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Electro-dewatering of wastewater sludge: Influence of the operating conditions and their interactions effects

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ABSTRACT

Electric field-assisted dewatering, also called electro-dewatering (EDW), is a technology in which a conventional dewatering mechanism such a pressure dewatering is combined with electrokinetic effects to realize an improved liquid/solids separation, to increase the final dry solids content and to accelerate the dewatering process with low energy consumption compared to thermal drying. The application of these additional fields can be applied to either or both dewatering stages (filtration and/or compression), or as a pre-or post-treatment of the dewatering process. In this study, the performance of the EDW on wastewater sludge was investigated. Experiments were carried out on a laboratory filtration/compression cell, provided with electrodes, in order to apply an electrical field. The chosen operating conditions pressure (200–1200 kPa) and voltage (10–50 V) are sufficient to remove a significant proportion of the water that cannot be removed using mechanical dewatering technologies alone. A response surface methodology (RSM) was used to evaluate the effects of the processing parameters of EDW on (i) the final dry solids content, which is a fundamental dewatering parameter and an excellent indicator of the extent of EDW and (ii) the energy consumption calculated for each additional mass of water removed. A two-factor central composite design was used to establish the optimum conditions for the EDW of wastewater sludge. Experiments showed that the use of an electric field combined with mechanical compression requires less than 10 and 25% of the theoretical thermal drying energy for the low and moderate voltages cases, respectively.

1. Introduction

Over the last decades the increase in municipal and industrial wastewater purification activities have been confronted with a dramatically increasing flow of sewage sludge. A common characteristic of different type of sludge is the very high water content, the colloidal and compressible nature of the sludge. Activated sludge is an important class of these waste products and has to be treated and disposed of. After gravitational thickening, sewage sludge still contains only as little as about 1–5% (wt%) on a wet basis of dry solids content, the remaining fraction being water (95–99%) (Saveyn et al., 2005). This excessive water content of sludge increases the volume and the cost for truckling to ultimate disposal site. Moreover, sewage sludge requires more supplemental bulking agent during composting and cannot be incinerated as its energy content is low. Therefore, it is both economically and technologically feasible to decrease the water content. This facilitates the possible use of sludge as a fuel and reduces transport and disposal costs.

It is well documented that sludge dewatering is one of the most challenging technical tasks in the field of wastewater

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engineering (Tchobanoglous et al., 2003; Glendinning et al., 2007). In fact, when compared with thermal (evaporative processes) for water reduction, mechanical dewatering is often selected due to its low energy requirement (Vaxelaire et al., 1999). This operation not only reduces the total waste volume but also increases the caloric value of the product (Vaxelaire and Olivier, 2006; Tuan and Sillanpää, 2010a).

Dewatering is mainly performed by mechanical techniques based on gravitational settling centrifugation, or filtration/compression, e.g. by belt or filter presses. However, the colloidal and compressible nature of the sludge will hamper its dewatering without pretreatment. The presence of organic components, mainly bacterial cells and EPS (Extracellular Polymeric Substances), in the sludge makes it very difficult to dewater even at high pressure. Chemical conditioning prior to mechanical dewatering is usually used to overcome partially these problems. The selection of the appropriated chemical and dosage is quite difficult because it depends on both the sludge composition and the dewatering device and remains widely empirical (Vaxelaire and Olivier, 2006; Saveyn et al., 2008).

However, one of the steps generally involved in thickening and dewatering is the flocculation of sludge with inorganic (ferric or aluminium chloride) or organic flocculant (synthetic polyelectrolyte), called conditioning. In this way, an inorganic or organic flocculant may be added to induce the formation of flocculated particle networks, resulting in an improved structure with reduced water retention.

Despite conditioning and many technical improvements during recent years, wastewater sludge remains hard to dewater and, for many applications, it cannot achieve a sufficiently low water content. A plateau value of 35% (wt%) dry solids content seems to be the highest efficiency which can be commonly reached by the three most employed mechanical dewatering techniques: centrifugation, dewatering by belt filter press or dewatering by filter press (La Heij et al., 1996).

The difficulty has been attributed mainly to the fact that particles are very fine, colloidal in nature and gel like structure due to polymeric flocculation. Therefore an improvement in the traditional pressurized dewatering equipment is desirable. As a consequence, current research tends to propose potential alternatives to enhance the dewatering ability of conventional processes (Tarleton, 1992; Mahmoud et al., 2010).

Different options have been investigated to enhance the wastewater sludge dewatering, one of the most successful used is the pressure dewatering assisted by an electrical field (D.C. or A.C.).

In fact most mechanical dewatering processes (MDW) involve two stages; the first is the filter cake formation stage and the second is the compression stage where further water is squeezed from the cake by the application of a mechanical force. The application of additional fields can be applied to either or both dewatering stages, or as a pre-or post-treatment of the dewatering process. According to Friehmelt et al., 1995; Miller et al., 1998; Barton et al., 1999; Lee et al., 2002 and Saveyn et al., 2005 who noticed that application of the electric field at the start of the whole dewatering run, in the filtration stage, did not show any beneficial effect to the dewatering result, the additional effect of a vertically electric field applied is investigated during compression stage in this paper.

The operating conditions of the electric field and pressure used in the electrically assisted mechanical dewatering are sufficient to remove a significant proportion of the water that cannot be removed using mechanical dewatering technologies alone. Thus electro-dewatering (EDW) has the potential to be viable for a range of slurries, which either could not be sufficiently dewatered or would otherwise require extreme conditions using conventional dewatering devices.

Many experimental factors can influence the reduction of water content and, consequently, the process yield. The critical processing factors are voltage (current or electrical field), pressure, time, floc size distribution, electrochemical properties, conditioning parameters, polyelectrolyte characteristics etc. A study of the influence of certain of these factors should indicate the optimum experimental conditions. Treating each factor separately would be very time consuming; furthermore, if several factors play a role, their interactions would not be discernible even if they were dominant. Hence, the use of the experimental factorial design and of the RSM, already successfully applied in other fields, is well suited to the study of the main and interaction effects of the factors on the dewatering yield.

The present paper investigates the effects of the processing parameters (pressure, voltage) of the electrically assisted mechanical dewatering, using the RSM, for the reduction of water content using moderate process conditions. Other parameters, such as floc size distribution, pH, time, electrochemical properties, conditioning parameters, polyelectrolyte characteristics etc as mentioned above, can affect the dewatering behavior, but these are not discussed in this paper.

The feasibility of the EDW-process on activated sludge sampled from the Lescar Municipal Waste Water Treatment Plant (Pau, France) is tested. Experimental runs are modelled for the estimation of the final dry solids content and the energy consumption calculated per the additional mass of water removed, allowing the significance of the various phenomena to be discussed. Finally, in order to design efficient processes, the RSM is used to achieve the optimum dewatering performance.

2. Materials and methods

2.1. *Experimental set-up*

For the investigation of activated sludge dewatering by electro-dewatering, a lab scale set-up was made with a pressure controlled piston moving in a filtration/compression cell of 70 mm inner diameter.

The filtration/compression cell, represented in Fig. 1(a), consists of a compressive piston made of Teflon™, a cylindrical vessel and a filter medium. The filtration chamber has a diameter of 70 mm and a maximum height of 145 mm. In spite of its low mechanical resistance, Teflon™ was selected as constitutive material of the vessel walls not only to minimize the friction with the piston but also to ensure the electrical insulation. Consequently, a stainless steel external jacket was added to ensure the mechanical resistance of the unit. The cell is fitted with a planar medium of SEFAR TETEX MONO SK025, provided by CHOQUENET S.A.S (Chauny, France), deposited on