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Effect of polyelectrolyte conditioning on the enhanced dewatering of activated sludge by application of an electric field during the expression phase

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Abstract

Activated sludge is known to be poorly dewaterable due to its high surface charge density and the extreme solids compressibility, even after polyelectrolyte conditioning. The application of an electric field during pressure dewatering (PDW) of sludge can enhance the dewaterability by the electroosmosis effect.

A comparative study was conducted to investigate the additional effect of an electric field, applied during the expression phase, on the dewatering course of polyelectrolyte conditioned sludge, compared to mere PDW. It was found that the application of an electric field markedly improved the dewatering kinetics for all sludge samples, regardless of the conditioning treatment. Although the conditioning polyelectrolyte characteristics and dose had a major effect on the PDW of sludge, the conditioning history did not have a significant effect on the electroosmotic water transport efficiency during the sludge expression phase. By means of on-line streaming potential measurements and fractionated filtrate electrophoretic mobility measurements, it could be demonstrated that even at high polyelectrolyte doses, leading to positively charged sludge flocs, negative surface charges were still present inside the sludge matrix. During the expression of the sludge cake, when liquid is forced to move through the floc inside pores, these negative surface charges hampered PDW, but enhanced electroosmotic dewatering. Electroosmosis is therefore an appropriate technique to remove the water fraction that is associated with these negative surface charges.

Keywords: Cake filtration; Electrodewatering; Electroosmosis; Activated sludge; Streaming potential; Surface charge

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1. Introduction

Sludge production in Europe and many parts of the industrialized world has steadily been increasing during the last decades. Together with more stringent disposal regulations, this has caused a demand for more efficient sludge dewatering techniques. Sludges of biological origin such as waste activated sludge are known to exhibit a poor dewaterability. It is generally accepted

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Abbreviations: EDW, electrodewatering; PDW, pressure dewatering

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Nomenclature

Latin symbols

A	cross-sectional area of the capillary (m^2)
C	constant (kWh)
E	electric field strength ($V\,m^{-1}$)
J_q	current density ($A\,m^{-2}$)
k	apparent conductivity ($S\,m^{-1}$)
L	cake thickness (m)
p	hydraulic pressure (Pa)
t	time (s)
U_{str}	streaming potential (V)
V	water volume (m^3)
W	electric energy consumption (kWh)

Greek symbols

α	proportionality constant ($kWh\,m\,A^{-1}\,l^{-1}$)
ε	permitivity of the medium ($F\,m^{-1}$)
θ	slope ($kWh\,l^{-1}$)
η	viscosity of the liquid ($kg\,m^{-1}\,s^{-1}$)
ζ	zeta-potential at the capillary wall (V)

that the strong water retention in sludge is related to the presence of extracellular polymeric substances (EPSs), which form a negatively charged polymer network (Keiding et al., 2001; Mikkelsen and Keiding, 2002; Liu and Fang, 2003). In order to reduce the effect of the EPS and enhance the dewaterability, sludge is usually conditioned with positively charged inorganic or organic polymers, called polyelectrolytes (Novak et al., 1999; Dentel, 2001). Despite conditioning, a considerable amount of water is retained within the sludge, leading to extreme compressibility and moderate dewaterability (Sorensen and Hansen, 1993). Many options have been investigated to enhance the sludge dewaterability, the most successful being pressure dewatering (PDW) assisted by DC or AC voltages in the order of 10–200 V (Barton et al., 1999; Gingerich et al., 1999). This technique is often referred to as electrodewatering (EDW) or electroosmotic dewatering. It is based on the electrokinetic water transport in a porous matrix of charged particles, subject to an electric field (Hiemenz and Rajagopalan, 1997).

Electroosmotic dewatering has been reported to be used in conjunction with different common dewatering techniques, such as belt filter presses (Hwang and Min, 2003; Raats et al., 2002; Snyman et al., 2000), filter presses or diaphragm filter presses (Kondoh and Hiraoka, 1990), both on laboratory and pilot or full scale. However, a few technical problems have hampered its widespread distribution so far, such as the use of corrosion resistant electrode materials and the high power consumption (Raats et al., 2002). Process parameters such as timing of electric field application, total energy input and energy input distribution in time will affect the dewatering results and overall energy efficiency. Different modes of operation are possible, keeping voltage, current or electric field constant or vary it according to a certain pattern, such as a sine or block wave. Short to intermediate time interruptions have also been reported to enhance the process efficiency (Gopalakrishnan et al., 1996; Yoshida, 2000; Yoshida et al., 1999).

Although different researchers reported the experimentally observed beneficial effects of sludge conditioning in EDW (Kondoh and Hiraoka, 1990; Smollen and Kafaar, 1994; Miller et al., 1997; Snyman et al., 2000), it is not fully understood what interaction exists between the polyelectrolyte effects and the electrokinetic water removal. This work aims to investigate the influence of sludge conditioning on the performance of EDW of activated sludge compared to pressure-driven dewatering and to reveal the relation between dewatering efficiency and electric power consumption. Hereby, a constant electric field was selected, since this is one of the simplest modes of operation and allows an easy comparison of the different test results.

2. Materials and methods

2.1. Materials

Thickened activated sludge was sampled from the Ossemeersen Waste Water Treatment Plant (Aquafin, Ghent, Belgium). The nine considered sludge samples had a pH between 6.7 and 7.3, a conductivity between 1144 and 1576 $\mu S\,cm^{-1}$ and a dry matter content between 1.99 and 3.63% w/w, whereas their electrophoretic mobility ranged from -0.87 to $-1.45 \times 10^{-8}\,m^2\,V^{-1}\,s^{-1}$ (zeta-potential from -11.2 to -18.6 mV). After sampling, sludge was stored at 4 °C for maximum 3 days. Before testing, a 600 ml sludge sample was kept for 30 min in a waterbath at 20 °C.

Polyelectrolyte chemicals were a gift from Ciba Specialty Chemicals Belgium, and were delivered as beads or liquid dispersion formulation. Except for the LT 22 type, which belonged to the Magnafloc series, all polyelectrolytes were from the Zetag product range. All products are copolymers of polyacrylamide and quaternized dimethylaminoethyl acrylate (CAS Number 69418-26-4). Aqueous polyelectrolyte solutions were prepared at a 2 $g\,l^{-1}$ active polyelectrolyte concentration (0.2%), at least 24 h prior to application. A schematic overview of the polyelectrolytes used is given in Table 1.