APPLICATION OF SUGAR FOAM TO A PYRITE-CONTAMINATED SOIL

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ABSTRACT

Mining and mineral processing operations of sulphide ore deposits result in the generation of large quantities of wastes, most of which are characterised as toxic or hazardous due to the formation of acid drainage and to their heavy metal content.

Samples of pyrite-contaminated soil from a former flotation plant are studied in this work for the purpose of getting its environmental characterization and rehabilitation.

Acid mine drainage prediction by standard acid base accounting method (ABA) together with speciation techniques are used in order to determine the potential pollution of the area.

The effectiveness of sugar foam (a carbonate-rich byproduct from the manufacture of sugar) as an amendment in preventing acid drainage and metal dissolution is tested in this work.

The application of sugar foam results in a neutralizing action of calcium carbonate and in the pyrite oxidation inhibition, being the acid generation and the metals release significantly reduced.

Keywords: Acid rock drainage; Tailings; Environmental; Pollution.

1. INTRODUCTION

Pyrite tailings coming from flotation of metallic complex sulphide ores (fine-grained intimate associations of chalcopyrite, sphalerite and galena disseminated in dominant pyrite) consisted mainly of pyrite and small contents of the non-ferrous sulphides. Their average particle size is very small, ranging from 20 to 40 μm, due to the grinding required to recover the valuable components by flotation. The *in situ* storage of these wastes causes oxidation of pyritic material with oxygen and water (Eq. 1):

$$FeS_2 + 15/4\ O_2 + 7/2\ H_2O \longrightarrow Fe(OH)_3 + 2H_2SO_4 \tag{1}$$
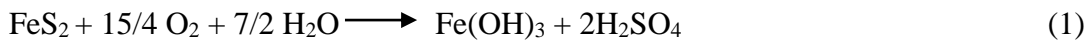
generating low-pH waters. Besides, the solubility of $Fe(OH)_3$ increases with decreasing pH, which accelerates the oxidation of pyrite and release of acid. Oxidation may also be accelerated by naturally occurring bacteria, such as *Acidithiobacillus ferrooxidans*, which metabolize sulphide, sulphur and Fe(II) species (Bryner et al., 1954). These bacteria are generally most active in acidic waters. The resulting effluent, called Acid Mine Drainage (AMD) or Acid Rock Drainage (ARD) is generally regarded as the principal environmental problem caused by the mining of sulphide deposits. Drying and consequent aeration of the tailings rapidly oxidizes sulphides to sulphates, lowers the pH and solubilizes the pollutants. In addition, the Fe(III) ions released by pyrite also accelerates the indirect bacterial oxidation of non-ferrous sulphides (Palencia et al., 1990). Although these minerals do not produce acid, they release heavy metals exacerbating the adverse environmental impact of the acid drainage.

AMD production in mine tailings has been extensively studied (Doyle, 1990).

Current static and kinetic tests for determining AMD potential are commonly used or proposed for predicting AMD from mines (White and Jeffers, 1994). These techniques includes Acid Base Accounting, the B.C. Research Initial (BCRI) and Confirmation Tess, Humidity-Cell Tests, Alkaline Production Potential vs. Sulphur Ratio, Hydrogen Peroxide Tests and Shake Flasks Tests. Although reports have been published with comments and recommendations regarding the effectiveness of these predictive tests, there is no general agreement on which test or series of tests will best determine potential to generate metals AMD (CANMET, 1989; CANMET, 1990).

The insidious feature of acid mine drainage is the fact that both the chemical and bacterial mechanisms responsible for its formation are autocatalytic; once acid mine drainage develops, the problem tends to worsen, and is extremely difficult to halt.

Although a great number of options for remediating pyrite-contaminated soils have been developed, only few of them have been applied successfully. Most often, the contaminated soil is capped in situ or is excavated and removed. As the scale of contamination will not allow metal removal techniques in a cost effective way, metal immobilization could be an approach to control the risks and spreading of these contaminants. Even if tailings are removed, a small amount remains in the soil, constituting a potential risk of water contamination.

Traditionally, the most common method of controlling AMD is through the mixing of alkaline substances, such as limestone, with the AMD producing materials. The addition of other amendments (as silicates, phosphates, carbonates, iron oxides, gypsum, organic matter, etc.) can also reduce the bioavailability of heavy metals (Paspaliaris, 1999). Soil amendments can be applied as layers or homogeneously mixed with sulphidic waste.

The use of industrial residues both to mitigate the acid generation and to retain heavy metals has recently been studied. This choice has the advantage that it reduces waste

disposal by transforming industrial wastes into industrial byproducts. This approach has been used with alumino-silicate beringite, steel shot, red mud, bone meal, phosphogypsum, red gypsum, cement kiln dust, dolomitic residue and sugar foam; the results varied depending on the particular metals and experimental conditions (Doye and Duchesne, 2003; Garrido at al., 2005; Illera et al., 2004; Lin et al., 2002; Lombi et al., 2003).

There have been numerous studies relative to the heavy metals bioavailability in soils affected by mineral sulphides contamination following the mine spillage at Aznalcollar (Spain) (Cabrera et al., 1999; Simón et al., 2001). The effect of an organic amendment (compost) and lime addition was that liming succeeded in controlling the soil acidification and that organic matter promote fixation of heavy metals in contaminated soils. In this line, some reports indicate that sugar foam was the soil amendment proposed for remediation (Calvo and Macías, 2000), having some important advantages: 1) high neutralizing potential, 2) fast reaction, 3) contribution of important elements for the recuperation (C, N, P, Mg and K) and 4) very low cost. Other considerations as the rate of application, long-term effectiveness and suitability for different metal species and soil conditions have not been found in the literature.

Sugar foam is the sugar manufacturing residue that remains after beet juice is purified by flocculation of colloid matter with a lime solution followed by treatment with CO_2. Although variability in the composition of the original limestone and in the procedures used to obtain sugar influence its chemical composition, it is always rich in fine-grained calcium carbonate and organic matter. The Spanish annual production of this type of residue is in the range 6-7 10^7 tons, about 50% of which is dry matter. However, a lowe percentage is used in amendments for soils, in clear contrast with other EU countries, which apply nearly all of their production to arable land.

The use of sugar foam as soil acidity amendment (Vidal et al. 2003; Vidal et al, 2004) and as an amendment for regulating the mobility of Cd, Cu and Pb (Garrido et al., 2005a; 2005b) has been recently reported. However, little information is available concerning the effect of sugar foam on pollution coming from pyrite tailings even though sugar foam was proposed as the best amendment during remediation of soils affected by the Aznalcollar spill on April 1998.
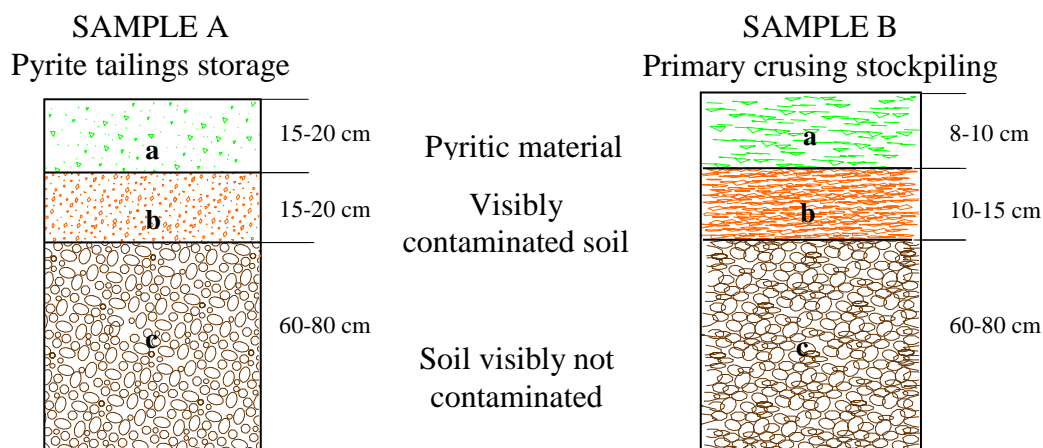
In this work, the authors have explored the potential of sugar foam for mitigating the contamination from pyritic materials (pyrite tailings and coarse fraction of complex sulphide from primary crushing) on soils at an abandoned mine in Aznalcollar (Spain). ABA and leaching tests have been used as technologies for predicting the pollution potential and speciation techniques for soil and residues characterization.

2. MATERIALS AND METHODS

In this work two samples of soil contaminated with pyrite are studied. Samples have been taken from an abandoned mine of complex polymetallic sulphides in Aznalcollar, Seville (Spain). Nowadays the mine activity has been suspended and the area is in a recuperation process.

Figure 1 shows the surface horizons of the two locations studied. In both sites, samples have been taken from horizon b (visibly contaminated soil).

Figure 1. Surface horizons of the soil in the sites studied.

SAMPLE A
Pyrite tailings storage

SAMPLE B
Primary crusing stockpiling

a — 15-20 cm	Pyritic material
b — 15-20 cm	Visibly contaminated soil
c — 60-80 cm	Soil visibly not contaminated

SAMPLE B:
a — 8-10 cm
b — 10-15 cm
c — 60-80 cm

Sugar foam was supplied by the Spanish sugar producer Azucarera Ebro S.L., company that markets it as a mineral amendment with the name of *Carbocal* (Azucarera Ebro, 2002). Characterization of sugar foam is shown on table I.

Table I. Sugar foam characterization.

	Sugar foam
pH (H20)	9.50
Conductivity (mS/cm)	0.43
Organic matter (%)	7.40
Cu (g/t)	25
Fe (g/t)	1050
Mn (g/t)	120
Zn (g/t)	35
% K_2O	0.22
% Na_2O	0.13
% CaO	41.30
% MgO	1.58
Total carbonates	75.40
% N	0.42
% P_2O_5	1.70
Ratio C/N	10.30

Materials characterization

Total sulphur was determined by Leco furnace in samples A and B. The sulphide sulphur was determined by Leco furnace after removing acid soluble sulphate with HCl 1.5%. Acid soluble sulphate sulphur was determined as the difference between total sulphur and sulphide sulphur. Sulphur content as sulphide and sulphate forms are showed on table II.

Sulphur in sugar foam was also analysed, resulting 0.52%.

Acid-basic accounting (ABA) was determined in order to predict the net acid-neutralization potential of the soils. ABA balances the acid-generating potential (AP) and the acid-neutralization potential (NP). This balance is expressed on table II as the difference NNP=NP-AP, and as the ratio of neutralizing potential to acid-generation potential (NP/AP).

AP is calculated considering that the sulphide sulphur content reacts stoichiometrically with oxygen and water to form sulphuric acid which has an equivalence in calcium carbonate; it is expressed as Kg of $CaCO_3$/ ton of soil.

NP (acid-neutralization potential) is determined by Sobek method (Sobek et al. 1978); this method basically consists of a titration with NaOH after a treatment with HCl in excess. NP measures the HCl consumption and it is expressed as its calcium carbonate equivalent (Kg $CaCO_3$/ ton).

ISO/DIS 10390 is followed to determine pH in water and in KCl.

ISO/DIS 11325 is followed to determine specific electric conductivity.

Table II. Samples characterization.

	SAMPLE A	SAMPLE B
pH (H_2O)	2.60	3.85
pH (KCl)	2.49	3.80
Conductivity (mS/cm)	0.427	0.3795
AP	29.36	14.52
NP	0	0
ABA(NP-AP)	- 29.36	- 14.52
ABA(NP/AP)	0	0
Sulphide sulphur (%)	0.94	0.46
Sulphate sulphur (%)	1.19	4.10
Moisture	9.70	10.8

Samples were characterized by speciation techniques.

The *water-soluble fraction* was determined shaking 2 grams of sample into 100 mL of deionised water for 2 hours at room temperature.

The *exchangeable fraction* was liberated by NH_4Cl 0.1M, 5 g of sample into 100 mL of NH_4Cl were shaken during 2 hours at 25°C (Wisotzky et al, 2003).

The *carbonate-fraction* was dissolved by $NaCH_3COO$ 1M at pH= 5 (CH_3COOH), 5 g of sample into 100 mL of solution were shaken during 2 hours at 25°C (Tessier et al. 1979).

The *Mn-hydroxides and Fe-hydroxides fraction* was dissolved by $(NH_4)_2C_2O_4$ 0.2 M at pH=3 ($H_2C_2O_4$), 5 g of sample into 100 mL of solution were shaken during 2 hours at 25°C (Wisotzky el al, 2003).

Metals content was determined by acid digestion (aqua regia), also an HF-digestion (HNO_3, H_2SO_4, HF) was performed in order to dissolve the residual fraction (silicates).

Tables III and IV show the metals dissolved from samples A and B respectively with the different treatments.

Table III. Sample A characterization

Reagent	H₂O	NH₄Cl	NaCH₃COO	NH₄COO	Aqua regia	HF
Fraction	water-soluble	Exchangeable	Carbonate	Mn and Fe hydroxides		
Fe (mg/kg)	545	780	2340	20975	69000	68800
Cu (mg/kg)	65	70	52,8	100	322	327
Zn (mg/kg)	380	374	420	425	800	800
Mn (mg/kg)	120	140	135	130	270	325
Na (mg/kg)	70	37		215	1360	3500
K (mg/kg)	400	82	255	253	2500	19500
Mg (mg/kg)	650	545	560	410	2290	4000
Ca (mg/kg)	3500	3280	3290	5	570	250
Pb (mg/kg)	5	2	8	244	1723	1000
Al (mg/kg)	1400	1120	2010	2085	13100	23200
Cd (mg/kg)	2	2	3	0	3	-
As (mg/kg)	0	1	0	335	702	-

Table IV. Sample B characterization

Reagent	H$_2$O	NH$_4$Cl	NaCH$_3$COO	NH$_4$COO	Aqua regia	HF
Fraction	Water-soluble	Exchangeable	Carbonate	Mn and Fe hydroxides		
Fe (mg/kg)	705	685	1480	19400	102200	78800
Cu (mg/kg)	353	338	520	855	1180	1200
Zn (mg/kg)	2875	3200	650	2000	4500	4500
Mn (mg/kg)	316	356	370	335	570	475
Na (mg/kg)	70	41		220	770	247500
K (mg/kg)	450	81	394	168	2050	20800
Mg (mg/kg)	825	760	750	550	4870	3000
Ca (mg/kg)	29200	15800	40000	5	37200	275
Pb (mg/kg)	18	14	86	20	400	
Al (mg/kg)	308	533	1740	3840	11500	121800
Cd (mg/kg)	18	18	19	1	29	-
As (mg/kg)	5	0	0	455	748	-

As it can be observed on tables, both samples are different in composition. Sample B has higher content in Na, Ca, Al, Cu, Zn and Cd than sample A. It must be emphasized the high concentration of Zn in the water-soluble fraction, being remarkable also those of Mn and Cu. In sample A, heavy metals concentrations in exchangeable and bound to carbonate fractions are similar to those in water soluble fraction. Heavy metals concentrations in water are higher in sample B than in sample A, so that sample B is corresponded with a more contaminant soil. As sulphur is mainly as sulphate in sample B (see table II), the high solubility of metals in water can be attributed to the presence of metallic sulphates as a result of the sulphide weathering. The dissolution of Na, K and

Al strongly increase after the HF- attack, this indicates that these metals are bound to non-soluble in aqua regia minerals (probably silicates).

Mineralogical composition

X-ray diffraction spectra of samples A and B are shown on figure 2. Silica, muscovite, and gypsum are detected in both samples. Also kaolinite is present in sample B.

As is shown on figure 3, X-ray diffraction spectrum reveals calcite as the main component of sugar foam.

Determination of stoichiometric sugar foam required

In order to ascertain the demanded amount sugar foam to neutralize the soil acidity, the following assumptions were made:

- Oxidation of sulphide sulphur is the exclusive source of acidity.

- H^+ ions are only neutralized by carbonate ions from sugar foam.

As carbonate content in sugar foam is 75.4%, the stoichiometric proportion of sugar foam for 100 g of soil can be calculated as the percentage of sulphide sulphur in soil multiplied by 4.165.

Shake-flask tests

In order to determine the mobility of metals, leaching tests, that simulate the processes of geochemical weathering at an accelerated rate, were performed. They provide semi-quantitative information on drainage water quality.

Triplicated experiments were carried out in 250 mL conical flasks with 50 g of sample and 100 mL of distilled water at room temperature. In several tests different amounts of sugar foam were added, stoichiometric or double stochimetric proportion were used (see table V). At the beginning of the test, every flask was weighted and covered with parafilm. The flasks were agitated at 180 min^{-1} on an orbital shaker during one hour everyday; the rest of the time, flasks were left to stand. Periodically 50 g of solution was

extracted by a syringe. The solution was filtered using 0.45 μm Millipore filters and the leachate was analyzed for copper, zinc, iron, alumium, manganese, lead, cadmium, pH and conductivity.

After sampling, flasks were weighted and the weigh of removed solution was replaced by distilled water.

Metals in leaching solutions were analysed by flame atomic absorption spectroscopy (AAS).

The tests were 116 days long. At the end of each experiment, the slurry was filtered using 0.45 μm Millipore filters and the residue was washed with distilled water, dried and stored in a dessicator for subsequent analysis and characterization.

Table V summarizes the set of tests carried out and the amount of sugar foam added in every one.

Table V. Leaching tests

TEST	SAMPLE	SUGAR FOAM (g)	
0A	A	NO	0
ASF	A	STOICHIOMETRIC	1.96
A(SF)$_2$	A	DOUBLE STOICHIOMETRIC	3.92
0B	B	NO	0
B(SF)	B	STOICHIOMETRIC	0.96
B(SF)$_2$	B	DOUBLE STOICHIOMETRIC	1.92

Residues characterization

The *carbonate-fraction* and the *Mn-hydroxides and Fe-hydroxides fraction* were sequentially determined in the leaching residues. Once carbonate fraction was dissolved the solid was filtered and treated with $(NH_4)_2C_2O_4$ 0.2 M at pH=3 $(H_2C_2O_4)$ in order to dissolved the *Mn-hydroxides and Fe-hydroxides fraction*.

3. RESULTS AND DISCUSSION

pH evolution

Figure 2 shows the evolution of pH in periodically taken samples.

Sample A shows the minor pH value, around 2.5 during all test and sample B presents higher pHs than sample A, ranging from 3.75 to 4.5. That is in accordance with the pH values showed on table II.

When sugar foam is added in stoichiometric proportion to sample A, pH passes from 6.5 to 7.5 in the first 20 days, and then it remains constant to the 70th day and eventually decreases to 7.0, while sample B with stoichiometric sugar foam quantity produces pH close to 6.5 during all time. In spite of the fact that sample A is more acid than sample B, the increase of pH is higher in leachates from sample A, because the amount of sugar foam in A(SF) is higher than in B(SF) as is showed on table V.

With double sugar foam dose, pH is similar in both samples and close to 8 during all test.

Sugar foam avoid the acidity of leachates in both samples, being enough the stoichiometric dose to neutralize the acid produced by the dissolution of the samples in water.

Figure 2. Evolution of pH
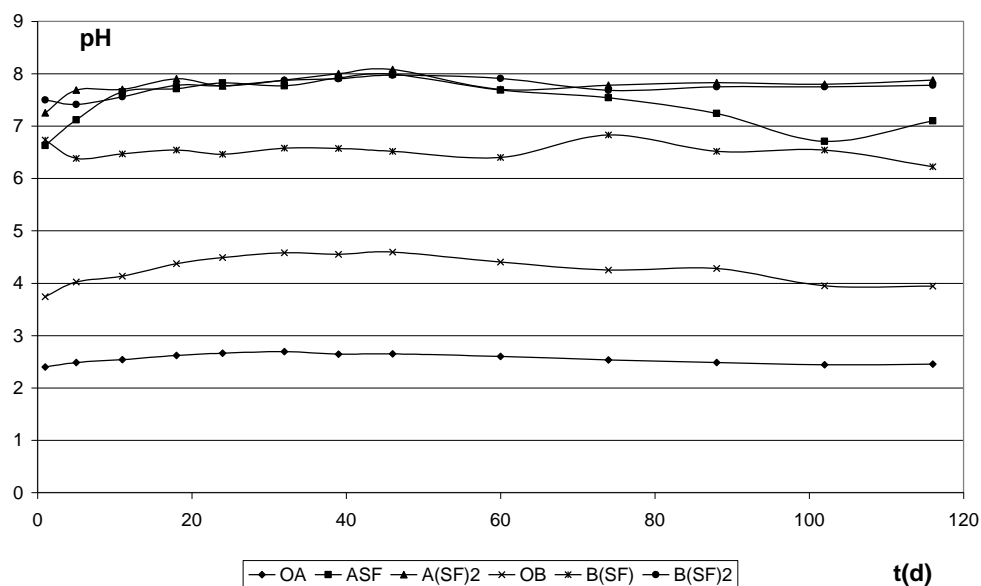
Conductivity evolution

Figure 3 shows the evolution of conductivity in periodically extracted lixiviates. The highest values correspond to samples A and B without sugar foam, reaching the maximum values at the beginning of the tests, 6.9 mS/cm y 6.1 mS/cm respectively. These values are decreasing during the tests to 2.0 mS/cm y 2.5 mS/cm respectively. The samples with sugar foam have a similar behaviour, reaching the maximum values at the beginning of the tests, between 3.5 and 4 mS/cm, and decreasing to 1.5-2.5 mS/cm, values kept constant till the end of the tests. The obtained results make possible to state that sugar foam favours the ions retention in soil basically at the beginning of leaching. Once the soil is washed (32 days, 300 mL of water) conductivity values are similar in all the tests, showing that the ions concentrations in dissolution are in the same range. With respect to the sugar foam dose added, the values of conductivity prove the observed result in pH graph (figure 4), the stoichiometric amount is enough to get the desired effect.

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Figure 3. Conductivity evolution
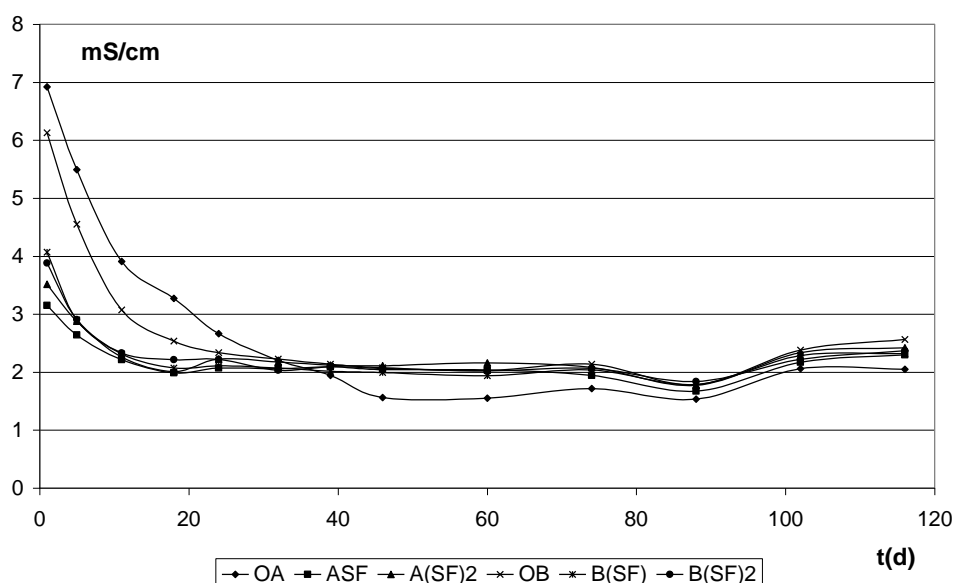
Metals concentrations evolution

Figures 4-9 show the metal concentrations in the leachates versus time for samples A and B as they are (legend 0A, 0B) and for both samples with sugar foam in stoichiometric (legend A(SF), B(SF)) and in double stoichiometric (legend A(SF)$_2$, B(SF)$_2$) doses. Every point in the graph is corresponded with a wash stage.

Generally, metal concentrations decrease in the successive washes. Leachates from sample B present higher concentrations of metals than leachates from sample A; these results agree with those obtained in sample speciation tests (tables III and IV).

Cu, Fe, Al concentrations evolution

Appreciable concentrations of Cu, Fe and Al in lixiviates of soil with sugar foam are not noticed. These results are consistent with the Pourbaix diagrams (Pourbaix, 1974) for these metals. The corresponding diagrams show that Cu, Fe and Al are precipitated at the pH values of the lixiviates.

Figure 4. Cu concentration evolution
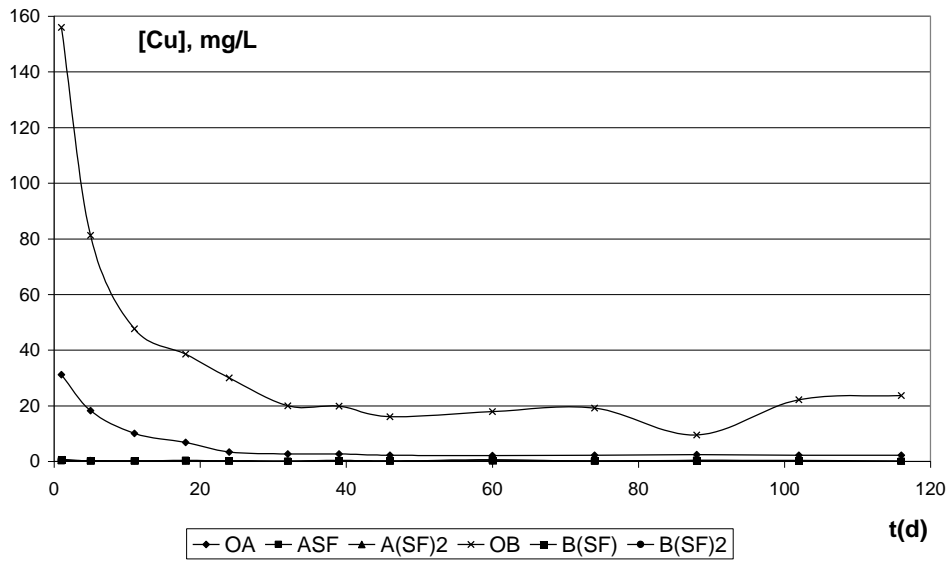
Figure 5. Fe concentration evolution


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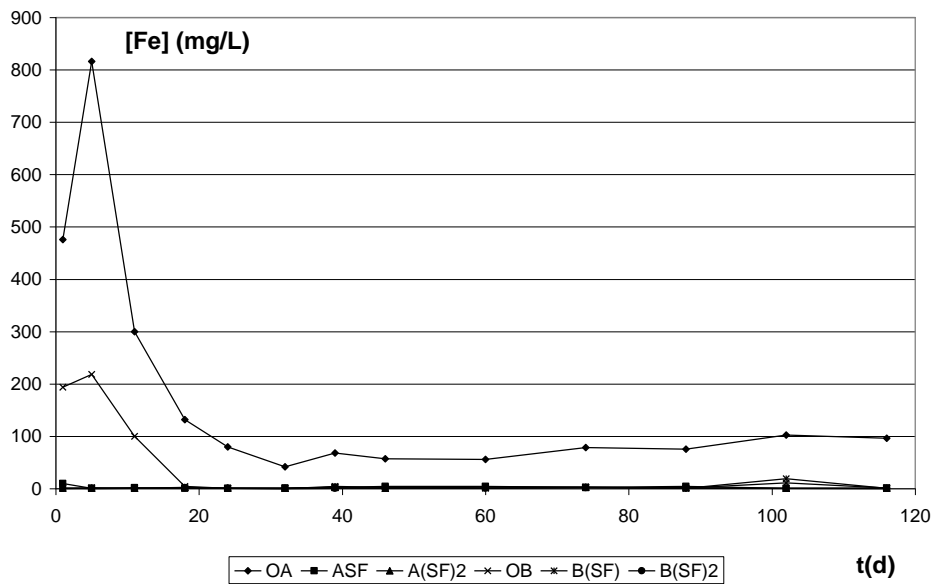
Figure 6. Al concentration evolution
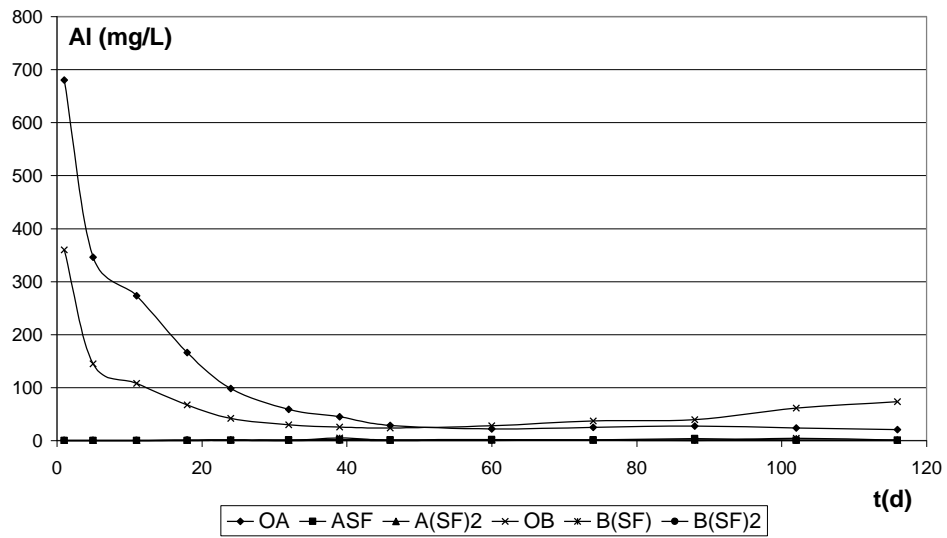
In order to ascertain if retention of metals by soil or /and sugar foam components (basically carbonates and organic matter) might have taken place, final solid residues have been analysed by X-ray diffraction. There are not differences between the spectra of residues with and without sugar foam. These findings do not help to clarify the question because some minerals probably escape detection due to the low proportion and/or their lack of crystallinity.

Zn concentration evolution

Figure 7 shows a dramatic fall with exponential trend for Zn concentration in sample B. As is shown in Figure 7 the [Zn] in lixiviates from sample B decreases from 1400 to 80 mg/L in 46 days. In samples with *carbocal* an effect of sugar foam dose is observed. In the second wash stage (5 days, 100 mL of water) Zn concentration is reduced a 83% with the stoichiometric dose and a 99% with the double stoichiometric dose.

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Regarding sample A, it can be observed that Zn extraction is 7 times lesser than in sample B. Zn concentration reaches a peak of 200 mg/L and decreases to 20 mg/L in 24 days. With stoichiometric dose of sugar foam [Zn] is reduced a 67% and a 98% with double dose. It can be said that Zn dissolution is affected by the mass ratio soil/ sugar foam, being necessary a double stoichiometric dose to inhibit it appreciably. Pourbaix diagram for Zn and the pH values in lixiviates explains the results obtained. As is shown in Figure 2, pH of lixiviates from sample B with stoichiometric dose is near to 6, witch is not high enough to precipitate Zn.

Figure 7. Zn concentration evolution
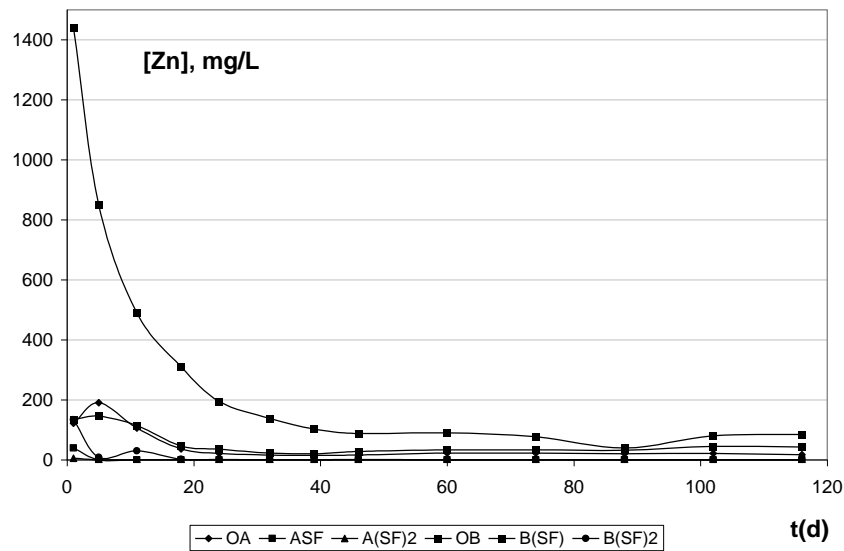
Mn concentration evolution

Figure 8 shows the evolution of Mn concentration with time. It can be observed that the addition of sugar foam does not avoid the dissolution of Mn, being the manganese concentration from sample B higher than that from sample A.

In the case of sample B, [Mn] starts at 154 mg/L and falls to 3.4 mg/L. With stoiciometric sugar foam [Mn] goes from 126 to 8.1 mg/L, and with double dose from 98 to 0.9 mg/L. The dissolution of manganese depends on the mass ratio soil/ sugar foam, as zinc dissolution. In sample A, Mn release is only observed in the first 40 days. In sample A with stoichiometric sugar foam Mn is only dissolved during the first 10 days, moreover in low concentrations.

Figure 8. Mn concentration evolution
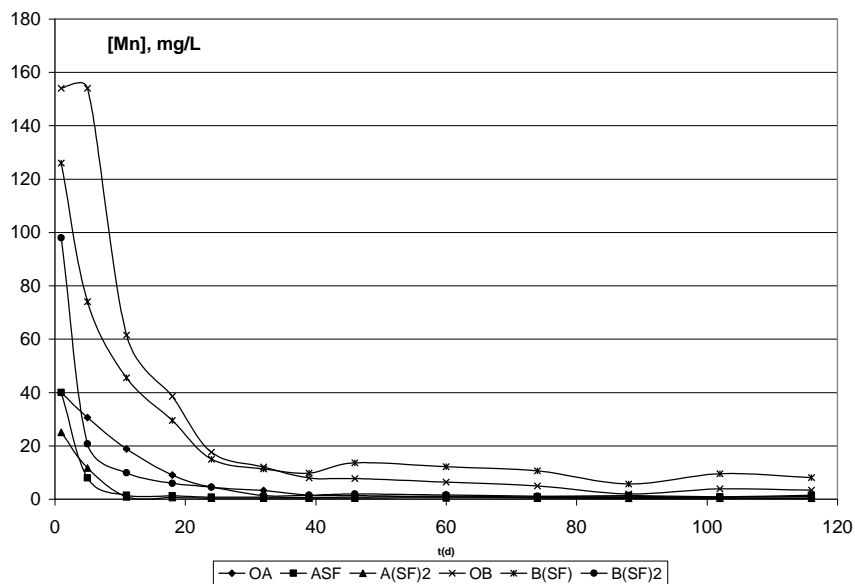
Cd concentration evolution

Figure 9 shows the evolution of Cd concentration versus time. [Cd] is only observed in samples without sugar foam and in sample B with stoichiometric sugar foam. Tests of sample B shows high Cd concentrations which decrease with successive washes. This fact is in accordance with the Cd content in sample B (see table IV) and with Cd Pourbaix diagram that shows dissolution of Cd at pH below 7.

Figure 9. Cd concentration evolution
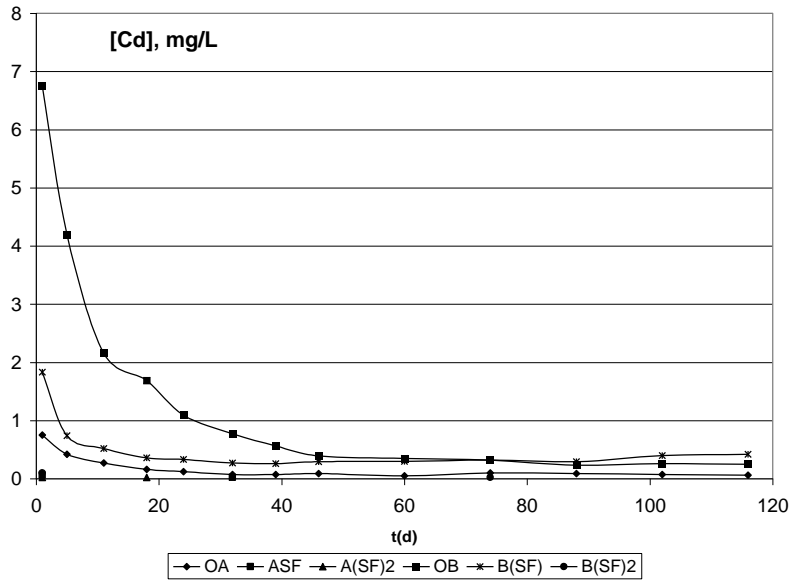
In Figures 10-15, the accumulated amount of metals per mass of soil (mg/kg) are plotted. The amount of extracted metal in each wash stage (50 mL of solution) is graphed. These amounts represent the minimum values reached after irrigating the soil with an equivalent volume of water, that is 13L/kg of soil. In real situations of continuous drainage, these values might be incremented because the saturation of solution inherent to the modus operandi would be eliminated.

Figure 10. Cu extraction in mg per kg of soil

Cu mg/kg

Legend: 1 2 3 4 5 6 7 8 9 10 11 12 13
X-axis: OA3, AEA3, A(EA)23, OB3, BEA3, B(EA)23
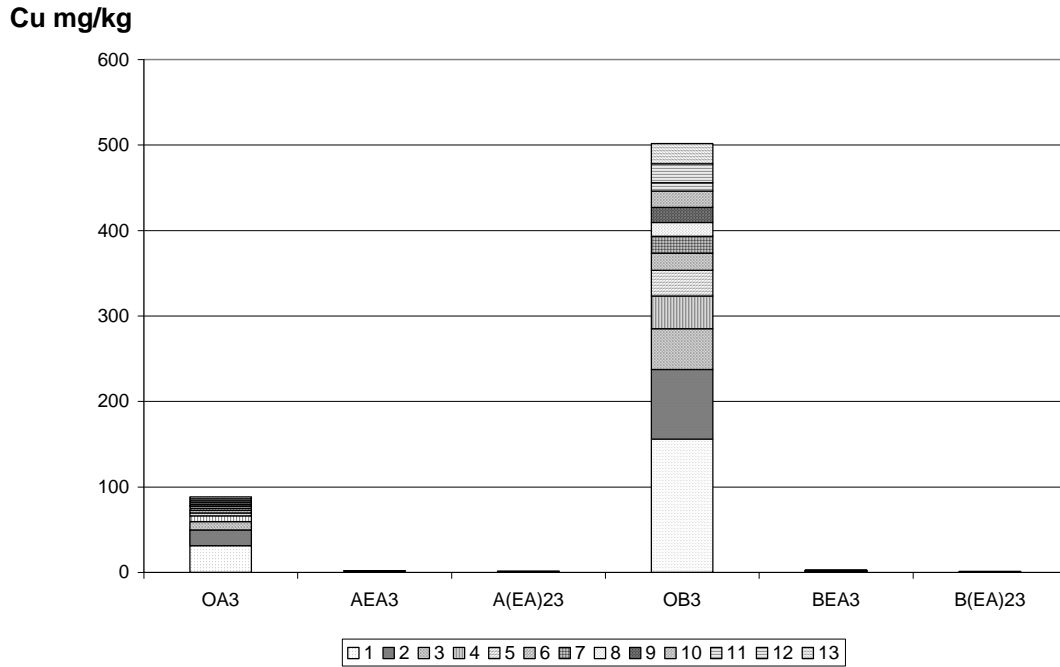
Figure 11. Zn extraction in mg per kg of soil

Zn, mg/kg

Legend: 1 2 3 4 5 6 7 8 9 10 11 12 13
X-axis: OA3, AEA3, A(EA)23, OB3, BEA3, B(EA)23
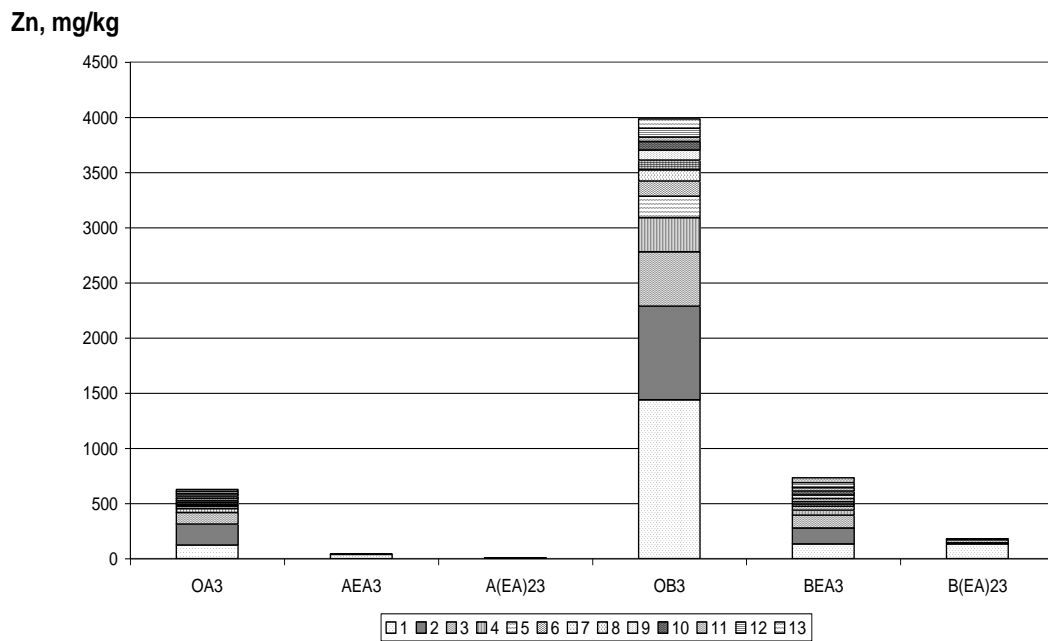
Figure 12. Mn extraction in mg per kg of soil

Mn, mg/kg
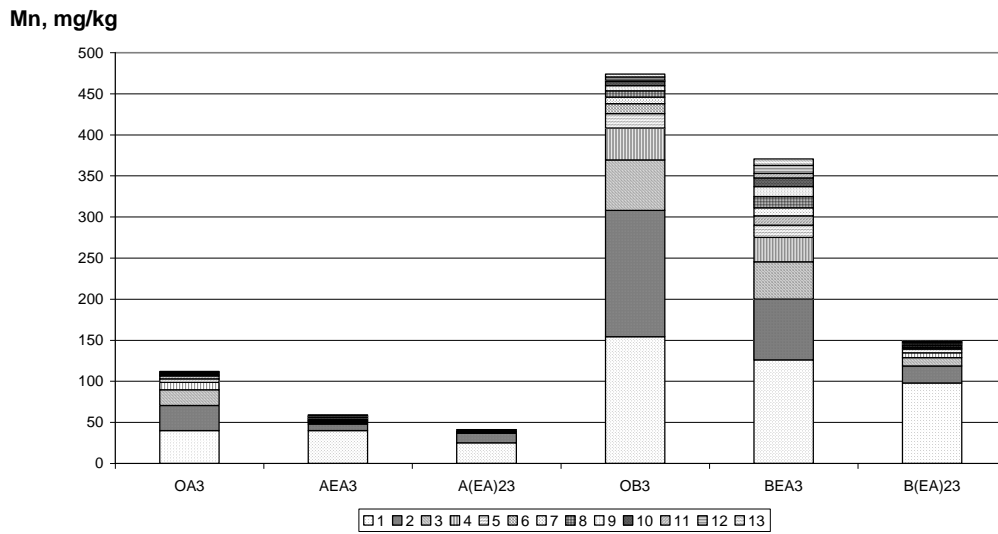
Figure 13. Al extraction in mg per kg of soil

Al, mg/kg

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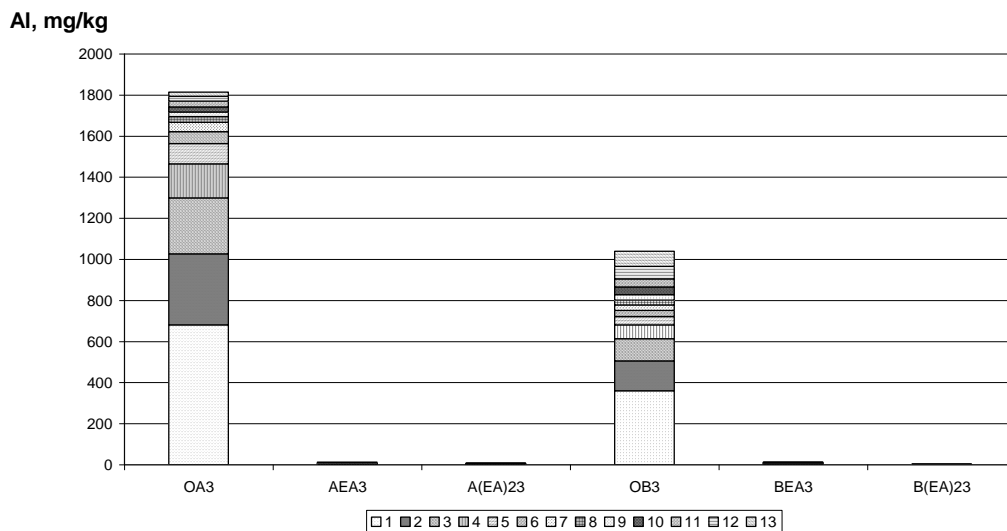
Figure 14. Fe extraction in mg per kg of soil

Fe, mg/kg
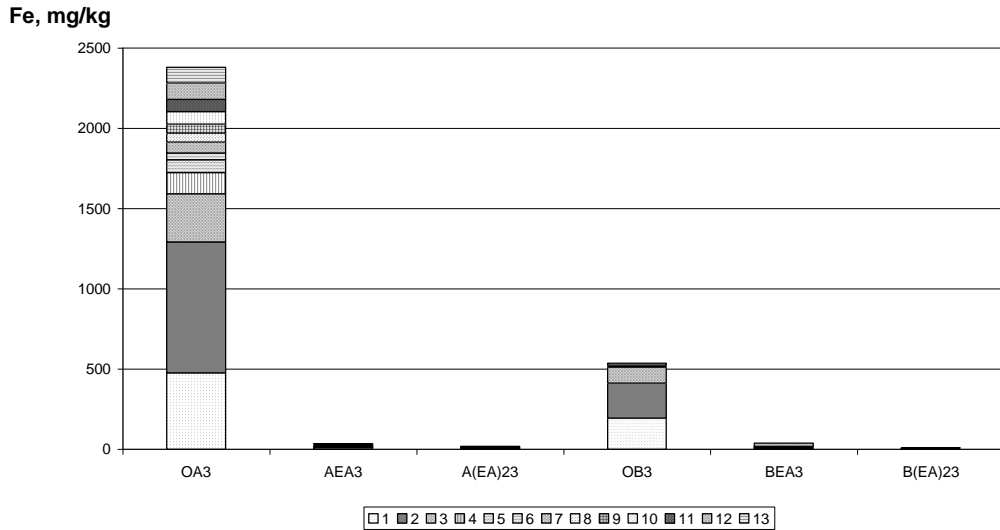
Figure 15. Cd extraction in mg per kg of soil

Cd, mg/kg

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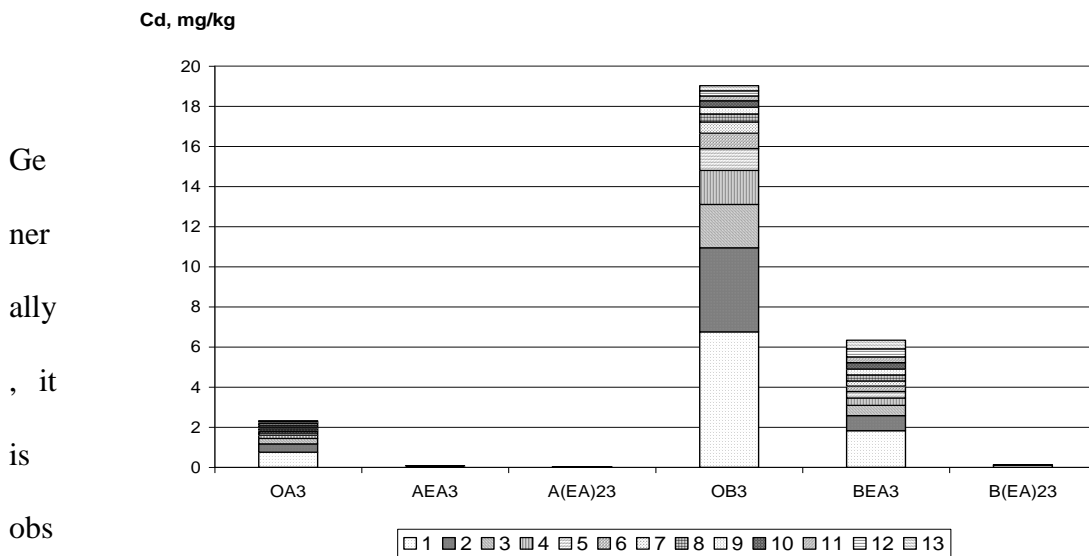
erved that the amount of dissolved metal decreases during the tests, so the soil potential

contamination also decreases. The graphs shows that the addition of stochiometric sugar

foam completely avoid the dissolution of Cu, Al and Fe in both samples.

Sugar foam is a suitable amendment in order to avoid Zn and Cd dissolution in sample A. The addition of sugar foam reduces the Zn and Cd dissolution in sample B, being the diminution proportional to the dose of sugar foam.

In the case of Mn, a sugar foam concentration effect is also observed and, in the studied range, Mn dissolution is not inhibited.

Residues speciation

Figures 16 and 17 show the sequential speciation of residues from tests performed during 116 days with samples A and B respectively and stoichiometric sugar foam. In these residues, the water-soluble fraction has disappeared. Therefore, the sequential application of sodium acetate and ammonium oxalate is useful to determine heavy metals bound to carbonates and to hydroxides respectively.

As it was expected, in both cases high concentration of calcium is extracted with sodium acetate due to the calcium carbonate dissolution. Also, high concentrations of iron is leached by amonium oxalate indicating that iron remains in the residues as oxyhydroxide.

Heavy metals, Cu, Zn, Cd and Pb are associated to carbonates and to iron-oxyhydroxides fractions, while As is present mainly in oxyhydroxides fraction.

Aluminium shows different behaviour in each residue. From sample A residue, aluminium is mainly extracted by sodium acetate, so Al is bound to carbonates in this residue, while from sample B residue, Al is leached by amonium oxalate, meaning that Al is associated to iron oxyhydroxides.

Figure 18. Sequential speciation of residue from test performed with sample B
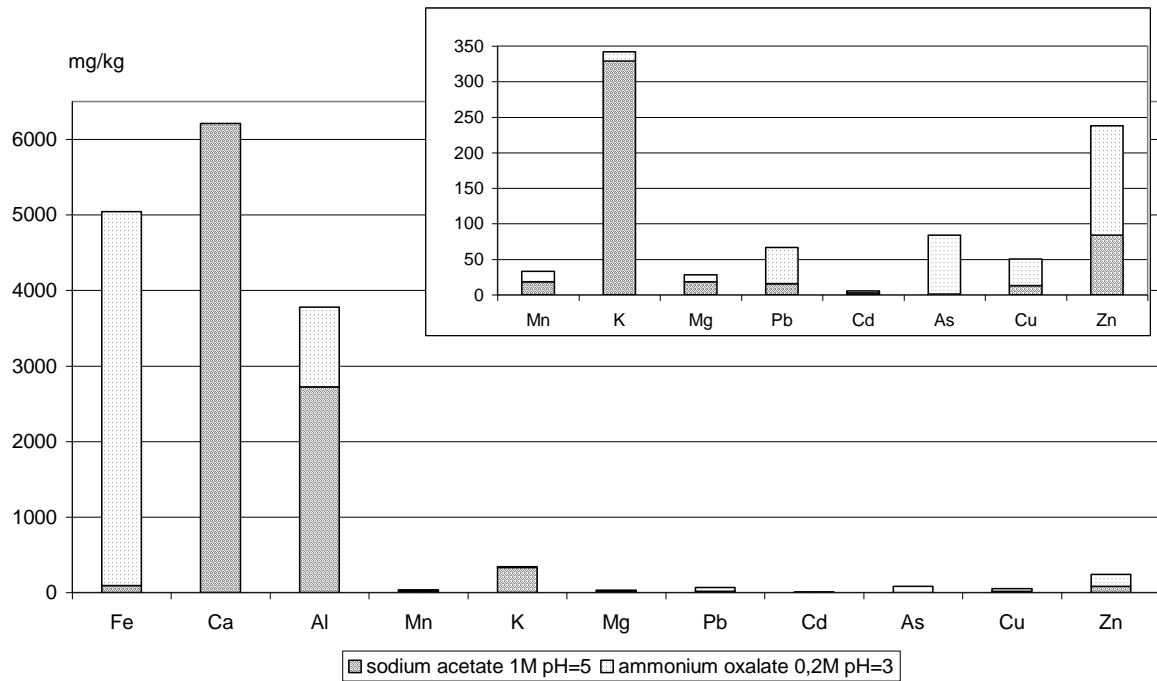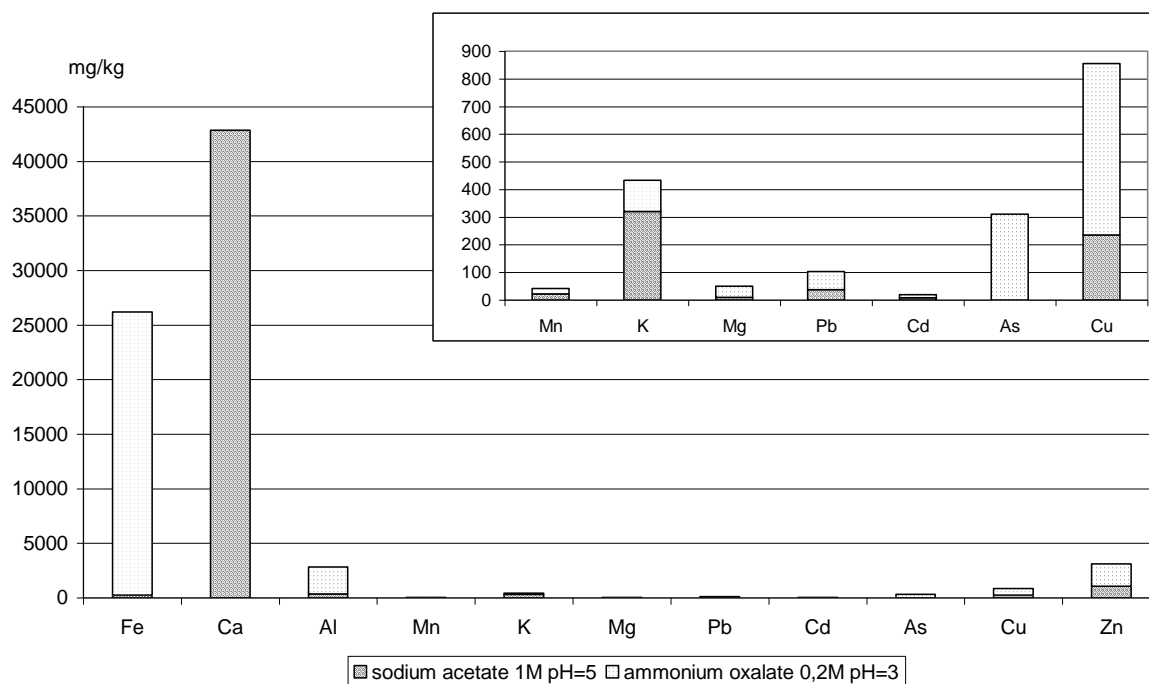
and stoichiometric sugar foam during 116 days.

mg/kg

sodium acetate 1M pH=5 □ ammonium oxalate 0,2M pH=3

4. CONCLUSIONS

The soils sampled from two locations at a former flotation plant of complex mineral sulphides are contaminant materials due to the acidity and heavy metals content of their leachates. Sample composition and acid potential corresponds to the origin of each one, higher sulphate and heavy metals content in soil sampled at the former stockpile of the coarse fraction from the primary crusher and more acidity in leachates of soil sampled at the former storage of pyrite tailings. The application of sugar foam as an amendment results in a significant reduction of the acid generation and heavy metals release. The effect of heavy metals immobilization could be attributed to the alkaline nature of the sugar foam; other mechanisms such as adsorption and bacterial inhibition due to organic matter and increase of pH could be simultaneously occurring. The stoichiometric dose of sugar foam was enough to stop or delay the water leaching of copper, aluminium and iron, whereas the release of cinc, manganese and cadmium are influenced by the massic relation sugar foam/sulphide sulfur of the

soil. Arsenic has not been detected in water leachates, probably due to the fact that it is a low mobile element in an oxidizing environment. Sequential extraction of the leaching residues show that immobilized heavy metals are associated to carbonates and iron and manganese hydroxides. Long-term monitoring and evaluation are needed in order to complete this study.

5. ACKNOWLEDGEMENTS

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