ELECTRODEWATERING OF DIFFERENT SEWAGE SLUDGES UNDER CONSTANT ELECTRIC CURRENT: IMPACT OF PHYSICO-CHEMICAL PROPERTIES ON THE DEWATERABILITY AND THE SEPARATION KINETICS

amina chiboub, Jérémy Olivier, Jean Vaxelaire

ELECTRODEWATERING OF DIFFERENT SEWAGE SLUDGES UNDER CONSTANT ELECTRIC CURRENT: IMPACT OF PHYSICO-CHEMICAL PROPERTIES ON THE DEWATERABILITY AND THE SEPARATION KINETICS

A.Chiboub, J.Olivier and J.Vaxelaire
Univ Pau & Pays Adour/E2S UPPA, Laboratoire de thermique énergétique et procédés - IPRA, EA 1932, 64000 Pau, France

ABSTRACT

A sewage sludge is the by-product of a wastewater treatment plant (WWTP), and is mainly composed of water and the rest of its mass is the dry solids (DS). Prior to the transport and valorisation of these sludges, a liquid-solid separation is necessary. Various processes allow this aim, but their performance is limited and can be enhanced to avoid the use of processes like thermal drying which consume high amounts of energy, that needs to be limited. Electro-dewatering (EDW) is a hybrid process in which a conventional filtration-compression process is combined with the application of an electric field in order to enhance sludge dewatering (with lower energy consumption compared to a conventional drying process).

Previous studies have proposed an empirical model that reveals a relationship between the evolution of DS over time. This mathematical model includes a kinetics coefficient that is proportional to the sludge's physicochemical properties. This model was developed for EDW tests carried out under a constant electric current (I-EDW), unlike most of the studies presented in the literature where a constant voltage (U-EDW) is commonly used. Although less studied in the literature, the I-EDW mode remains an interesting operating mode since it limits the raise of temperature which can be detrimental for the electrodes.

The objectives of this study are to evaluate the influence of the physicochemical properties on the response of the process, notably the kinetics of the liquid-solid separation and the DS evolution. Then, a mathematical relationship between the kinetics coefficient and the influencing parameters is proposed.

First step was to conduct I-EDW tests on different sludge types in a lab-scale equipment running with a constant current of I=0.32A, a constant pressure of P=36kPa and a constant sludge thickness (H) of 5mm height. The duration of tests was fixed at 15min. For every sludge, several physicochemical properties were measured (pH, conductivity, hydrophobicity, volatile suspended solids (VSS), surface charge and extracellular polymeric substances (EPS)).

Then simple correlation models were used among the studied parameters. Initial DS and soluble EPS seems to be the most influencing parameters on the kinetics. VSS and conductivity happens to have an important influence as well. Later, a mathematical relationship between the kinetics coefficient and the physicochemical properties was established using a multiple linear correlation. The experimental and the modelled kinetics coefficient appears to be comparable, we could then assume that this model is viable for our sludge types.

These results will help improving the existing empirical model, by integrating the influencing parameters on the kinetics. The model will help predict the evolution of DS over time depending on the sludge properties, the applied current, the sludge loading rate and the initial DS.

KEYWORDS

Correlation, Electrodewatering, Filtration-compression, Kinetics, Physicochemical properties

INTRODUCTION

The volumes of municipal and industrial wastewaters have increased over the past few decades due to the rapid development of urbanization and industrialization. Therefore, the production of residual sludges after the sewage treatment is constantly increasing. A residual sludge is mainly composed of water and the costs of their transport and disposal represents up to 60% of the total WWTP's budget. These costs are increasing since legislation becomes more and more stringent regarding the protection of environment (Mahmoud et al., 2010; Wu et al., 2020). Prior to its transport, valorization or disposal; a liquid-solid separation is necessary to remove as much water as possible. To date, mechanical dewatering processes are widely used and enable to reduce water content to obtain sludges with up to 20% DS. Therefore, even after mechanical dewatering, sludge still contain large amounts of water that can be further removed by deep dewatering methods (Sha et al., 2020). Thermal drying processes can achieve high dewatering performance (up to 80%DS) but consume high amounts of energy (Mahmoud et al., 2010).

The EDW process has gained much attention in recent years as a solution to enhance the liquid-solid separation process efficiency with low energy consumption (compared to thermal drying) to increase the final DS content and to accelerate the dewatering kinetics. EDW is a hybrid process combining a conventional pressure consolidation with an electric field applied to the sludge sample placed between two electrodes (Citeau et al., 2012; Mahmoud et al., 2010, 2016).

The main factors affecting EDW are the operating parameters and the properties of the sludge.

To date, many researchers have studied the influence the operating parameters (pressure, electric mode, temperature, cake thickness, electrode configuration…) (Citeau et al., 2012; Mahmoud et al., 2016; Navab-Daneshmand et al., 2015; Tuan et al., 2008; Tuan & Sillanpää, 2010); and more recently the influence of some sludge properties (pH, conductivity, EPS...) (Bai et al., 2019; Li et al., 2020; Sha et al., 2021; Zhang et al., 2021) on the performance of the EDW process in terms of electrical resistance, energy consumption, final moisture content and EDW rate. These studies were mainly conducted under constant voltage U-EDW, and the dewatering kinetics weren't taken into account.

In this work the tests were carried out under I-EDW mode which, although less studied in the literature, remains an interesting operating mode as mentioned in some previous studies (Citeau et al., 2012). Indeed, when applying a constant voltage, it was shown that heating due to Joule effect was not controlled in the earlier stages of EDW. This raise of temperature is detrimental for the electrodes.

From our experiments we proposed a relationship between the sludge properties and the dewatering kinetics coefficient under constant electric current. This will help providing deeper understanding of the I-EDW mode and later improving the empirical model previously developed to help predict the evolution of DS over time (Olivier et al., 2015).

MATERIAL AND METHODS

Sludge samples

Different types of sludge from several WWTPs were used in this study: 4 urban activated sludges, 1 urban anaerobically digested sludge, 3 industrial sludges. The wastewater treatment plant details are listed in Table 1.

Table 1: sludges and wastewater treatment plants details

Sludge name	Sludge type	WWTP capacity (p.e)	Wastewater treatment process	Sludge dehydration process
AS-L	Urban activated sludge	190000	Activated sludge with prolonged aeration process	Centrifuge
DS-M	Urban digested sludge	45000	Anaerobic digestion	Belt filter press
IS-J	Industrial sludge from a cheese production industry	22000	Activated sludge	Drip table
AS-U	Urban activated sludge	20000	Activated sludge with anaerobic-anoxic-aerobic process	Centrifuge
IS-G	Industrial sludge from a honey production industry	48 (m^3/day)	Anaerobic digestion	Filtration bags (teknofonghi ©)
AS-A	Urban activated sludge	55000	Activated sludge with aerobic-anoxic process	Centrifuge
IS-A	Industrial sludge from packed meals industry	34000	Activated sludge	Centrifuge
AS-EA	Urban activated sludge (Mixed of several rural WWTPs of less than 2000 p.e)	34000	Mainly activated sludge	Centrifuge

All sludges were collected after the dewatering process, and were stored at 4°C and used within a period of one week. This period of one week limits the biochemical changes within the samples.
Prior to the EDW tests, sludge samples were left in the open air at room temperature for approximately one hour to reach room temperature.

Experimental set-up

The experimental set-up used for this study consisted of a compression device without side wall, connected to a current generator. The upper anode is made of titanium coated with mixed metal oxide to prevent its oxidation. The lower cathode is made of titanium, and a filter cloth is put over the cathode (SEFAR TETEX MONO SK025, provided by CHOQUENET SAS France). Both electrodes are a perforated disk shaped of a 65mm of diameter (manufactured by INDUSTRUE de Nora Italy and supplied by ESC-Electro Chemical Service-France). The direct current generator (EV202 CONSORT) is connected to the anode and cathode to provide maximum of 300V and 2A. The pressure is applied by adding some weights over the anode. The filtrate was collected in a beaker installed over a scale. The experimental setup is presented in Figure 1.

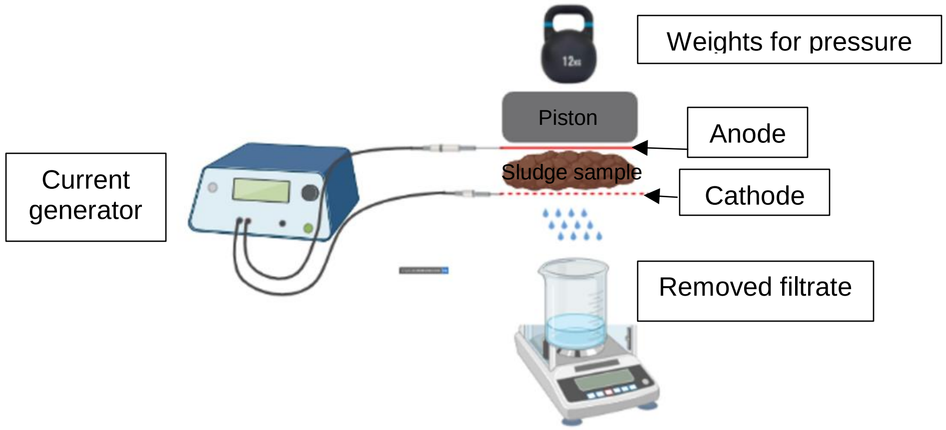

Figure 1: experimental setup

Experimental procedure

The dewatering process consisted of applying the electric current on the dewatered collected sludge samples to allow the collection of the additional filtrate removed only thanks to the electrical contribution. After reaching room temperature, all the samples were previously mixed in a kneader in order to make the sample more homogeneous. A cylindrical sludge cake was then made using a cylindrical cutter of 5 mm high and 65mm in diameter. The cylindrical sludge sample was then put over the filter cloth and the pressure (36kPa) was applied in order to remove excess sludge which overflows laterally relatively to the diameter of the electrodes. Then, an electric current of 0.32A was applied for 15minutes, and the removed filtrate collected. Experimental data (filtrate mass, current and voltage) were recorded over time every 10 seconds for the first 5 minutes, then every 30 seconds for the rest of the test. At the end of the test, the dewatered cake was removed from the filtration-compression device and weighed, then placed in the oven at 105°C for 24 hours in order to measure the dry solids content (DS) according to the European Standard procedure EN 12880. Each series of tests was carried out four times.

Physicochemical properties analysis

The analysis methods used are listed in Table 2. Each analysis was carried out three times for reproducibility.

Table 2: physicochemical properties analysis methods

parameter	method	reference
DS	105°C for 24hours	European standard procedure EN 12880
VSS	550°C for 2hours	
pH	5g sludge+ 50mL ultrapure water => stir 4hours => centrifuge 15min at 10000G => measure pH and conductivity on the supernatant	(Carter & Gregorich, 2008)
Conductivity		
Surface charge	Colloidal titration: 1mL sludge sample+150mL ultrapure water+ 5mL polybrène => titration by polyvinylsulfuric acid potassium salt (PVSK) until neutrality is reached	(Wilén et al., 2003)

EPS	Extraction method based on cations exchange resin, then colorimetric dosage method	(Lowry et al.,1951 ; Dubois et al.,1956 ; Frolund et al., 1996)
Hydrophobicity	40g sludge+ 20g hexadecane => stir 20min => separation of hydrophilic and hydrophobic phases in a separating funnel	(Wilén et al., 2003)

The kinetics model

Previous studies *(Olivier et al., 2015)* have proposed an empirical model that reveals a relationship between the evolution of dry solids content and the dewatering kinetics coefficient during constant electric current application (I-EDW) (Equation 1). It was outlined that the dewatering kinetics depends on the properties of the sludge through the $K_{I\text{-}EDW}$ coefficient.

$$DS_t = K_{I-EDW} * \frac{I_{app}}{m_{DS}} * t + DS_i \qquad \textit{(Equation 1)}$$

With DS_t the evolution of DS over time (%), K_{I-EDW} the dewatering kinetics coefficient (g/s.A), $I_{app}$the applied electric current (A), m_{DS} the sludge loading DS mass (g), *t* time and DS_iinitial DS (%).

RESULTS AND DISCUSSION

Physicochemical properties of the tested sludges

The physicochemical properties of the sludges are listed in Table 3.

Table 3: physicochemical properties of the different sludges (mean ± standard deviation)

Sludge	**Initial DS (%)**	**VSS (%DS)**	**pH (-)**	**Conductivity (mS/cm)**	**Hydrophobicity (%)**	**Surface charges (mEq/gDS)**	**EPS (mg/gVSS)**		
							Soluble EPS (S-EPS)	**Bound EPS (B-EPS)**	**Total EPS (T-EPS)**
AS-L	20.43 ± 0.15	77 ± 1	7.71 ± 0.17	0.66 ± 0.06	99.69 ± 0.09	-0.97 ± 0.2	676.96 ± 16.88	1030.26 ± 1.61	1707.22 ± 15.85
DS-M	14.6 ± 1.11	58 ± 1	8.17 ± 0.05	0.47 ± 0.06	98.97 ± 1.04	-0.97 ± 0.42	159.12 ± 21.21	204.8 ± 15.43	363.92 ± 42.22
IS-J	8.24 ± 0.14	69 ± 4	7.81 ± 0.71	0.83 ± 0.06	98.88 ± 0.93	-0.77 ± 0.15	42.69 ± 1.40	248.68 ± 0.78	291.37 ± 1.40
AS-U	18.66 ± 0.08	72 ± 0.4	7.21 ± 0.18	0.5 ± 0.00	99.38 ± 0.15	-1.46 ± 0.7	955.06 ± 57.32	437.17 ± 9.00	1392.23 ± 66.32
IS-G	11.26 ± 0.19	----	7.99 ± 0.05	2.8 ± 0.00	98.44 ± 1.24	-5.02 ± 0.17	---	---	---
AS-A	18.41 ± 0.14	76.58 ± 0.18	6.94 ± 0.07	0.93 ± 0.05	99.68 ± 0.16	-2.93 ± 0.81	187.22 ± 6.90	627.14 ± 55.63	814.36 ± 62.43
IS-A	34.95 ± 0.82	82.44 ± 0.51	8.04 ± 0.07	2.17 ± 0.12	98.78 ± 0.26	-4.23 ± 0.1	5769.08 ± 60.53	459.53 ± 12.66	6228.6 ± 47.87
AS-EA	18.56 ± 0.87	76.11 ± 3.47	7.87 ± 0.16	0.9 ± 0.00	99.87 ± 0.00	-3.14 ± 0.37	145.33 ± 11.7	1607.41 ± 43.69	1752.74 ± 31.99

Sludge dewaterability and dewatering kinetics

To investigate the dewaterability of the tested sludges, the DS has been calculated over time from the removed filtrate thanks to Equation 2 (Mahmoud et al., 2016) and presented in Figure 2.

$$DS_t = \frac{m_{DS}}{m_{total}^{in} - m_{filtrate(t)}} \qquad \text{(Equation 2)}$$

Where DS_t is the dry solids content over time (%), m_{DS} is the mass of dry solids introduced into the EDW device (g), m_{total}^{in} is the mass of introduced sludge sample into the EDW device (g) and $m_{filtrate(t)}$ is the mass of collected filtrate over time (g).

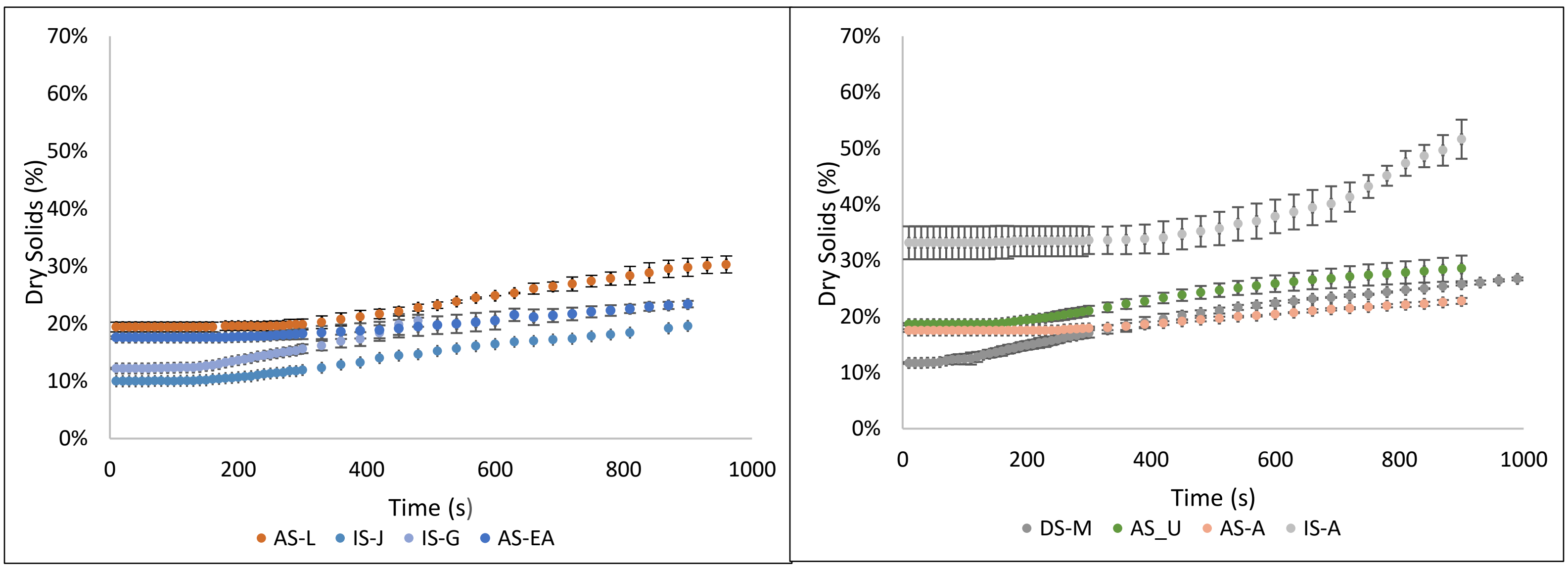

Figure 2: evolution of dry solids content over time during electrodewatering tests

EDW tests enabled to separate a significant amount of water that was still held inside the sludge samples after mechanical dewatering. It allowed to gain from 5% up to 19% of DS depending on the sludge.

In order to evaluate the dewatering differences between the different sludges, the dewatering kinetics coefficient (K_{I-EDW}) from the empirical model (Equation 1) have been calculated through the slope of the evolution of DS thanks to Equation 3 (Olivier et al., 2015).

$$K_{I-EDW} = \frac{slope * m_{total}^{in}}{I_{appied}} \qquad \text{(Equation 3)}$$

With K_{I-EDW} the dewatering kinetics coefficient (g/s.A), m_{total}^{in} the mass of introduced sludge sample into the EDW device (g) and I_{appied} the applied electric current (A).

The DS gain was also considered in the interest of evaluating the dewatering efficiency, and was calculated thanks to Equation 4.

$$\Delta DS = DS_f - DS_i \qquad \text{(Equation 4)}$$

With ΔDS the DS gain (%), DS_f the final DS of the sludge sample (%) and DS_i the initial DS of the sludge sample (%).

Figure 3 represents the results of evolution of DS content and the dewatering kinetics coefficient differences between all the tested sludges.

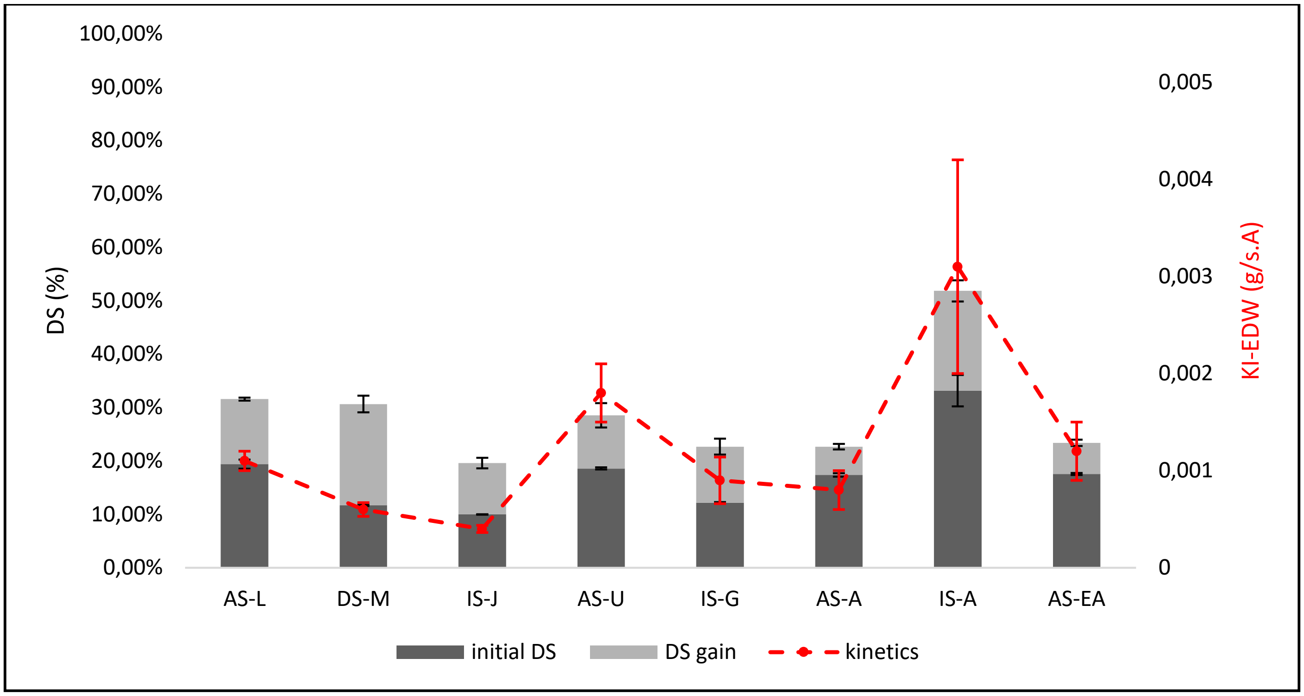

Figure 3: EDW tests performance for different sludges (final DS and dewatering kinetics)

In the following Table 4, the obtained values are listed.

Table 4: DS and kinetics values obtained after EDW tests

Sludge	Initial DS (%)	Final DS (%)	ΔDS (%)	Kinetics coefficient (g/s.A)
AS-L	20.43 ± 0.15	31.12 ± 0.28	12.17 ± 0.01	0.0011 ± 1E-04
DS-M	14.6 ± 1.11	30.7 ± 1.56	18.96 ± 0.02	0.0006 ± 7.07E-05
IS-J	8.24 ± 0.14	19.6 ± 0.99	9.62 ± 0.01	0.0004 ± 3.69E-05
AS-U	18.66 ± 0.08	28.56 ± 2.28	9.94 ± 2.26	0.0018 ± 0.0003
IS-G	11.26 ± 0.19	21.71 ± 1.94	10.52 ± 1.14	0.001 ± 5.63E-05
AS-A	18.41 ± 0.14	22.79 ± 0.52	5.29 ± 0.77	0.0008 ± 0.0002
IS-A	34.95 ± 0.82	51.83 ± 1.98	18.68 ± 4.73	0.0031 ± 0.0011
AS-EA	18.56 ± 0.87	23.39 ± 0.57	5.83 ± 0.55	0.0012 ± 0.0003

Dewatering kinetics coefficient and DS gain differences between the sludges were observed. These differences are probably due to differences of the initial DS, the origin of the sludges, the different treatment processes used and the differences of physicochemical properties between the sludges.

Sludges AS-L and AS-U that are both urban activated sludge with similar DS_i have similar ΔDS (around 9-12%), where DS-M which is an urban digested sludge perform with higher ΔDS (19%). Digested sludge seems to perform better than activated sludge. This confirms some observations made by previous studies (Visigalli et al., 2017) where digested sludge gained 10% DS while activated sludge performed lower with 7% ΔDS for tests under constant voltage. These differences between activated and digested sludges could be explained by the lower VSS fraction in digested sludge compared to activated sludge (58% for DS-M and 72-77% for AS-L and AS-U). The stabilization process under anaerobic conditions may cause a decrease of the organic fraction, thus lower VSS which can be explained by the lower presence of EPS (around 363 mg/gVSS for DS-M against 1707-1392 mg/gVSS for AS-L and AS-U respectively). Higher presence of EPS hinders water removal from sludges.

Comparing all urban activated sludges that have similar DS_i around 18-20% (AS-L, AS-U, AS-A and AS-EA), we notice some differences in the DS gain. AS-L and AS-U performed 9-12% ΔDS while AS-A and AS-EA performed only around 5% ΔDS. The noticed differences may be explained by the observed conductivity values (around 0.55 mS/cm for AS-L and AS-U, against around 0.9 mS/cm for AS-A and AS-EA). Higher conductivity led to lower DS gains. (Citeau et al., 2011) mentioned that the increase of conductivity was detrimental for EDW rate.

Industrial sludge IS-A performed the best with 19% ΔDS, although it was the sludge with highest DS_i (35%), the highest EPS concentration (6228 mg/gVSS), the highest conductivity (2.17 mS/cm) and the highest VSS content (82%). This result is contradictory with the aforementioned conclusions and we can assume that there are certainly other sludge properties that we didn't include in our study that have greater impact on EDW.

Correlation analysis between physicochemical properties and dewatering kinetics

The dewatering kinetics coefficient (Equation 2) was used to investigate the performance of EDW. To reveal the correlation between the tested physicochemical sludge properties and the kinetics coefficient, Pearson's correlation was used. Then, the mathematical relationship was investigated using a multiple linear regression model between the parameters and the EDW response (the kinetics coefficient).

Pearson's correlation

In order to quantitatively describe the main sludge properties affecting the dewatering kinetics, Pearson's correlation was used. Pearson's correlation coefficient (R) between the measured sludge properties and the dewatering kinetics are presented in Table 5.

Table 5: Pearson's correlation coefficients between the dewatering kinetics and studied sludge properties ($p<0.05$)

	KI-EDW
KI-EDW	1
Initial DS	0,9340438
VSS	0,63856341
pH	0,08570593
ORP	-0,04846469
Conductivity	0,39296028
Hydrophobicity	-0,12572334
Surface charge	-0,45526621
S-EPS	0,92461445
B-EPS	-0,07740631
T-EPS	0,9420207

The kinetics coefficient positively correlated strongly with initial DS ($R=0.93$, $p<0.05$) and S-EPS ($R=0.92$, $p<0.05$), while it significantly positively correlated with VSS ($R=0.64$,

$p<0.05$) and conductivity ($R=0.393$, $p<0.05$), but significantly negatively correlated with surface charge ($R= -0.46$, $p<0.05$). pH, redox potential (ORP) and hydrophobicity doesn't seem to have influence on the kinetics coefficient (low R).

Some authors studied the correlations of some physicochemical properties on the EDW process. (Visigalli et al., 2017) showed that the most influencing parameters on the DS gain (ΔDS) were initial DS after mechanical dewatering, VSS and conductivity. (Bai et al., 2019) found that VSS strongly positively correlated with final DS content ($R=0.926$) and while they studied the components of EPS, they observed that polysaccharide inside EPS (EPS-Po) strongly correlated with final DS content ($R=0.852$), while conductivity had an insignificant impact ($R=-0.099$). (Zhang et al., 2021) also examined the impact of some parameters on the process and identified S-EPS to be the most influencing parameter affecting EDW rate ($R=0.87$, $p<0.01$). They also studied the B-EPS and found out that its composition of tightly bound EPS (TB-EPS) and loosely bound EPS (LB-EPS) played different roles. Indeed, they highlighted that LB-EPS are those that affected the EDW rate ($R>0.81$, $p<0.01$) while TB-EPS didn't strongly correlate with EDW rate ($R<0.61$, $p<0.01$). In another study where (Li et al., 2020) investigated the differences in the properties of sludge cake between the anode and cathode in different layers, and they established a correlation between some sludge parameters and the process response. They concluded that pH was the main factor in the upper sludge layer in contact with anode (R between 0.676 and 0.993, $p<0.01$) affecting the process response in terms of energy consumption. On the other hand, they concluded that the main parameter affecting the energy consumption in the lower layers of sludge near the cathode were initial DS content (R between 0.860 and 0.990, $p<0.01$) and conductivity (R between 0.924 and 0.991, $p<0.01$).

The altogether cited studies used mostly urban activated sludges (digested sludge in the study of (Visigalli et al., 2017) and (Zhang et al., 2021)) and they all conducted EDW tests under constant voltage (U-EDW). The noticed differences between the results may be caused by the differences of the sludge's types and origins, the interaction between different sludge properties because they are not independent of each other and the different process response chosen for the correlations.

The greatest extent from the cited studies and ours, EPS has a significant influence on sludge dewaterability and the kinetics. Indeed, EPS can influence the surface charge of sludge flocs, absorb different ions and thus change conductivity of the sludge. Besides, EPS represents the larger part of DS, hence higher amounts of EPS will significantly limit the dewaterability of sludge.

In order to establish a mathematical relation between $K_{I\text{-}EDW}$ and the sludge properties, a multiple linear regression model was used in the next step of this study taking into account only the parameters that correlated using Pearson's correlation.

Multiple linear regression

In the interest of having a mathematical relationship between the kinetics coefficient and the sludge properties, a multiple linear regression model (Equation 5) was used to describe this relationship.

$$Y = \sum_{G=0}^{G} X_G . \beta_G + \varepsilon \quad \text{(Equation 5)}$$

Where Y the depending variable, X is the independent variables, β is the regression coefficient and ε the random error. In our study, Y would be the dewatering kinetics

coefficient and X the measured sludge physicochemical properties that correlated with Pearson's correlation (DS_i, VSS, Conductivity, Surface charge and S-EPS).
By applying the model to our study, we obtain Equation 6.

$$K_{I-EDW} = -0.0011 - 7.85E^{-05} * DS_i + 5.51E^{-05} * VSS - 0.0023 * C - 0.00043 * SC + 9.55E^{-07} * SEPS \quad \textit{(Equation 6)}$$

With DS_i the initial DS content (%), VSS the volatile suspended solids (%), C the conductivity (mS/cm), SC the surface charge (mEq/gDS) and S-EPS the soluble EPS (mg/gVSS).

Then the experimental kinetics coefficient was compared with the calculated one thanks to Equation 6. The results are shown in Table 6.

Table 6: experimental and modelling kinetics coefficient

sludge	Experimental kinetics coefficient (g/s.A)	Modeled kinetics coefficient (g/s.A)	Error (%)
AS-L	0.0011	0.0011	3
DS-M	0.0006	0.0006	6
IS-J	0.0004	0.0003	14
AS-U	0.0018	0.0018	2
AS-A	0.0008	0.0010	26
IS-A	0.0031	0.0031	0
AS-EA	0.0012	0.0010	16

By applying the modelling kinetics coefficient, we found out similar values to the experimental ones. We can assume that this model is viable for the sludge types we used in this study.

CONCLUSION

In this study, different types of sludges mechanically dewatered were used for EDW tests under constant electric current (I-EDW). Some of their physicochemical properties were analysed and the dewatering kinetics measured. EDW tests allowed to remove extra water from the sludges at different levels, and differences in the dewatering kinetics were also observed.
The DS gain was higher for digested sludge compared to activated sludge. The stabilization step on anaerobic digestion could explain a decrease in the organic fraction and thus a lower VSS and lower EPS concentrations in the digested sludge compared to activated sludge. Some DS gain differences between four urban activated sludge were noticed and could be explained by the conductivity differences. Indeed higher conductivity led to lower DS gains. Industrial sludge from packed meals industry performed well in terms of DS gain even though the physicochemical properties we studied were high for this sludge type and we could expect the contrary. We assume that some other properties (that we didn't include in our study) could have important influence on the EDW process. The effects of sludge's properties on the kinetics were also evaluated using Pearson's correlation. Thus, the preliminary results provide information about the most influencing properties on the kinetics coefficient among the studied ones. Notably, initial DS after mechanical dewatering and soluble EPS are highly positively correlated with the kinetics coefficient. A higher initial DS content and a higher EPS concentration will lead to an

increasing dewatering kinetics. Conductivity, surface charge and VSS were also significantly correlated with the dewatering kinetics.

From the Pearson's correlation results, the most influencing parameters were used in a multiple linear regression model. This permitted a mathematical relationship between the kinetics coefficient and the physicochemical properties. This allowed to mathematically model the kinetics coefficient and compare it to the experimental one. The results were similar and we could assume that this model is viable for the types of sludge we studied. This study helped have a better understanding of the impact of physicochemical properties on the EDW process in terms of DS gain and kinetics coefficient. The kinetics coefficient is a part of the empirical model that was previously developed. The next step is trying to improve the kinetics model more precisely by including the sludge physicochemical properties. This model will help predict the evolution of DS over time not only by information about applied current, the sludge loading rate and the initial DS, but also by adding the sludge physicochemical properties.

REFERNCES

Bai, H., Zhu, R., An, H., Zhou, G., Huang, H., Ren, H., & Zhang, Y. (2019). Influence of wastewater sludge properties on the performance of electro-osmosis dewatering. *Environmental Technology*, *40*(21), 2853–2863. https://doi.org/10.1080/09593330.2018.1455744

Carter, M. R., & Gregorich, E. G. (Eds.). (2008). *Soil sampling and methods of analysis* (2nd ed). Canadian Society of Soil Science ; CRC Press.

Citeau, M., Larue, O., & Vorobiev, E. (2011). Influence of salt, pH and polyelectrolyte on the pressure electro-dewatering of sewage sludge. *Water Research*, *45*(6), 2167–2180. https://doi.org/10.1016/j.watres.2011.01.001

Citeau, M., Larue, O., & Vorobiev, E. (2012). Influence of Filter Cell Configuration and Process Parameters on the Electro-Osmotic Dewatering of Sewage Sludge. *Separation Science and Technology*, *47*(1), 11–21. https://doi.org/10.1080/01496395.2011.616567

Li, Y., Liu, Y., Yu, X., Li, Q., Zhang, R., & Zhang, S. (2020). Enhancement of sludge electro-dewaterability during biological conditioning. *RSC Advances*, *10*(6), 3153–3165. https://doi.org/10.1039/C9RA09126B

Mahmoud, A., Hoadley, A. F. A., Conrardy, J.-B., Olivier, J., & Vaxelaire, J. (2016). Influence of process operating parameters on dryness level and energy saving during wastewater sludge electro-dewatering. *Water Research*, *103*, 109–123. https://doi.org/10.1016/j.watres.2016.07.016

Mahmoud, A., Olivier, J., Vaxelaire, J., & Hoadley, A. F. A. (2010). Electrical field: A historical review of its application and contributions in wastewater sludge dewatering. *Water Research*, *44*(8), 2381–2407. https://doi.org/10.1016/j.watres.2010.01.033

Navab-Daneshmand, T., Beton, R., Hill, R. J., & Frigon, D. (2015). Impact of Joule Heating and pH on Biosolids Electro-Dewatering. *Environmental Science & Technology*, *49*(9), 5417–5424. https://doi.org/10.1021/es5048254

Olivier, J., Conrardy, J.-B., Mahmoud, A., & Vaxelaire, J. (2015). Electro-dewatering of wastewater sludge: An investigation of the relationship between filtrate flow rate and electric current. *Water Research*, *82*, 66–77. https://doi.org/10.1016/j.watres.2015.04.006

Sha, L., Yu, X., Wu, Z., Liu, X., Wang, H., Jiang, Q., & Zhang, S. (2021). Study of the variations in apparent electrical resistivity of activated sludge during the electro-dewatering process. *Environmental Research*, *198*, 110453. https://doi.org/10.1016/j.envres.2020.110453

Tuan, P. -A., Jurate, V., & Mika, S. (2008). Electro-dewatering of sludge under pressure and non-pressure conditions. *Environmental Technology*, *29*(10), 1075–1084. https://doi.org/10.1080/09593330802180294

Tuan, P.-A., & Sillanpää, M. (2010). Effect of freeze/thaw conditions, polyelectrolyte addition, and sludge loading on sludge electro-dewatering process. *Chemical Engineering Journal*, *164*(1), 85–91. https://doi.org/10.1016/j.cej.2010.08.028

Visigalli, S., Turolla, A., Zhang, H., Gronchi, P., & Canziani, R. (2017). Assessment of pressure-driven electro-dewatering as a single-stage treatment for stabilized sewage sludge. *Journal of Environmental Chemical Engineering*, *5*(6), 6122–6131. https://doi.org/10.1016/j.jece.2017.11.034

Wilén, B.-M., Jin, B., & Lant, P. (2003). The influence of key chemical constituents in activated sludge on surface and flocculating properties. *Water Research*, *37*(9), 2127–2139. https://doi.org/10.1016/S0043-1354(02)00629-2

Wu, B., Dai, X., & Chai, X. (2020). Critical review on dewatering of sewage sludge: Influential mechanism, conditioning technologies and implications to sludge re-utilizations. *Water Research*, *180*, 115912. https://doi.org/10.1016/j.watres.2020.115912

Zhang, Y., Cao, B., Ren, R., Shi, Y., Xiong, J., Zhang, W., & Wang, D. (2021). Correlation and mechanism of extracellular polymeric substances (EPS) on the effect of sewage sludge electro-dewatering. *Science of The Total Environment*, *801*, 149753. https://doi.org/10.1016/j.scitotenv.2021.149753