 2 – pH = 6.96

The initial orthophosphate content affected the effectiveness of their removal in the process of electro-dewatering (Fig. 6). With a high initial concentration of 351.82 mg PO_4/dm^3, the effectiveness of orthophosphates removal was much better as compared to that at the initial value of 127.30 mg PO_4/dm^3.

The process of electro-dewatering was accompanied by changes of pH of the filtrate. The changes depended on the current intensity applied; its increase resulted in the maximum pH of 10.64 (Fig. 7). An increase in the filtrate pH results from the water electrolysis which takes place on the electrodes. Hydrogen ions (H^+) usually form on the anode, whereas on the cathode, hydroxyl ions (OH^-) are formed which are present in the filtrate after the dewatering process. Similar changes of pH in sedimentary waters confirmed Saveyn et al. [17] using the model sludge.

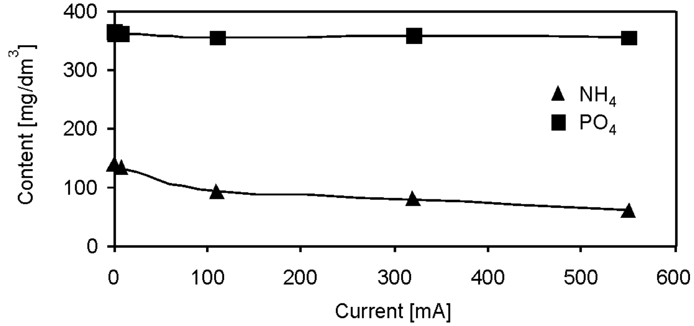

Fig. 8. Ammonium nitrogen and orthophosphate content in the filtrate. Filtering barrier as an anode

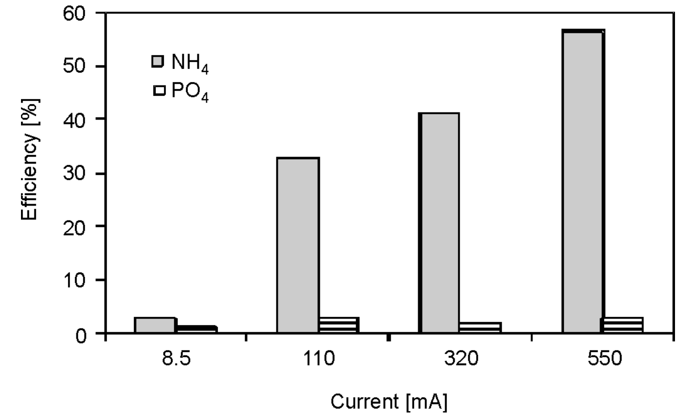

Fig. 9. Effectiveness of ammonium nitrogen and orthophosphate retention. Filtering barrier as an anode

When the filtering barrier was used as an anode, the orthophosphate content in the filtrate changed slightly, decreasing from the initial value of 367.43 mg PO_4/dm^3 to

357.25 mg PO_4/dm^3 with increasing current intensity (Fig. 8). The effectiveness of their removal was low and reached only 2.9 % (Fig. 9). On the other hand, the ammonium nitrogen content in the sample decreased with increasing current intensity from the initial value of 138.63 mg NH_4/dm^3 to 60.21 mg NH_4/dm^3. The maximum effectiveness achieved at the highest current intensity was equal to 56.57 % (Fig. 9).

4. CONCLUSIONS

The results of the investigation confirm the possibility of using constant electric field to simultaneous increase the dewaterability of sludge and removing nitrogen and phosphorus from water sedimentary. It was demonstrated that retention of nutrients in the sediment depends on the intensity and direction of current flow. The resulting efficiency of retention of ammonium nitrogen in the model vacuum device was 56.57% (filtering barrier as an anode), while that of orthophosphate – 66.23% (filtering barrier as a cathode).

Electro-dewatering method can successfully be used in the processing of sludge in the sewage treatment plant "Łyna" in Olsztyn. Sludges used for studies after anaerobic digestion are dewatered in centrifuges and outflow of sludge filtrate goes to the main technological treatment including inflow sewage. Implementation of the proposed technology will increase the efficiency of wastewater treatment, as well as increase the value of sewage sludge fertilizer.

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