

Evaluation of metal mobility and adsorption capacity of a compacted lateritic soil by sequential extraction

**S.G.Gabas, M.E.G.Boscov,
J.E.Sarkis and M.H.Kakazu**

Soil

- **Lateritic residual clay of diabase**
- **59% clay, 14% silt, 21% fine sand, 6% medium sand**
- **$w_L=30\%$ and $PI=15\%$**
- **$\gamma_{dmax}=15.7 \text{ kN/m}^3$ and $w_{opt}=26.3\%$; $K=1 \times 10^{-9} \text{ m/s}$**
- **Kaolinite, iron oxides (ilmenite, hematite and magnetite), quartz, gibbsite and vermiculite**
X-ray diffraction and separation treatments: electromagnetic separation, FeO extraction, glycol addition, heating at 490°C
- **Organic content = 26 mg/kg (Walkley - Black method)**
- **Mass loss by 440°C heating = 13 - 14%**
- **pH = 5,2 - 5,5 (4 different methods)**
- **Point of zero charge = 4,0 - 4,5 (potentiometric titration)**

Methods

- **Pb and Cd contamination by diffusion tests on compacted samples.**
- **Sequential extraction procedure.**
- **Determination of Cd and Pb at various soil fractions.**
- **Chemical analyses: spectrometry of atomic emission with inductive coupled plasma (ICP-AES) and mass spectrometry with inductive coupled plasma (ICP-MS)**

Diffusion Tests

- **Compaction at γ_{dmax} and w_{opt}**
- **Nitric acid solutions at pH 3.0 and 5.5**
Cadmium (Cd): 3 mg/L; Lead (Pb): 100 mg/L
Alert values of soil contamination (CETESB, 2001)

Sequential extraction

- **Application of reagents sequentially to the same soil sample; stability of bonds increases and mobility of metals decreases at each step.**

Sequential extraction

BCR method (2001):

- **Step 1: exchangeable cations**, including water-soluble phases and carbonates, extracted with acetic acid solution (0.11 mol/L);
- **Step 2: easily and moderately reducible phases adsorbed and precipitated with iron and manganese oxides and hydroxides**, extracted with hydroxylamine chloridrate solution (0.5 mol/L);
- **Step 3: solid organic and sulfitic phases** extracted with ammonium acetate solution (1.0 mol/L);
- **Step 4: residual fraction, occluded in primary minerals**, extracted with aqua regia.

Diffusion tests (without metals)

	Cd		Pb	
pH	3	5,5	3	5,5
Concentration in the reservoir (mg/L)				
Initial	0,002	0,024	0,001	0,002
Final	0,22	0,77	0,013	0,024
Concentration in pore water (mg/L)				
Layer 1	0,01	0,03	0,00	0,17
Layer 2	0,03	0,06	0,01	0,27
Layer 3	0,02	0,09	0,03	0,19
Layer 4	0,03	0,03	0,04	0,04
Layer 5	0,06	0,07	0,03	0,20

Diffusion tests (with metals)

	Cd		Pb	
pH	3	5,5	3	5,5
	Concentration in the reservoir (mg/L)			
Initial	3,12	2,95	112	101
Final	0,12	0,29	0,14	0,14
	Concentration in pore water (mg/L)			
Layer 1	23,1	33,2	0,61	9,30
Layer 2	1,29	1,46	0,27	1,00
Layer 3	0,26	0,22	0,23	0,60
Layer 4	0,04	0,11	0,16	0,68
Layer 5	0,10	0,15	0,10	0,24

Sequential extraction

Cd Concentration in dry soil mass ($\mu\text{g/g}$)

	Step 1	Step 2	Step 3	Total
Natural Soil	0,01	0,02	0,02	0,05
Diffusion tests without metals				
pH 3	0,11	0,15	0,09	0,35
pH 5,5	0,12	0,15	0,17	0,43
Diffusion tests with Cd solutions				
pH 3	27,31	18,68	0,11	46,10
pH 5,5	23,87	8,20	0,05	32,12

Sequential extraction

Pb Concentration in dry soil mass ($\mu\text{g/g}$)

	Step 1	Step 2	Step 3	Total
Natural Soil	0,05	0,35	1,74	2,14

Diffusion test
without metals

pH 3	1,08	53,29	22,36	76,73
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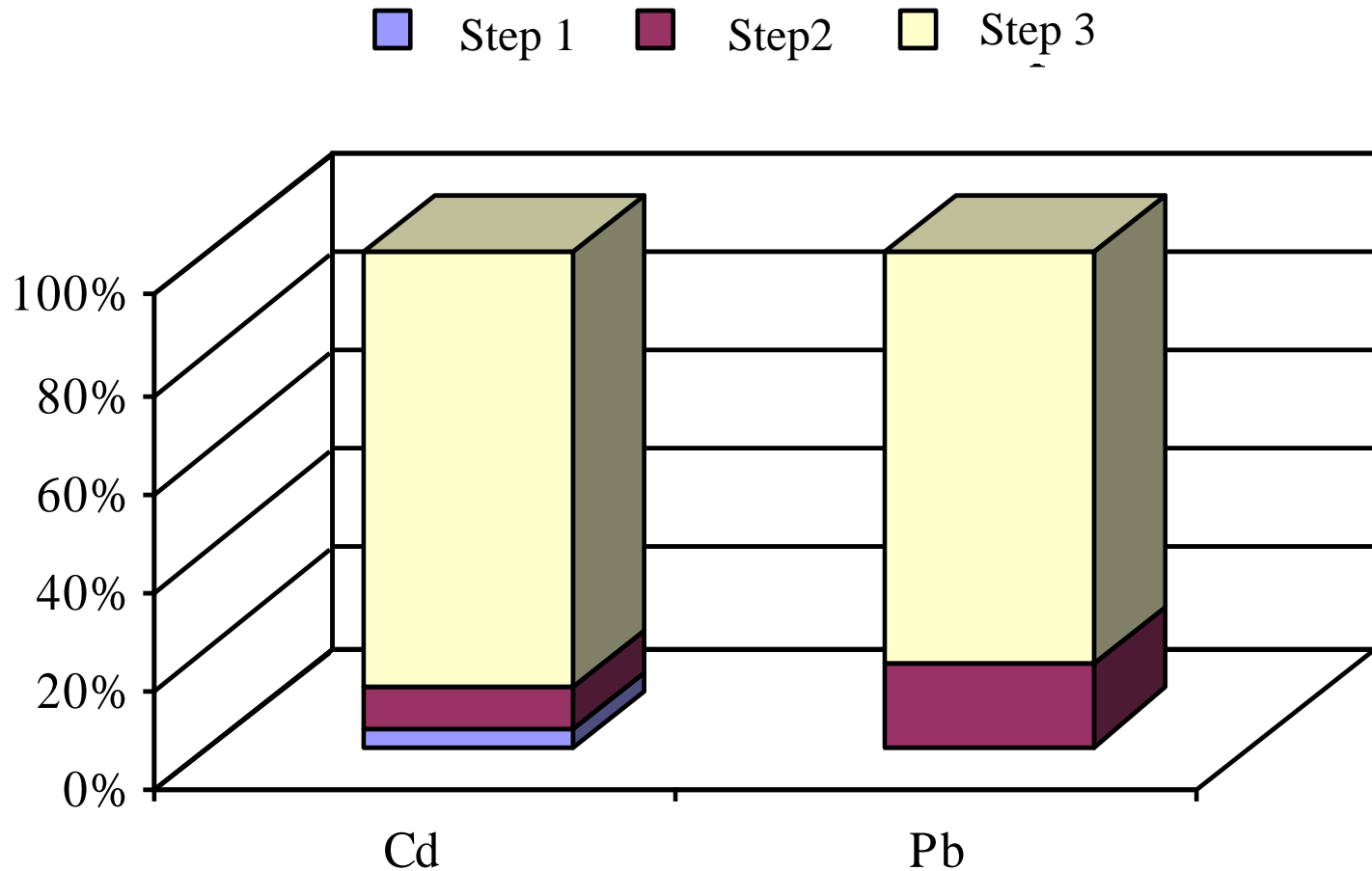
pH 5,5	0,82	53,30	29,87	83,99
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Diffusion tests
with Pb solutions

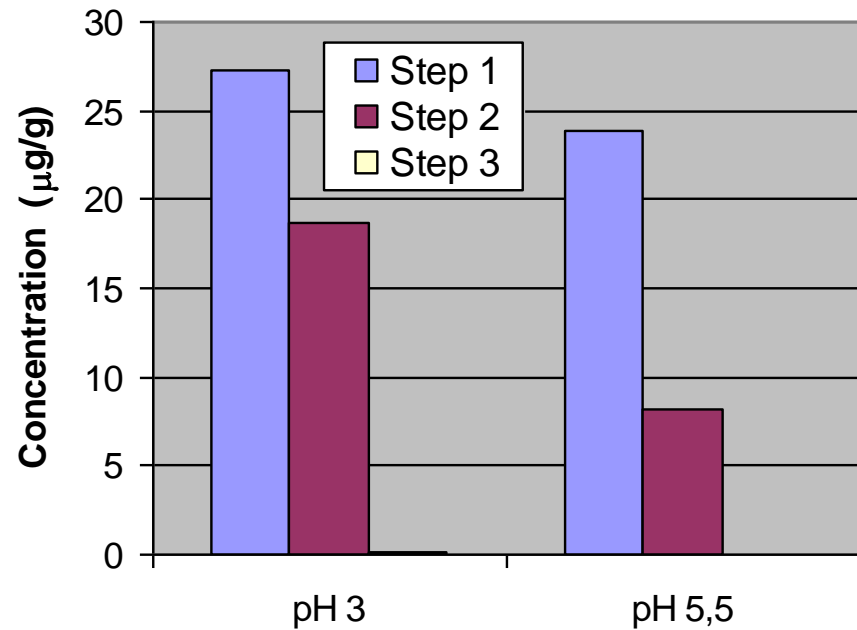
pH 3	689,42	1864,16	30,51	2584,09
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pH 5,5	597,80	1453,30	23,10	2074,20
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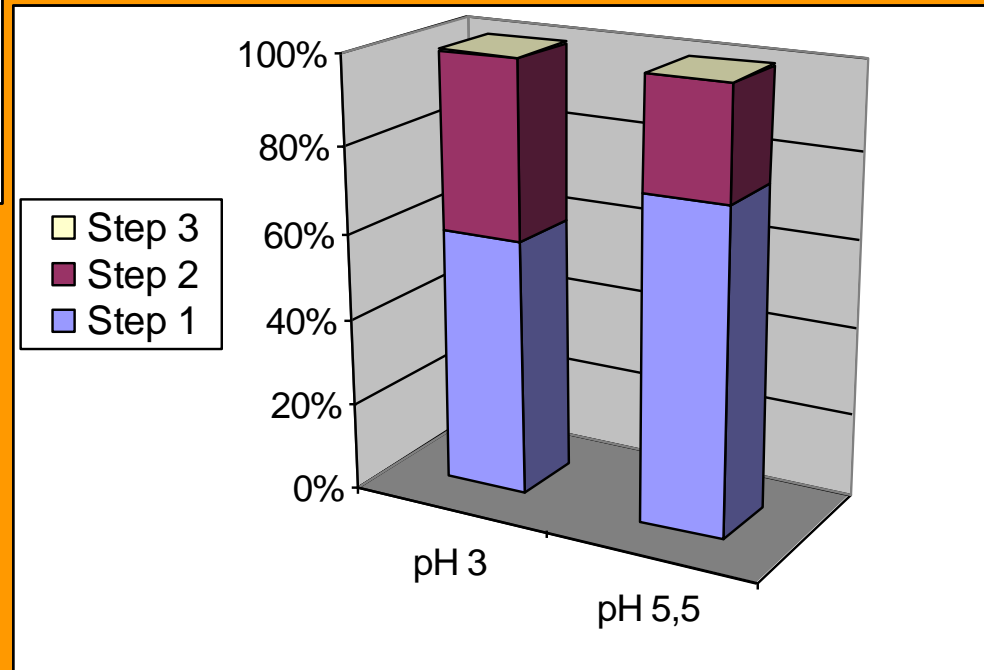
Sequential extraction (natural soil)



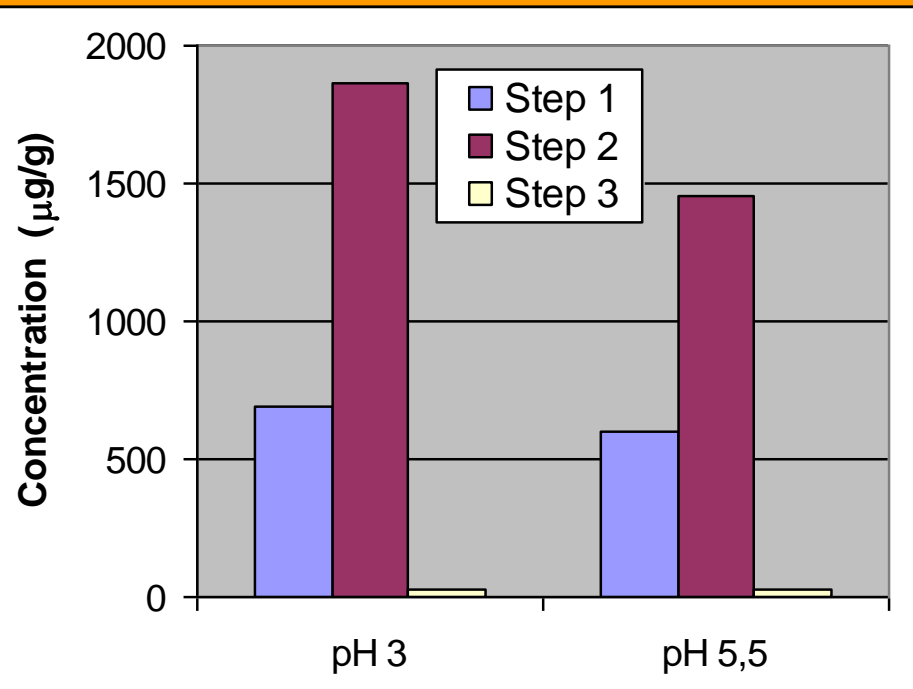
Sequential extraction (diffusion tests with metals)



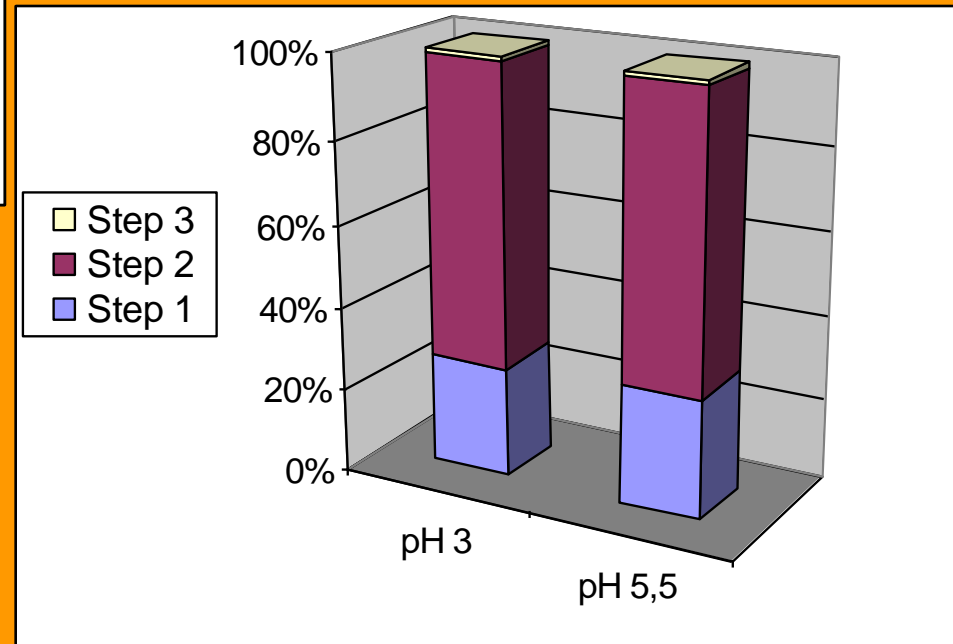
Cd



Sequential extraction (diffusion tests with metals)



Pb



Conclusions

- **Cadmium is more mobile than lead in the studied soil, as expected.**
- **Both metals are significantly retained in the soil at pH 3 and 5,5.**
- **Oxide phase is responsible for retention of lead, and partly for retention of cadmium.**
- **Sequential extraction is useful to evaluate mobility and retention of metals in clay liners.**