

Mechanism of Separation of Heavy Metals from Water by Means of Active Filter Plate

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Abstract: Filtration methods are dynamic processes, where depending on intensity of media flowing in the filter pores, participate on trapping processes of hydro-colloid particles also shear forces [1, 2]. Amongst the most widespread separation procedures belong filtrations working on various spatial levels (common filtration, micro-filtration, ...). Intense drop of filtered media specific flow, with particle size drop contained in the media is typical for these methods. Another negative effect manifests itself here as well - poly-dispersity of flow pores' sizes.

Keywords: Oxycellulose, Linters, Separation, Active Filter Plate

1. INTRODUCTION

A. SF filtration

It is a modern separation process that falls into so called active nano-technologies. The separation of colloid and soluble substances happens in nano-space of the pores around the active centre, ensuring focusing of separated substances and their agglomeration - usually coagulation and flocculation.³ Flocculated substances are irrevocably trapped inside of the filter bed. Schematically, the process is depicted in fig.1. Execution of SF separation is easy - it is a high-flow and efficient filtration.

The disadvantage is a difficult regeneration of the filter plate (FD) and gradual fouling associated with increase of hydraulic friction, similar to common filtration.

The advantage is an easy FD deposition with heavy metal concentration and complete biodegradability of FD - burning is also possible.

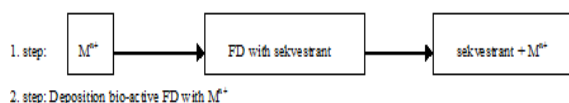


Fig.1. Sorptive- Filtration Process With Using Active FD

B. Cellulose Filter Plates

Filter plate can be envisioned as a three-dimensional in-depth filter, formed by absorbents, with a large inner specific surface. It is a maze of differently long small chambers and channels inside of the plate, in which ions M^{n+} are being caught. There are three specified filtration mechanisms, existing for filtration through the filter plate. All three are being used in practice.

1) Mechanical filtration: direct filtration of metal compound particles through a porous layer. The particles bigger than the pores are being caught mechanically.

2) Absorption: the principle is weak intermolecular

interactions, so called van der Waals forces, acting in between molecules, nano- and micro-particles of hydrous systems and the material of the plate. The particle smaller than a pore is being caught inside of the small chamber or channel.

3) Electro-kinetic absorption: the principle is opposite, so called Zeta potential of micro-particles and flow pores, and, attractive forces of electro-static nature created in between them during mutual motion. It is being usually used for plates with micro-biological effects and for trapping of anion-active impurities.

C. Separation process

Separation of heavy metals from water by application of activated filter plates cannot be considered an easy sorptive process, but a complex colloid-sorptive process [3].

The sorption itself does not happen on the surface or inside of the hydro-colloid particles, fibres and similar sequestrants by a classical ion-exchange mechanism, but, the sorbed particles themselves, i.e. ions, molecules, or hydro-colloid adducts with metals, diffuse into neighbouring immobilized water layers of sequestrants, depending on their thickness and viscosity, by working of electro-static, or eventually other inter-molecular forces [3]. Hydration forces can also be taken into account. At the same time, the sorption particles are, layer by layer, gradually being pushed in, by the aforementioned forces, deeper and deeper into a layer of rising viscosity of immobilized water of the sequestrants. Hereat, the concentration of the sorption particles in each of the layer, is determined by working of repelling electro-static forces, applying themselves by the means of diffuse layers around each of them. The thicker the infusion layer, the higher the resistance of the environment against their mutual proximity, and, the lesser will also be the tendency of their rising and the tendency of rising sorption capacity of the sequestrant. Generally, increasing of the ion force of the environment leads to decreasing of the diffuse layer thickness around ion-active particles, and therefore also to a drop of repelling electro-static forces amongst them. The result is increased concentration of sorbed particles in the environment of proper, so called, active sequestrant centres, followed also by levelling up of their eventual agglomeration, i.e. by coagulation or flocculation - phenomenon termed as surface flocculation. The consequence of such processes is then increased capacity of sequestrants.

Provided the sorbed particles remain unchanged, the sorption capacity of the sequestrants would go up along with rising thickness of their neighbouring immobilized

water layers. In reality though, often the size of sorption particles increases, by the de-stabilization of hydro-colloid systems, with only the sole presence of colloid-active ions and molecules. By this decelerates their infiltration into neighbouring layers of immobilized sequestrants' water, and, decreases depth into which they are capable to penetrate, due to their lower mobility. Significant it is chiefly in case of colloid-active cation presence [4].

2. MATERIALS AND METHODS

A. Separation efficiency

Separation efficiency SE expresses a quantity of metal M^+ , which has been trapped on the fibres of cellulose suspension. It is given by ratio of sorbed amount of metal M^{n+} to total initial amount of metal M^{n+} , which has been used in the experiment.

$$SE = \frac{c_a}{c_p} = \frac{c_p - c_{rovn.}}{c_p}$$

The metal tested was cadmium Cd^{2+} in model water containing competitive ions of calcium and magnesium of pH 11.5. It was carried out with cadmium cation, or more precisely, hydrated colloid particles CdO trapped, owing to relatively high pH of model water, on nano-interface of filter plate pore walls, by working of electro-static forces.

B. Filter plates

For experiments, two types of filter plates were elected. Filter plates SD 100N and S 80R were made of special types of high-quality cellulose fibres, diatomaceous earth, perlite and cellulose activated by cationic quaternary oligomer epoxy-propyl-trimethylammonium chloride substance. They created three-dimensional in-depth filter with large inner surface. The placed were delivered by company Hobraškolníks.r.o. Filter plates s 80R were made of cationic-activated cellulose.

Table 1: The parameters are shown in the following table [5]

Filter plates	Type of activation	Flow capacity $m^3/m^2/h$	Porosity μm	Basic weight g/m^2	Retentiveness μm
S 80R	Active	50-90	7,0	1000-2000	8
SD 100N	Non-active	90-120	9,0	900-1200	11

C. Description of experiment

- Constant specific amount of flown-through filtrate SFA=constant (250 mL model water), changes c_M ($c_M=0,5; 1; 2g CdCl_2/L$)

For filtration through filter plates SD 100N and S 80R was prepared a series of solutions with increasing content of Cd^{2+} ($c_M=0.5; 1; 2g CdCl_2/L$), by dissolving in 250 mL of model water. After stirring, the mixture was (250ml constant specific amount) filtered through suction filter funnel with relevant dry-air filter [6].In filtrate the absorbance was measured and concentration of untrapped cadmium ions determined

- Constant value of c_M changes amount of flown-through filtrate SFA \neq constant (50, 11, 15, 200 and 250mL amount of flown-through filtrate)

Spare solution of concentration $c_M = 0.4g CdCl_2/L$ of model mixture, was prepared. Out of spare solution were pipetted 50, 100, 150, 200 and 250mL (specific amount of flown-through filtrate) samples and poured over filter plates (dry-air). In the filtrate the absorbancy was measured and concentration of untrapped cadmium ions determined.

D. Spectrophotometric determination of Cd^{2+} ions

The concentration of Cd^{2+} in the filtrate was determined spectrophotometrically with the help of dithizone extract (0,005% solution of dithizone in chloroform) of alkalinized filtrate (by use of 10% solution of NaOH with the ratio 1:1) at $\lambda = 515 nm$ [6].The same measurements were conducted at this wavelength against the reference solution (solution with chemicals without Cd^{2+}).

The procedure was the same as describe above. The basic cadmium solution was prepared by dissolution of 0.1 g in $CdCl_2$ and refilling with distilled water up to the 1 litre volume. 1ml of the solution thus contained $61.32 \mu g Cd$.

The amount of ions in the filtrate was then determined by use of spectrophotometry and standard addition method of quantitative analysis approach $c=c_{rovn}$ [7].

$$c_{rovn.} = \frac{A_0}{k}$$

3. RESULTS AND DISCUSSION

- Constant specific amount of flown-through filtrate SFA=constant (250 ml model water), changes c_M ($c_M=0,5; 1; 2g CdCl_2/l$)

A sample of model water with Cd^{2+} was filtered through suction filter funnel with the relevant filter. The filtration was very quick.

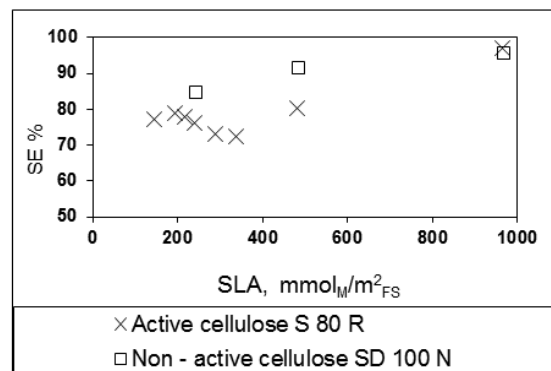


Fig. 2. Dependence of SE Versus SLA, $mmol_M/m^2$

Table 1: Dependence of SE versus SFA active filter plate S 80 R

SE, %	$c_p, g/l$	$mmol_M/m^2_{FS}$	$mmol_M/g_{FS}$
767,968	0,1840	144,70	0,1637
790,112	0,2453	192,93	0,2182
782,188	0,2759	217,05	0,2455
759,952	0,3066	241,17	0,2728
730,697	0,3679	289,40	0,3273
723,339	0,4292	337,64	0,3819
802,053	0,6132	482,34	0,5455
971,899	12,264	964,67	10,910

Table 2: Dependence of SE versus SFA no active filter plate SD 100 N

SE, %	$c_p, g/l$	$mmol_M/m^2_{FS}$	$mmol_M/g_{FS}$
852,692	0,3066	2,411,682	0,2728
916,895	0,6132	4,823,363	0,5455
960,985	12,264	9,646,726	10,910

The filter plates made of activated cellulose S 80 R have cation-active character, since they are above all created by activated pulp of cation-active character. The plate contains smaller pores, which quickly get jammed. As can be seen in fig. 2, dependence of SE vs. SLA are not simple, but goes through extremes.

For the filter plate made of non-activated cellulose, the course was different. They are more sufficient separators of cadmium ions, in regards of anion-activated character of untreated cellulose. With rising of specific loading, the separative efficiency is monotonously going up. (Fig. 2) In measured range of concentrations, the separative efficiency in reference to Cd^{2+} increases with growth of specific filter loading, achieved only by rising its concentration, whereas specific amount of filtrate remains constant.

- Constant value of c_M changes amount of flown-through filtrate SFA \neq constant (50, 11, 15, 200 and 250ml amount of flown-through filtrate)

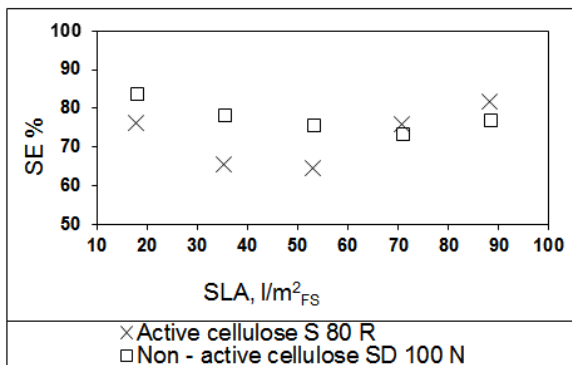


Fig.3. Dependence of SE Versus SLA, l/m^2_{FS}

Table 3. Dependence of SE versus SFA active filter plate S 80 R

SE, %	V, l	l/g_{FS}	l/m^2_{FS}
764,638	0,05	0,02	176,841
652,870	0,10	0,04	353,682
645,342	0,15	0,06	530,523
759,019	0,20	0,08	707,364
814,991	0,25	0,10	884,205

Table 4: Dependence of SE versus SFA no active filter plate SD 100 N

SE, %	V, l	l/g_{FS}	l/m^2_{FS}
837,967	0,05	0,02	176,841
784,990	0,10	0,04	353,682
757,300	0,15	0,06	530,523
734,756	0,20	0,08	707,364
771,270	0,25	0,10	884,205

In comparison with the previous example there is a great difference here. At the both types of filter plates, at first

the separative capacity of plates declines with a rise of flown-through filtrate amount - more obvious it is with the activated filter plate S80 R. Finally, follows a gradual rise of this capacity. There is only one extreme here - a minimum, showing up in comparison with anion-active filter plate at lower specific loading of a filter plate containing also cation-active oligomeric groups.

4. CONCLUSION

It comes out, that filter plates S 80R, which were activated and contained cation-active groups, are more suitable for separation of Cd from waste, at its higher concentrations in alkaline waters.

During filtration process using activated filter plates S 80R, three different specified filtration mechanisms are taking place (see fig 4), characterized by two extremes on SE vs. SLA dependencies, at constant specific amount of flown-through filtrate. At first, classical adsorption takes place, then follow hydro-colloid processes, up until the anion-active centres have been fully exhausted. After that comes classical mechanical trapping, promoted by hydro-colloid processes, in the sense of their displacing from the vicinity of cationic nano-centres and de-stabilisation (surface flocculation) in the vicinity of surface anionic nano-centres, where on the contrary, their concentration goes up.

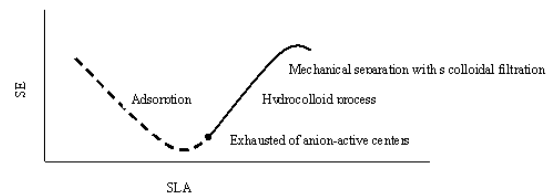


Fig. 4. Separation Process

The filter plates SD 100N were not activated, were therefore only of anion-active character. During sorption, only the negative Zeta potential was exercised, and, corresponding to that, attractive electro-static forces against cadmium colloid particles. Those filter plates are more suitable for using in case of lower concentrations of Cd in waste.

Differences in separation efficiency for both types of filter plates are gradually vanishing, with growth of cadmium concentration. It can be expected, that at higher cadmium concentrations begins a positive influence of projected oligomeric groups of activator used (quaternary oligomeric 2-hydroxy-propyl-3-trimethylammonium group). They also have a capability of creating complex compounds, which induces in nano-space another agglomeration (surface agglomeration) of cadmium ions at the rise of hydrated nano-particles of cadmium oxide.

During filtration, mechanical trapping takes place, that is why at the increase of specific loading of the filter, always rises its separation efficiency, as a consequence of its blocking. In addition to process of surface flocculation, sorption processes also take place. Those cause a creation of extremes on the curves SE vs. SLA.

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A_0	absorbance unknown sample
c_M	original concentration of Cd^{2+} (g/L)
$c_{rov\bar{n}}$	equilibrium concentration of Cd^{2+} (g/L)
c_a	equilibrium concentration of the Cd^{2+} adsorbed onto the pulp surface(g/L)
c_p	total concentration of the dye in the aqueous system (g/L)
FS	filter plate
K	regression parameter of equation line
M^{n+}	Cd^{2+}
SFA	specific amount of filtrate remains (L/m^2_{FS}); (L/g_{FS})
SLA	specific loading of filter plate($mmol_M/m^2_{FS}$); ($mmol_M/g_{FS}$)

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AUTHORS PROFILE



Michaela Filipi was born in Pardubice on 25th of July 1980. She attended the University of Pardubice, especially in Institute of Chemistry and Technology of Macromolecular Materials. The topic of her work is concentrated on fundamental and applied problems of cellulose chemistry,