ANALYSIS OF THE PHYSICAL AND CHEMICAL PROPERTIES OF ARSENIC SLUDGE TO IMPROVE DEWATERING AND DISPOSAL

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ABSTRACT

Arsenic (As) is a metalloid, considered to be carcinogenic for human beings when consumed. As a consequence, there are several types of technologies that remove it, which by doing so, generate waste with high concentrations of As. Therefore, the aim of this study was to optimize the processes of conditioning and dewatering of the sludge generated in the coagulation-flocculation processes for water containing As. For said purpose, the physical and chemical quality of sludge was analyzed, as well as the factors that have an influence in the dewatering.

Arsenic (As) is chemically classified as metalloid with valences As^{3+}, As^{5+}, As^{3-}. The changes in the ionization of arsenite and arsenate take place at different pHs and redox potentials. The toxic effects of arsenic have been documented; they are subjected to the concentration of arsenic at the moment of the exposure, the frequency and duration of the exposure, and the type of arsenic present during said exposure. According to ATSDR (2007), acute exposure is >2 mg/kg/d and chronic exposure is 0.03-0.1 mg/kg/d. As a consequence, different authorities have established the following maximum allowable limits of As in water: for the World Health Organization (WHO): 0.010 mg/L; risk of cancer for the Environmental Protection Agency (EPA): 0.020 mg/L; and for the Official Mexican Standard NOM-127-SSA1-1994: 0.025 mg/L.

As it has been mentioned before, residual is generated through the removal of arsenic from water for human consumption by different treatment systems. This residual must be minimized in the early stages through the selection of source of raw water, treatment process, hydraulic configuration of the process units, dosed chemical reagents, media or membranes: filtering, adsorbent, and ionic exchange, Table 1.

Therefore, the treatment of sludge containing As generated from plants that produce drinking water is of great importance. And it is also of vital importance to eliminate totally or partially the sludge water contain, and as a consequence, decrease its volume in order to facilitate its transportation and final disposition operations. Among the

treatment methods that reduce the volume of sludge we can find: thickening, conditioning, and dewatering.

The thickening process is carried out when the sludge generated in a water treatment plants is sedimented to produce a more concentrated solid and a liquid fraction relatively free of particles. This supernatant is recirculated to the influent of the process, which allows a considerable reduction in the volume and an increase in the concentration of solids. This has a direct effect in the subsequent processes (conditioning and dewatering) since they show a better functioning, more efficiency, and a reduction in the size of the units. There are mainly two types of thickening devices: gravity decanter or flotation decanter, (Fernández, 2015).

Table 1. Residuals produced from arsenic removal in drinking water
(Adapted by Garrido, 2016 de Amy *et al.*, 1999)

Technology	Removal As (%)	Volume of residuals produced (L/m³)	As concentration in residuals (mg/L)	Quantity of solids produced (kg/m³)	Leached (TCLP) (mg As/L)
Conventional[3] coagulation	As(V): >80 As(III): >20-80	4.3	9.25[1]	21.59	0.0009
Coagulation[3] + microfiltraion	As(V): >95	52.6	0.76	13.50	1.56
Softening	As(V): >90	9.6	4.2	239.89	0.0039
Ion exchange	As(V): >85	4.0	10	0.623	-
Activated alumina	As(V): >95	4.2	9.52	2.8	0.0093
Iron oxides coated sand	As(V): >99 As(III): >80	21	1.9	2.8	-
Nanofiltration/RO	As(V): >90/95 As(III): >70	200-300[2]	0.098	-	-

On the other hand, few studies results have been published concerning the relationship between floc characteristics and drainability. Large, loose or bulky flocs with great proportion of free filtrate (free water) are required for thickening. They are generally obtained with structured high molecular weight emulsion polymers or high cross-linked polymers with a higher dosage (Ginisty *et al.*, 2011).

Although the thickening of the sludge decreases the moisture percentage between 3% and 5%, it is not enough since it is necessary to conditioning it to optimize the percentages and reach from 20% to 30% of solids in the sludge, mainly if they are formed by heavy and granular solids (Syed, 2000). The chemical conditioning using polymers modifies the physical and chemical characteristics of the sludge, so later the sludge can be dewatered through mechanical methods thus reducing its moisture content and as a consequence, decrease the transportation costs until reaching its final destination.

Nowadays, facilities for dewatering within treatment plants are considered, but there are not enough studies about the physical and chemical properties of sludge for its later treatment and proper disposition.

The purpose of this study was to analyze the physical and chemical properties of the sludge generated in the coagulation-flocculation of water containing arsenic, in order to optimize the conditioning and dewatering processes, for a better final disposition.

Methodology and materials

In order to optimize the thickening, chemical conditioning, and dewatering processes for the waste generated in the coagulation-flocculation of water containing arsenic, the following procedure was followed:

First, the removal of arsenic from water for human consumption was carried out in order to obtain the sludge resulting from coagulation, flocculation, and sedimentation processes with three initial concentrations of arsenic: 0.050 mg/L, 0.100 mg/L, and 0.150 mg/L. Sodium arsenate was added to well water located in the facilities of the Mexican Institute of Water Technology (*Instituto Mexicano de Tecnología del Agua, IMTA*).

The variables used to carry out the experimental design were established with studies carried out from Garrido et al. (2013a, b): (A): pH 6.5, 7.0 and 7.5, (B) Coagulant dosing (FeCl$_3$) 20, 30, and 40 mg/L (relations of Fe(III)-mg$_{dosed}$/As(V)-µg$_{removed}$: 1:20, 1:30, 1:40); (C): cationic polymers HMW496, CATC5310-2, and Polyfocal-CH, speed gradients in the rapid mix: 300 s^{-1}/10 s; slow mix: 65 s^{-1}/5 min; 30 s^{-1}/5 min; 17 s^{-1}/5 min and 10 s^{-1}/5 min, sedimentation: 10 min. The equipment used was a Jar test (Phipps & Bird brand), with an operation interval of 0-300 rpm, which is composed by six jars of 2 L each. The experimental design was central composite: N=2^3; and the response variables were: settleable solids (SETS) and the concentration in the As supernatant, with the Statgraphics software version XVII.

Then, the physical and chemical properties and characteristics of sludge resulting from coagulation-flocculation processes were analyzed. The physical properties were: sludge humidity (c_i), humidity of the cake (c_f), solids in the wet cake, solids in the dry cake, specific resistance to filtration (SRF), filtration time (Ft), compressibility, according to (Cornwell, *et al.*1987) total solids, settlable solids, according to (NMX-AA-034-SCFI-2001), density, flocculation index by Willcomb and Z Potential (Microtrac, Zeta Check). Chemical properties: distribution of moisture, according to Coackley (1962), Arsenic, iron by (spectrophotometry, Shimadzu UV-1800) and pH (NMX-AA-008-SCFI-2011).

Second, for the chemical conditioning of the sludge resulting from the process of gravity thickening for 12 h, a screening with five polymers (organic cross-linked polyacrylamide of cationic and anionic charge), Bufloc 5426, Bufloc 5290, Bufloc 5631, Fo4490UHM, Fo4650SSH) was carried out in order to select the best two polymers, taking into consideration the response variables: final concentration of As in the supernatant and SS of the produced sludge.

Later, with the selected polymers, an experimental design was employed (central composite N=2^3) to optimize the study variables: pHs of 6.5, 7.0, and 7.5; with a slow mix stirring of 30 rpm for 1, 2, and 3 min; and a dosage of polymer 1 and polymer 2 of 150, 200, and 250 mg/L; having as response variables: final concentration of As in the supernatant and SETS in the resulting sludge. The physical and chemical

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characteristics of the sludge obtained by the conditioning of the two polymers were analyzed, according to what was described beforehand.

Third, the dewatering of the chemically conditioned sludge (under the optimization conditions described previously) was performed in belt-filter equipment (Bootest-IFTS). It is composed of two sludge flocculators (volume capacity of 1.35 L) and two drainable cells with automatic transfer from one to another (Figure 1). The two flocculators are stirred in the same conditions. The test was carried out mixing time, 2 min and impeller speed, 30 rpm and 500 mL of sludge sample and room temperature 25°C. Drainage cells are equipped with filter cloth, NFMM 281 type, with a permeability of 40 ft^3/ft^2 min. The parameters for drainage kinetics are the ratio of filtrate mass over the sludge initial mass (M/M_0) at different times as recommended in EN 14701-4.

Figure 1. Sludge flocculation and dewatering device (Bootest-IFTS)

On the other hand, to compare with another device, dewatering tests were carried out with a centrifuge from the international brand Equipment Company, model IEC HN-SI. Tubes of 25 mL were placed with samples of the sludge obtained in the conditioning stage for the two best polymers selected, with a speed of 3000 rpm during 4 min. Later, total solids were analyzed.

Results and Discussion

First all, the conditions for the removal of As contained in water for human consumption and the production of sludge resulting from the coagulation-flocculation and sedimentation process were optimized. The optimum values of the variables were: for an initial concentration of As: 0.150 mg/L and selected polymer, HMW496, which was

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showing the best performance in the tests: (A) pH: 7,20; (B) Dosage of FeCl₃: 34,33 mg/L; (C) Dosage of the polymer: 0,89 mg/L The response variables of the As concentration in the supernatant were of < 0,003 mg/L and SETS of 7.59 mL/L. The concentration of iron in the supernatant was of 0.058 mg/L.

These results, under the analysis of variance (ANOVA) revealed that with a confidence interval of 95%, the three variables (A), (B), and (C) showed meaningful statistic differences, with a value of $P < 0.05$, Figure 2.
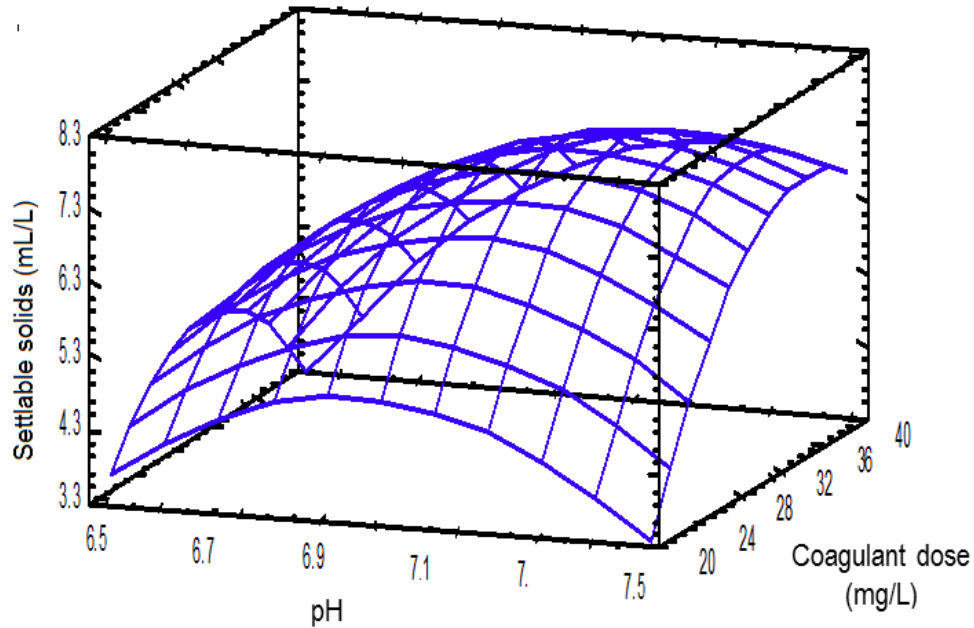

Figure 2. Response surface for factors (A) and (B) optimized. As initial concentration of 0.150 mg/L, HMW496 polymer. R^2: 85.09% and R^2 (ajusted for g.l.): 68.31%

Table 2 shows the physical and chemical properties and characteristics of the initial sludge (obtained from the removal of arsenic from water for human consumption) for the test for which the variables (A), (B) and (C) were optimized.

Table 2. Optimum values of characteristics and physico-chemical properties of iron sludge coming As removal human consumption water

Parameter	Units	Optimum values of initial sludge from C-F
Físicas		
The Willcomb Flocculation Index	-	6 – 8*
Total solids	(g/L)	0.48
Setteable solids	(mL/L)	7.59
Total solids in wet filter cake	(g/L)	2.904
Total solids in dry filter cake	(g/L)	0.405
Initial sludge moisture content (ci)	(%)	99.95
Final sludge moisture content (cf)	(%)	86.07
Density 25°C	(g/mL)	1.0100

Densidad 70°C	(g/mL)	0.9749
Potential Z	(mV)	-57.1
Químicas		
Arsenic	(mg/L)	19.76
pH	Units	6.70
Iron	(g/L)	0.66

* Good. floc that is deposited easy but not completely;
C-F: Coagulation-Flocculation process

The values obtained for the physical properties of the specific resistance to filtration (SRF), compressibility and filtration time (Ft) are shown in Figures 3 and 4, which were obtained by applying the Poiseuille-D´Arcy law, from which the basic filtration equation is obtained (Cornwell, et al., 1987; Ramalho, 1993), Equation (1).

$$\frac{dV}{dt} = \frac{PA^2}{\mu(rcV + R_m A)} \qquad \text{Equation (1)}$$

Where:
V: Filtering volume (m^3)
t: Filtration time (s)
P: Vacuum pressure (dinas/cm^2 = g/cm. s^2)
A: Filtration area (cm^2)
μ: Viscosity of the filtrate (poise = g/cm. s)
r: Specific resistance of the cake passing through the filtrate (cm/g)
c: Concentration of solids settled per filtering volume unit (g/cm^3)
R_m: Initial resistance of the filtering medium (generally negligible cm/g)

The integration and arrangement of Equation (1) allows the calculation of the specific resistance (r), obtaining (Equation 2):

$$\frac{t}{V} = \left(\frac{\mu r c}{2PA^2}\right)V + \frac{\mu R_m}{AP} \qquad \text{Equation (2)}$$

From Equation (2) it is derived that the resulting graphic of t/V in relation to V would be a straight line of the **y = bx + a** type, were:

$$b = \frac{\mu r c}{2PA^2} \qquad\qquad a = \frac{\mu R_m}{PA}$$

If the resistance of the filtering medium R_m is considered negligible and b (s/cm^6) the slope, the specific resistance to filtration is given by Equation (3):

$$r = \frac{2\text{PA}^2 b}{\mu c} \qquad \text{Equation (3)}$$

In Figure 2 and Figure 3, it can be observed that by increasing the differential pressure, the pores of the cake contract, which causes a higher resistance to filtration, until obtaining dewatering due to the smashing of the sludge cake.

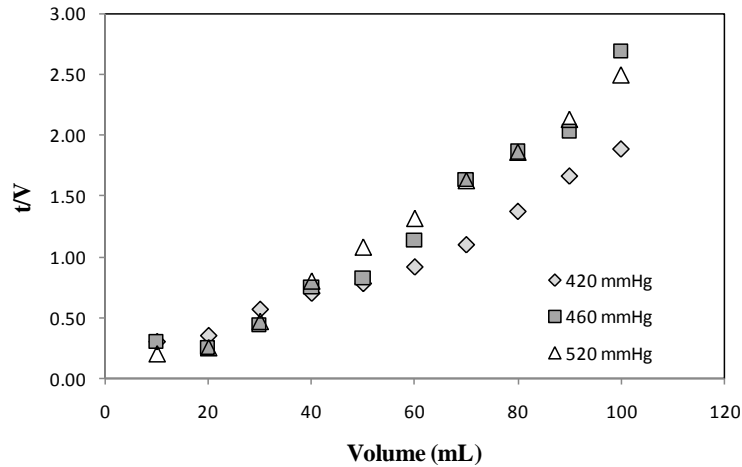Filtration time (Ft) was determined in 107 s, for an initial volume of 100 mL.

Figure 3. Specific resistance to filtration (SRF), at different pressures: 420, 460 and 520 mmHg
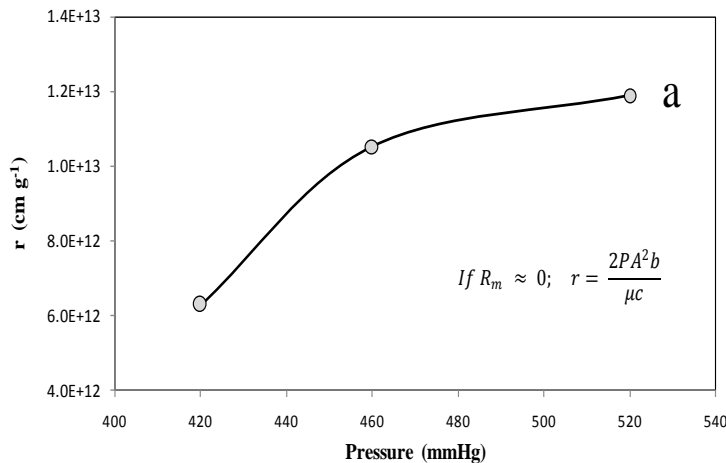

$$If \ R_m \approx 0; \quad r = \frac{2PA^2 b}{\mu c}$$

Figure 4. Compressibility of FeCl$_3$ sludge at three pressures: A: 40.71 cm^2; μ (20°C): 0.01 Poise (g/cm s); c: 5.01^{-4} g/cm^3

The percentage of moisture, as a chemical characteristic of the initial sludge, was calculated with Equation (4):

$$Moisture \ percentage \ (\%) = \left(P_i - \frac{P_t}{P_i} \right) 100 \qquad \text{Equation (4)}$$

Where Pi: Initial weight of the sludge (g); Pt: Sludge weight at each time interval (min) (Figure 5).

Then, once the sludge was thickened for 12 h and the screening has been performed with the five polymers (Table 3), the following polymers were selected: P1: Bufloc 5290 and P2: Fo4650SSH, which provided the best results, in relation to the response variables: final concentration of As in the supernatant (0 mg As/L) and SETS of the produced sludge (350-380 mL/L respectively), in addition to the filtration time (Ft). In relation to the specific resistance of sludge, the smallest value was obtained for P2.

Table 3. Screening of the five polymers dosed for the chemical conditioning of the sludge obtained from the removal of arsenic from water for human consumption

Variable	Bufloc 5426	Bufloc 5290	Bufloc 5631	Fo4490UHM	Fo4650SSH
Charge	Aniónico	Aniónico	Aniónico	Catiónico	Catiónico
pH	3.48	3.33	4.39	6.73	3.43
$As_{supernatant}$ (mg/L)	8	0	6	5	0
SETS (mL/L)	373.3	350	325	345	380
Ft (s)	80	153	195	204	167
r (cm/g)	1.261E+14	7.74129E+13	4.7687E+13	5.5895E+13	4.7687E+13

Then, with polymers P1 and P2, a central experimental design was proposed, $N = 2^3$, in which the optimal values of the variables were obtained: A: Dosage of polymer 1 and 2: 28.4 mg/L; B: pH: 6.4; and C: Time: 2 min. These results, under variance analysis, with a 95% confidence interval, only polymer 2 showed statistically significant differences, with a value of $P < 0.05$. The characteristics and the physical and chemical properties in the chemical conditioning stage are shown in Table 4.

Table 4. Optimum values of characteristics and physico-chemical properties of iron sludge in the chemical conditioning

Parameter	Units	Polymer P1	Polymer P2
Físicas			
The Willcomb Flocculation Index	-	10*	10*
Total solids	(g/L)	6.028	5.443
Setteable solids	(mL/L)	320	290
Total solids in wet filter cake	(g/L)	3.17	3.63
Total solids in dry filter cake	(g/L)	0.56	0.59
Initial sludge moisture content (ci)	(%)	99.39	99.45
Final sludge moisture content (cf)	(%)	82.65	83.75
Density 25°C	(g/mL)	1.0108	1.0121
Densidad 70°C	(g/mL)	0.9713	0.9795
Potential Z	(mV)	-45.3	-40.4
Químicas			
pH	Units	6.1	6.2
Iron	(g/L)	2.98	2.24

* Good. Flocs that deposits easily and completely

As shown in Table 4, the physical and chemical characteristics and properties of the sludge conditioned with the two polymers (P1, P2) improved significantly in relation to the initial sludge obtained in the coagulation-flocculation and sedimentation processes (Table 2): Willcomb Flocculation Index (floc is appropriate and precipitates easily, improving sludge compression); in the total and settlable solids, there was an increase with P1 dosage of 92.03% and P2 of 91.18%: P1 of 97.63% and P2 of 97.38 respectively; solids in the wet and dry cake showed an increase for P1 of 8.31% - 19.64% and for P2 of 20% - 31.36% respectively. Regarding moisture percentages of the dry cake (c_f), it can be said that they were low before and after the conditioning; for the sludge produced in the C-F it was of 86.7% and passed to P1 82.65% and P2 83.75%. So, moisture in the cake must be decreased for a better dewatering. The increase of iron concentration in relation to the initial sludge was; 4.54 times (P1) and 3.42 times (P2). The pH was slightly acidic for the conditioning step.

The moisture content of the sludge in the chemical conditioning is related to the distribution of the free water that represents most of the sludge (not related to the solid particles) and thermodynamically, it behaves as pure water. The evaporation curve for the three types of sludge showed the same trend and there were no significant differences in the slope, Figure 5.
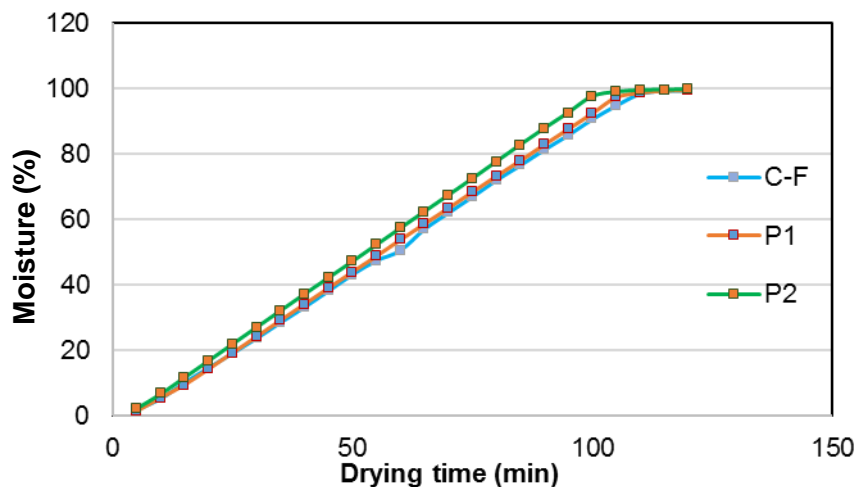

Figure 5. Comparative evaporation curve of initial polymer and polymer P1 and P2 in the conditioning

Once the physical and chemical properties of the two types of sludge (P1 and P2) were studied, dewatering was carried out in the belt filter (Bootest), under optimal conditions of the conditioning stage. Figure 6 shows the drainage kinetics of the sludge after its conditioning with P1 and P2. These tests were performed with the sludge prior to thickening (P1 and P2 c/supernatant) and the sludge after thickening. The thickened P1 showed better kinetics showing its smallest value during filtration time.
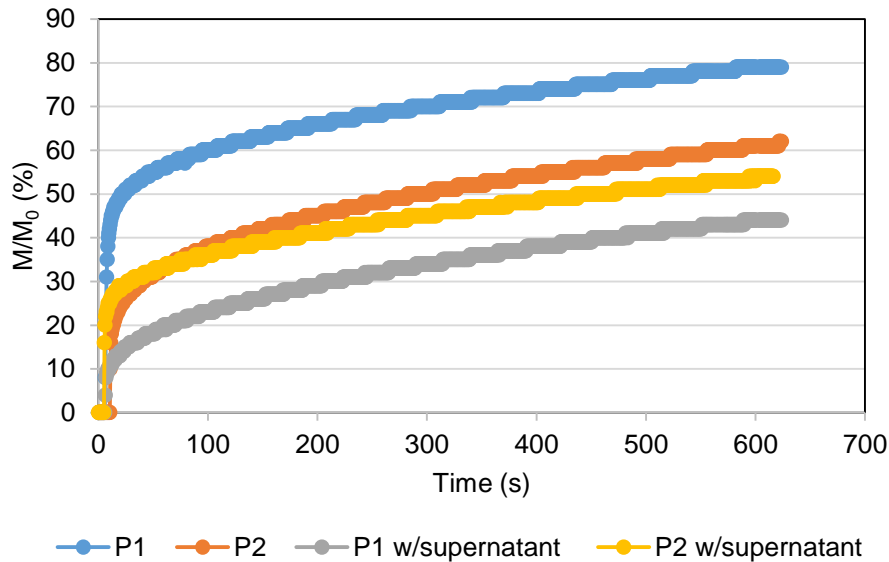
Figure 6. Drainability kinetics in belt filter Bootest

Then, calculations to determine the drainability index (Eg) were carried out, as follows;

Dryness characterization: Solids concentration factor (P1) which refers to the maximum concentration of solids in the sludge. It can be assessed by the ratio of the thickened sludge dryness (Si_f) and the initial solids (Si_0) content of the sludge,

$$P_1 = \frac{Si_f}{Si_0}$$

Equation (5)

Where:
Si_f: Final content of total solids (g/L)
Si_0: Initial content of total solids (g/L)

Kinetics characterization: The value of P2 was obtained carrying out water release kinetics, (Figure 6). For that purpose, M/M_0 was plotted, M: filtered sludge mass, M_0: initial sludge mass. With it, the value (t90) was obtained:

$$P_2 = \frac{t_{90}}{60}$$

Equation (6)

Where:
t_{90}: Minimum time to recover 90% of the total mass of the filtering (s).
60: It is referred to the 90% of the total mass being filtered in less than 60 seconds

Characterization of capture rate: A good capture rate is characterized by a low concentration of suspended solids in the filtrate, less than 1%. Consequently, a filtrate quality (P3) was defined, as the ratio between the residual concentration of suspended solids in the filtrate and the initial solids content of the sludge.

$$P_3 = \frac{SM_r}{Si_0}$$

Equation (7)

Where:
SM_r: Amount of suspended solids in the filtered volume, (g/L).
Si_0: Final amount of total solids, (g/L).

Drainability index: A good drainability is simultaneously characterized by a high value P1, and low values of P2 y P3, That is why the following equation has been considered to define the drainability index:

$$Eg = \ln \frac{P1}{P2^{\alpha} * P3^{\beta}} = \ln \left(\frac{\frac{Si_f}{Si_0}}{\left(\frac{t_{90}}{60}\right)^3 \left(\frac{SM_r}{Si_0}\right)^{\frac{1}{4}}} \right)$$

Equation (8)

Table 5 shows the results obtained for the two types of sludge, P1 and P2, applying the equations (5), (6), (7), and (8) for the dewatering process by belt filter.

Table 5. Dewatering belt filter results of the variables and drainability index for P1 and P2

Parameters	Polymer 1	Polymer 2	Pol. 1 c/supernatant	Pol. 2 c/supernatant
t_{90}	339.49	425.82	468.29	402.26
P1 (g/L)	27.784	15.134	5.302	5.566
P2 (g/L)	5.658	7.097	7.805	6.704
P3 (g/L)	0.04	0.21	0.18	0.20
Eg	-1.1	-2.8	-4.1	-3.6

In order to obtain the drainage index of the sludge (Eg), it was observed that the t_{90} was between 339.49 s and 468.29 s. These values were very high, since it was intended to obtain 90% of the sludge drained in 60 s. This time could be decreased by increasing the concentration of solids in the sludge and by modifying the permeability size of the filtering mesh. The characteristics of the sludge with As showed a loose flocs and difficulty to drain.

In the dewatering by centrifuge, an increase of solids for each process was observed, which was done in relation to the decrease in volume from the initial sludge to the centrifuge.

As shown in Table 6, the conditioning of the sludge with polymer P1 improved the dewatering process, obtaining sludge with a 6.03% of total solids, followed by the dewatering with a belt filter 9.33% of total solids. When the conditioned sludge was

centrifuged, a concentration of 22.48% was obtained. This percentage of solids allowed obtaining a cake of sludge easy to transport and to handle for any usage or for its final disposition.

Table 6. Total solids in the dewatering stage

Total solids (g/L)						
Initial sludge	Conditioned sludge		Band filter		Centrifugation	
	P1	P2	P1	P2	P1	P2
0.48	6.03	5.44	9.33	8.74	22.48	18.42

The conditioning of the sludge is used to improve the performance of the dewatering. As for the filtration, it is a procedure used to dewater or separate solid from liquid. These results clearly demonstrate the notorious increase of solids for each stage; centrifugation is the most efficient method to obtain the largest amount of sludge.

It is important to identify that the properties and characteristics of the initial sludge will be those that will define the necessary conditions to take into account when performing an optimization. Then, a comparative analysis with other researches is carried out, which refer to Al and sludge with Fe and Mn, from the treatment of drinking water, (Piña Soberanis & Rivera Huerta, 2013).
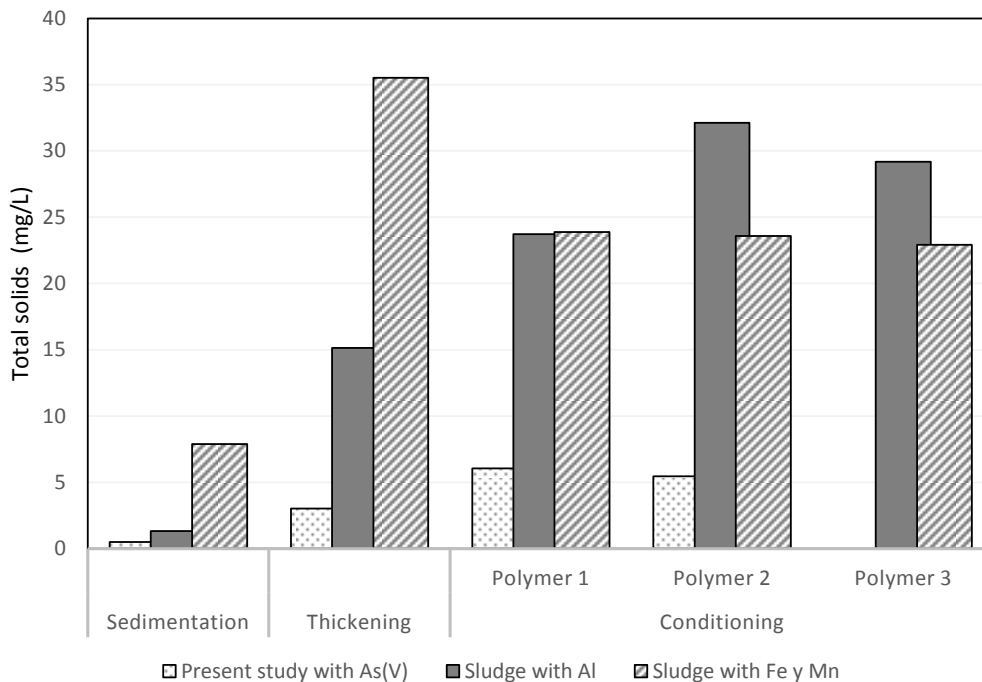

Figure 6 Comparison of total solids in different sludge treatment processes with As(V), Al and Fe with Mn

Figure 6 shows the behavior of the sludge in the different processes in relation to the total solids; for the sludge with Fe and Mn (from the sedimentation process to the thickening process), values of 77.85% were obtained, for sludge with As (V): 84% and for sludge with Al: an increase of 91.31%. It was observed that the percentage of total

solids in the sludge (from the sedimentation to the thickening process) increased, due to the settlement by compression of the particles, which were continuously added to the structure by sedimentation type (IV), therefore, the total solids increased. The highest percentage of solids in this stage was shown by the sludge with Al. In the conditioning-thickening process, the solids increased for the sludge with As(V) on average of its polymers by 48.4%, while for the sludge with Al by 45.72% and for the sludge with Fe and Mn, it decreased by 51%, obtaining a higher percentage for the sludge with (As). It was observed that the arsenic sludge showed an increase in ST concentration for each sludge treatment process.

As for the SRF, it was observed that it decreased in the thickened sludge, and subsequently increased with the chemical conditioning, due to the increase of solids percentage for each treatment process, showing a similar tendency for the different polymers in the three sludge types, in the conditioning step, (Figure 7).
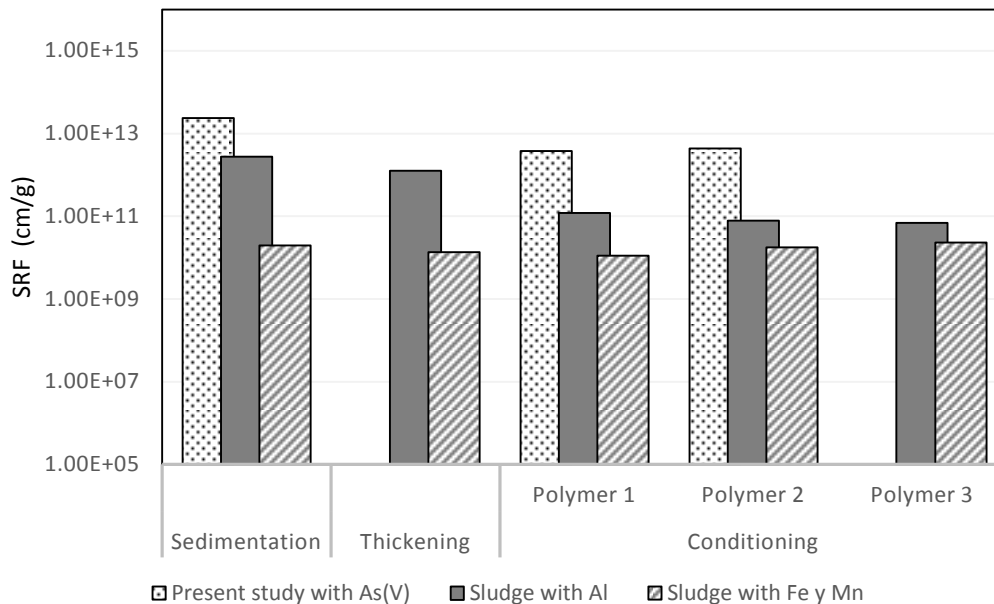

Figure 7 Comparison of the behavior of the SRF for sludge with As(V), Al and Fe with Mn in the different stages of the treatment

The study of filtration time (Ft) showed a resistance of sludge to filtration. When comparing these values with different types of sludge, in Figure 8, we can identify the time difference for sludge with As and sludge with Fe and Mn. Filtration time was higher for sludge with As, compared to sludge with Fe and Mn, and both were directly related to the type of polymer used in the treatment.
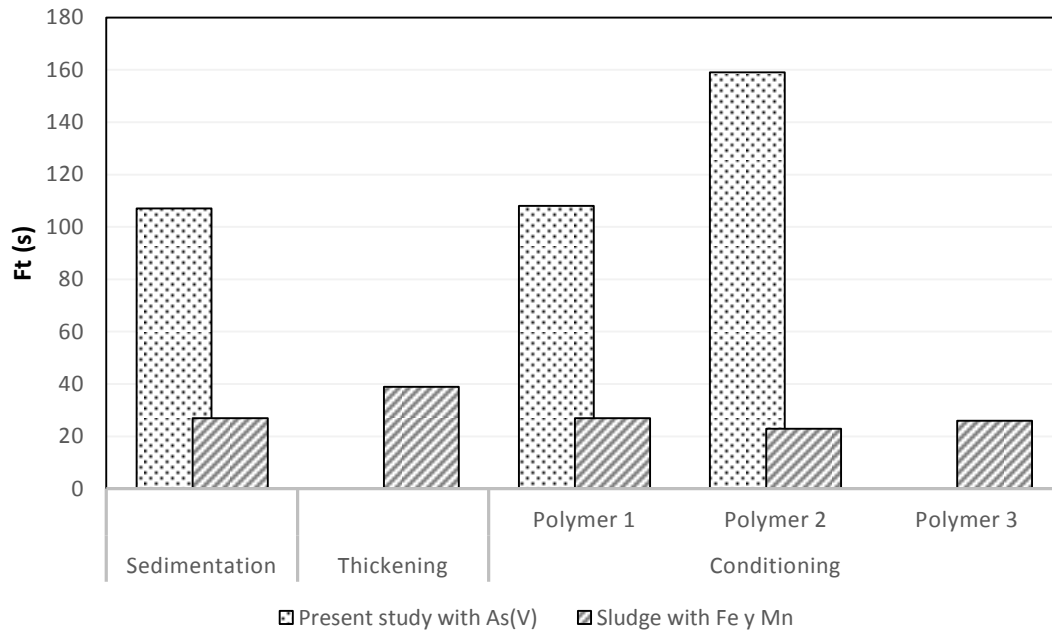
Figure 8 Comparison of the behavior in the analysis of Ft for sludge with As(V) and Fe with Mn

The Ft and SRF (in the different types of sludge) allowed us to analyze the behavior of humidity loss. By comparing the SRF and the sludge with Al with the sludge with Fe and Mn, it was observed that the sludge with Al showed a higher SRF, independent to the ST concentration. In contrast, the behavior of the sludge with As(V) showed a higher SRF and Ft, despite having a smaller amount of ST. This was due to the sludge composition and the distribution of each particle in the filter, causing a time increase in the sludge filtration.

Conclusions
- First all, it is important to study the physical and chemical properties of arsenic sludge to improve the thickened, conditioning and dewatering process.
- Polymer P1 was selected, which did not show important differences related to P2, in the sludge conditioning, but statistically analysis shows an improve in the dewatering process.
- Different concentrations of As were removed, keeping values under the maximum allowable limit established in the 2000 version of the Official Mexican Standard NOM-127-SSA1-1994.
- Sludge can be dewatered easily if conditioned and if a mechanic method for dewatering is employed, and the decrease of volume in the sludge treatment is highly noticeable.
- The most important aspects of drainage are: concentration ratio, kinetics of water release and quality filtrate. It demonstrate that the conditioning on the value of drainability index.

References

Amy, G., Edwards, M., Brandhuber, P., McNeill, L., Benjamin, M., Vagliasindi, F., Carlson, K., Chwirka, J. (1999). Arsenic Treatability Options and Evaluation of Residuals Management Issues; 90771. American Water Works Association: Denver, CO, USA.

(ATSDR) Agency for Toxic Substances and Disease Registry. (2007). Toxicological profile for arsenic. Draft for Public Comment. Atlanta: US Department of Health and Human Services. Availableat fecha de acceso 13 de febrero del 2016 DOI http://www.atsdr.cdc.gov/ToxProfiles/tp.asp?id=22&tid=3

Coackley, P. and Jones, B. R. S. (1956) Vacuum sludge filtration. I. Interpretation of results by the concept of specific resistance. Sewage and Indusrial Wastes. Vol. 28, No. 8, pp. 963-975.

Cornwell, D. A.; Bishop, M. M.; Gould, R. G. and Vandermeyden, (1987) C. Water Treatment Plant Waste Management. Handbook of Practice. American Water Works Association Research Foundation. pp. 431.

EN 14701-4. (2012). Characterization of sludges-filtration properties- Part: Determinationof drainability of flocculated sludge (European Standard), 2012 CEN TC308 in AFOR Library.

Ginisty, P. and Peuchot, C. (2011). New laboratory developments for sludge flocculation. Journal of Residuals Science and Technology, 8, pp 95-100.

Garrido Sofía, Avilés Martha, Ramírez Antonio, Grajeda Celia, Cardozo Saúl, and Velásquez Hayron, (2013 a). Comparison two operating configurations in a full-scale arsenic removal plant: Case study: Guatemala. Water. 5(2), 834-851.

Garrido, S., Piña, M., López, I.; De La O, D., Rodríguez, R. (2013 b). Behavior of two filters media for to remove arsenic from drinking water. Filtration, 13, 21–26.

Garrido & K. Garcia. 2016. Evaluation of dewatering performance and physical-chemical characteristics of iron chloride sludge: 490-492, en Proceedings Arsenic in the Environment. Arsenic Research and Global Sustainability As2016. Ed. CRS Press, Taylor & Francis Group, London, England, ISBN 978-1-138-02941-5. Series Editor ISSN: 2154-6568.

Piña Soberanis, M and Rivera Huerta, M. (2013). Lineamientos para la optimización del diseño, construcción y operación de la tecnología para la remoción de hierro y manganeso en agua potable. Informe Final, IMT-CONAGUA. Jiutepec, Mor. México.

Ramalho, R. S. (1993) Tratamiento de Aguas Residuales. De. Reverté, S. A. pp. 705.

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