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

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INTRODUCTION

Arsenic (As) is chemically classified as metalloid with valences As^{5+}, As^{3+}, As^{3-}

Table 1 authorities have established the following maximum allowable limits of As in water

Normativity	Maximum allowable limits (mg/L)
World Health Organization (WHO)	0.010
Official Mexican Standard, NOM-127-SSA1-1994	0.025
Risk of cancer for the Environmental Protection Agency (EPA)	0.020

Toxicity

>2 mg/kg/d
Acute exposure

0.03-0.1 mg/kg/d
Chronic exposure

Damage to health (HACRE)
•Skin cancer in the armpit •Black foot disease •Hyper keratosis feet
Peripheral vascular foot lesion

Figure 1. Human Implications

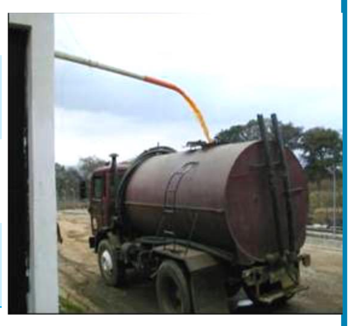
BACKGROUND

Arsenic is considered carcinogenic to humans type A. when it is consumed lengthily as arsenical water. Therefore, nowadays there are a number of *technologies* that remove this metalloid from contaminated wells, which *produce waste, such as sludge, water rejection, backwash water filters, and water regeneration exchangers*, with high arsenic concentrations which are discharges into surface water or sanitary sewers. If environmental conditions change such as pH, redox potential, the arsenic mobilize into the water again.

Table 2 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)	Concentration of As in residuals (mg/L)	Solids produced (kg/m³)	Leached concentration (TCLP) (mg As/L)
Conventional coagulation[3]	**As(V)>80 As(III)>20-80**	**4.3 7.0**	**9.25[1] 19.7**	**21.59 48.0**	**0.0009 -**
Coagulation[3] + microfiltration	**As(V)>95**	**52.6**	**0.76**	**13.50**	**1.56**
Softening	As(V)>90	9.6	4.2	239.39	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	-	-

[1]It is assumed that 40 mg/L of As in the treatment is removed; [2]Estimated; [3]$FeCl_3$ as coagulant. TCLP: Toxicity characteristics leaching procedure



METHODOLOGY

1. Optimization of the conditions for As removal from water for human consumption and obtaining iron sludge from the C-F process

Experimental design by statistical analysis of central composite N = 2^3, and response surface variables: SSED and As

Conditions of the process of Coagulation flocculation

Factors	Levels		
As: 0.05, 0.10, 0.15 mg/L	+1	-1	0
pH	7.5	6.5	7.0
$FeCl_3$ Dose (mg/L)	40	20	30
S. C-496HMW (mg/L)	1.5	0.5	1.0

2. Conditions of the process of thickener

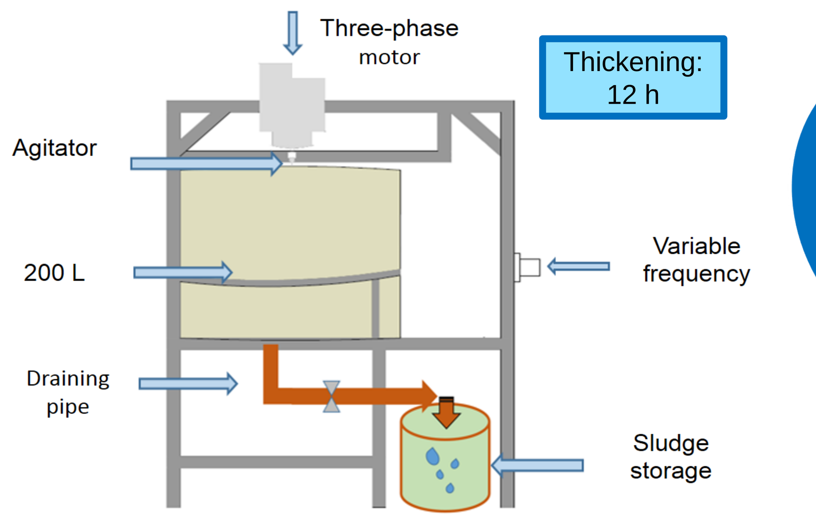


Figure 2. Gravity thickener

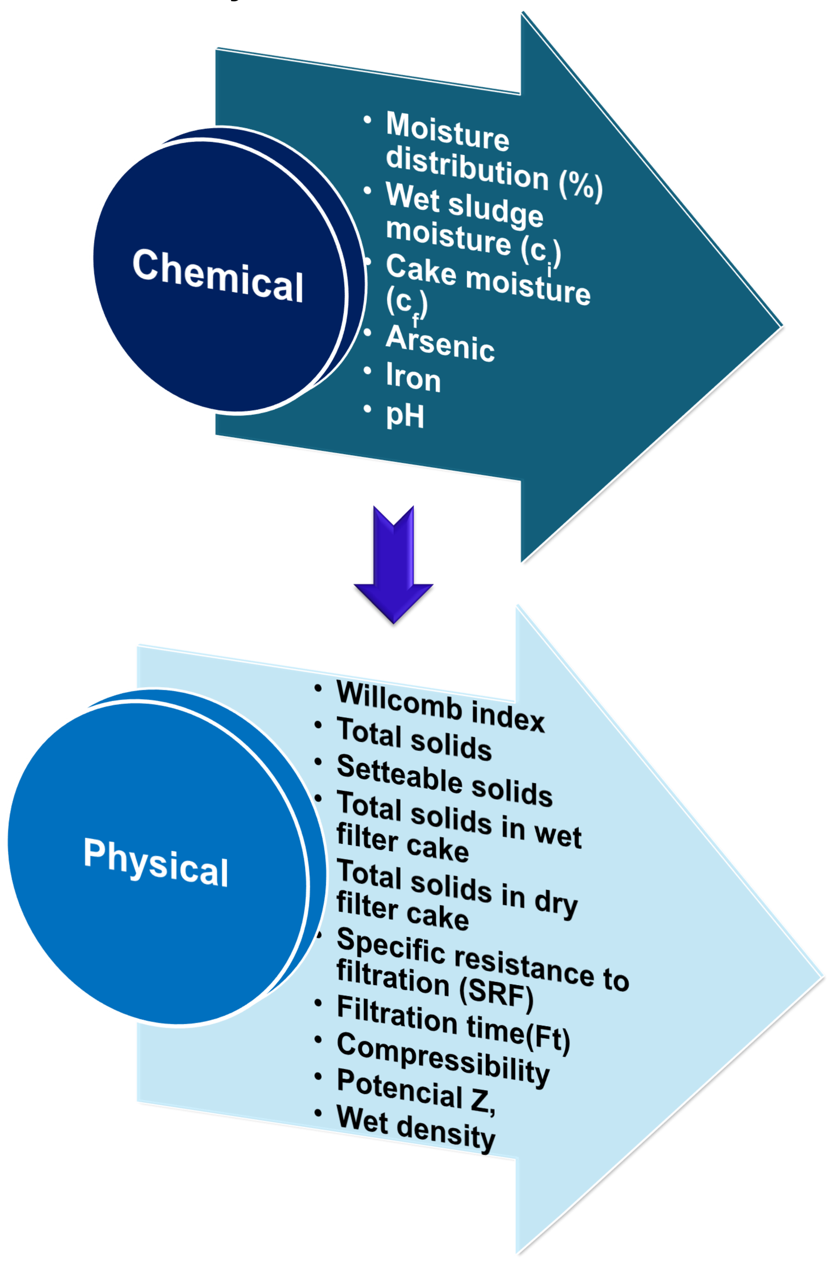
3. Optimization the sludge conditioning

- Screening with five cationics and anionics polymers
- Selection the best two polimers P1 performance (Bufloc 5240) and P2 (Fo465055H).

Experimental design by statistical analysis of central composite N = 2^3, and response surface variables: SSED and As.

Factors	Levels		
	+1	-1	0
Polymers dose (mg/L)	25	15	20
pH	7	6	6.5
Time (min)	3	1	2

4. Study of the physical and chemical properties of sludge from coagulation-flocculation and conditioning processes were analyzed.



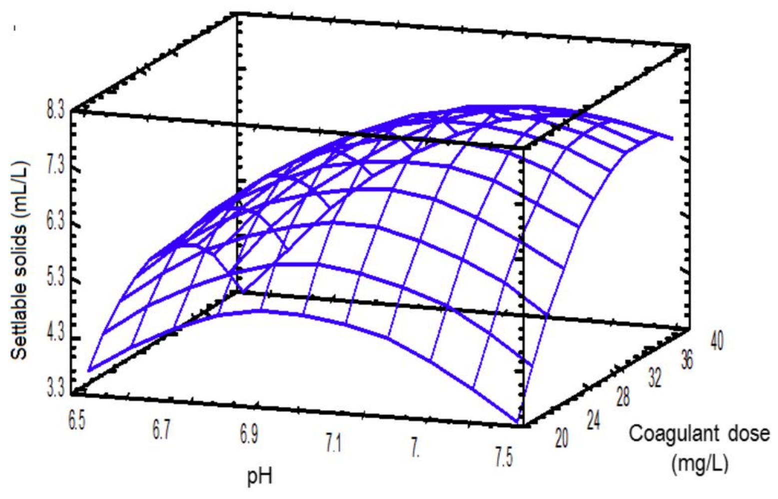
5. Dewatering of conditioned sludge

It was performed in belt-filter equipment (Bootest-IFTS) and centrifuge equipment (EC). The sludge tests were carry out under the optimal conditions.

Figure 3. Belt-filter equipment (Bootest-IFTS)

RESULTS

1. Optimization of the conditions for As removal and obtaining iron sludge from the C-F process: *The optimum values of the variables were: for an initial concentration of As: 0.150 mg/L,* (A) pH: 7,20; (B) Dosage of FeCl3: 34,33 mg/L; (C) Dosage of the polymer: 0,89 mg/L.



❖ As in supernatant: 0.003 mg/L
❖ Iron in supernatant: 0.058 mg/L

Figure 4. Response surface for factors (A) and (B) optimized. R^2: 85.09% and R^2 (ajusted for g.l.): 68.31%

2. Optimization the iron sludge conditioning obtained from the removal of arsenic from water for human consumption

Table 5. Screening of the five polymers dosed for chemical conditioning of the sludge

Parameter	Bufloc 5426	Bufloc 5240 (P1)	Bufloc 5631	Fo 4490UHM	Fo 465055H (P2)
Type	Anionic	**Anionic**	Anionic	Cationic	**Cationic**
pH	3.48	**3.33**	4.39	6.73	**3.43**
As final (µg/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**

Figure 5. Sludge conditioned

The optimal values of the variables were obtained for P1 and P1: A: Dosage 28.4 mg/L; B: pH: 6.4; and C: Time: 2.3 and 2 min.

3. Physical and chemical properties of iron sludge from coagulation-flocculation and conditioning processes

Table 6. Physico-chemical properties of iron sludge

Parameter	Units	Initial sludge C-F	P1	P2
Physical				
Willcomb index		8	10	10
Total solids	g/L	0.48	6.028	5.443
Setteable solids	mL/L	7.59	320	290
Total solids in wet filter cake	g/L	2.904	3.17	3.63
Total solids in dry filter cake	g/L	0.405	0.56	0.59
Wet sludge moisture (C_i)	%	99.95	99.39	99.45
Cake moisture (C_f)	%	86.07	82.65	83.75
Wet density (25° C)	g/mL	1.0100	1.0108	1.0121
Potential Z	mV	-57.1	-45.3	-40.4
Chemical				
pH		6.7	6.1	6.2
Arsenic in supernadant	mg/L	0	0	0
Iron	g/L	0.656	2.981	2.240

Wet breakable cake

Dry breakable cake

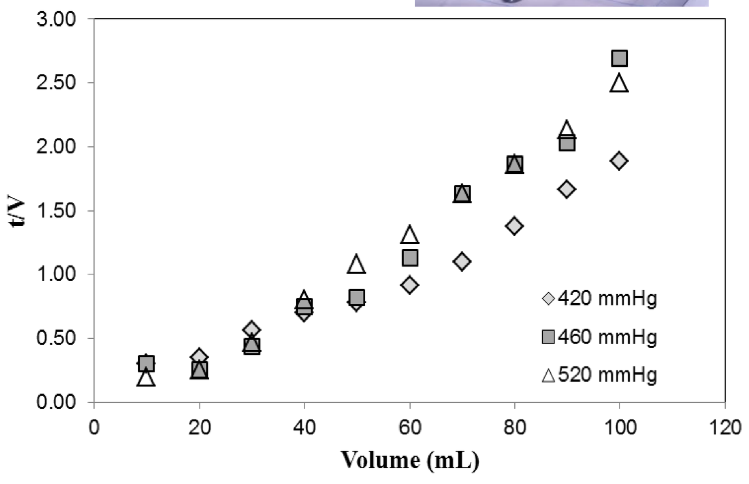


Figure 6. Specific resistance to filtration (SRF), at different pressures: 420, 460 and 520 mmHg

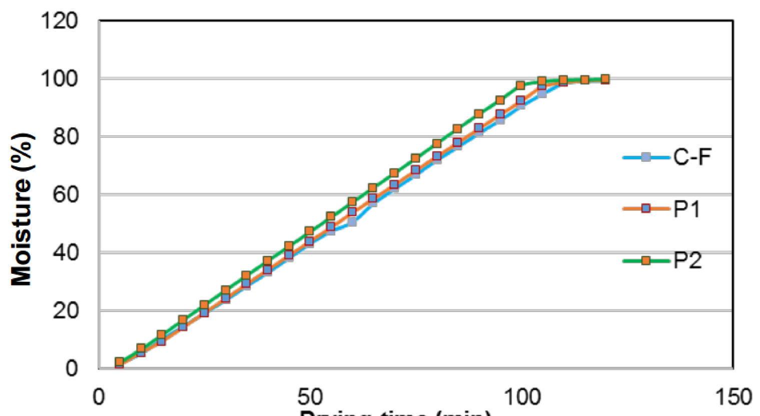


Figure 7 Comparative evaporation curve of initial polymer and polymer P1 and P2 in the conditioning

4. Dewatering of conditioned iron sludge

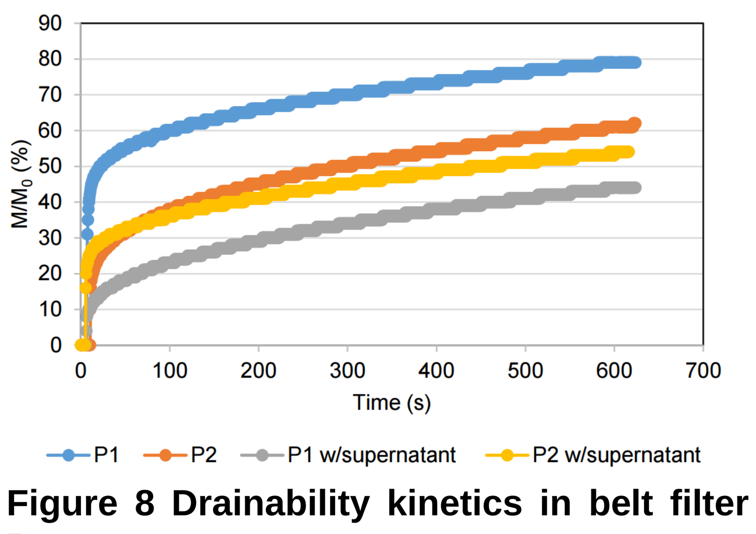
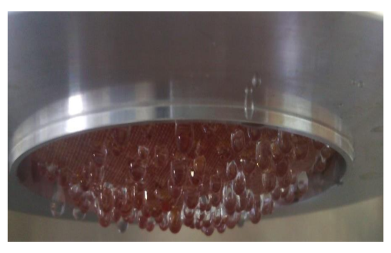


Figure 8 Drainability kinetics in belt filter Bootest.

Good drainage



Poor drainage

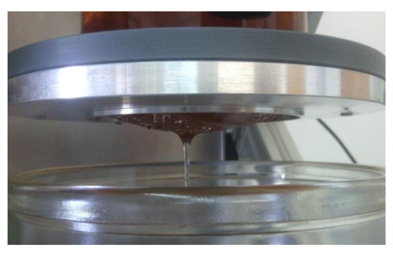


Table 7 Total solids in the dewatering stage

Total solids (g/L)				
Initial sludge	Press belt filter		Centrifuge	
	P1	P2	**P1**	P2
0.48	**6.03**	5.44	**22.48**	18.42

CONCLUSION

- 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.
- 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 is -1.1 for P1 and -2.8 for P2.

References: 1. Ginisty, P. and Peuchot, C. (2011). New laboratory developments for sludge flocculation. *Journal of Residuals Science and Technology*, 8, pp 95-100. 2. Garrido Sofía, Avilés Martha, Ramírez Antonio, Grajeda Celia, Cardozo Saúl, and Velásquez Hayron, (2013 a). *Comparation two operating configurations in a fullscale arsenic removal plant*: Case study: Guatemala. Water. 5(2), 834-851. 3. Garrido & K. Garcia. 2016. Evaluation of dewatering performance and physicalchemical 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.

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