Assessment of environmental aspects of using biomass bottom ashes as stabilising agent of expansive clays.

CONFERENCE PAPER

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7TH INTERNATIONAL CONFERENCE ON SUSTAINABLE SOLID WASTE MANAGEMENT

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THE PRIORITY IS THE SUSTAINABILITY

- Engineering and construction sectors are key productive segments to control

consumption of resources

waste generation

air pollution

climate change

- It makes necessary to search viable and eco-friendly alternatives with the environment.

ECO-FRIENDLY ALTERNATIVES

- These initiatives are extendable in the stabilization of soils in civil engineering
- The stability of infrastructures depends on the stability of the soil in which they are supported

If the soil were unstable

expansive or present poor technical properties

it should be discarded

But

if the expansive soil is stabilized on site?

consumption reduction of natural resources

second life cycle

In addition

If we do not use chemical additives as stabilizers but waste or a by-product ….

the proposal is **doubly sustainable**
It is starting point of the present study

SOIL STABILISATION

- Traditionally, stabilisation of soils has been achieved by mixing with chemical additives with pozzolanic properties as cement or lime
- Nowadays many studies have been focused on reduce the by adding non-traditional stabilizers such as:

petroleum emulsions | asphalt | resins | polymers | enzymes → **chemical additives**

another eco-friendlier option is possible → by-products as vegetable wastes

- Green policies are necessary for implementation of sustainable solutions

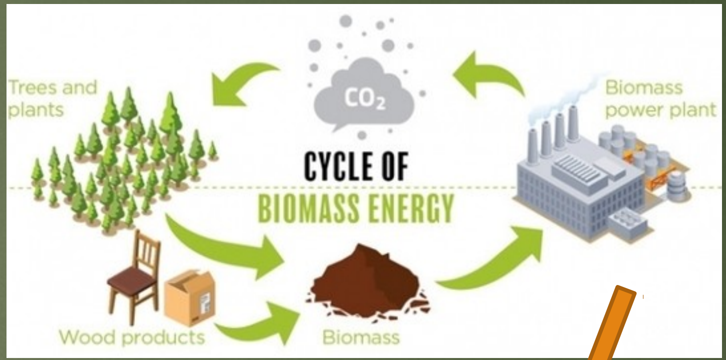
prioritizing the use of renewable energies and buildings compatible with the environment

BIOMASS IN ANDALUSIA

- Andalusia has a large historic agricultural tradition: crops such as olives, citrus or grapevine have been drivers of the regional economy.
- Thus, a large amount of vegetable wastes are produced:

4,6 MT of agricultural wastes	1,3 MT of forest wastes

- Andalusia leads the sector of production of electricity from biomass combustion
- 18 electric biomass cogeneration use the vegetable wastes as biomass-biofuel.
- However, the processing and disposal of BBA is actually an environmental and economic issue



Biomass bottom ashes

MAIN OBJECTIVE OF THE PRESENT RESEARCH

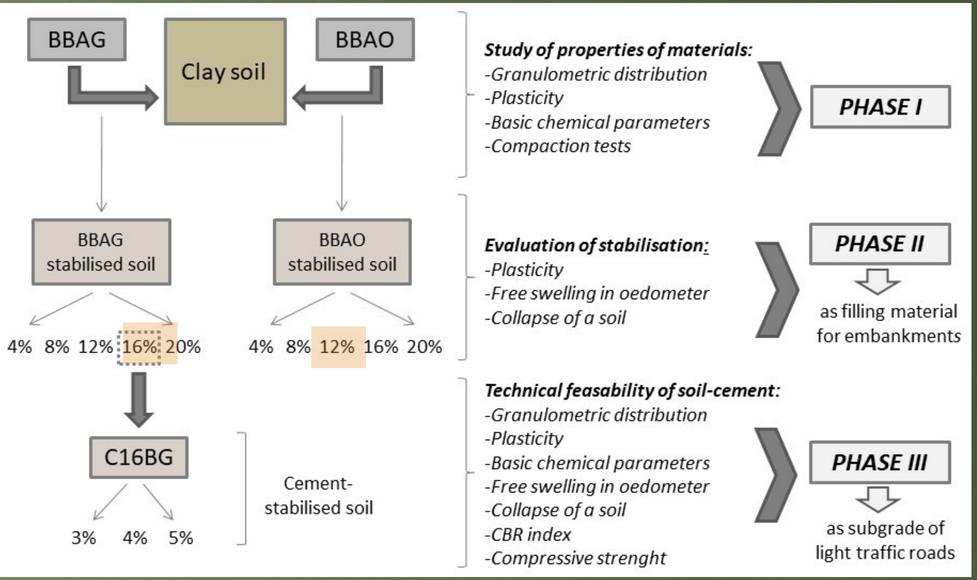
Could we substitute chemical agents by residues with stabilizing potential?

OUR PREVIOUS WORK PHYSICAL ASPECTS

Physical and mechanical properties were evaluated.

- *Optimum mixtures:*

16% BBAG and 12% BBAO



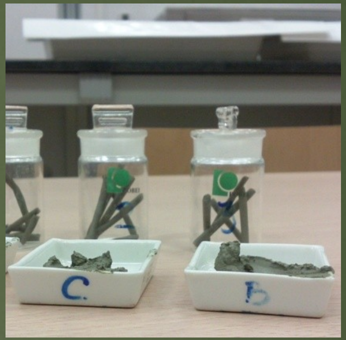
PRESENT WORK ENVIRONMENTAL ASPECTS

- The aim of the present research is the environmental assessment of waste (biomass bottom ashes) when they are used as soil stabilisers.
  - How are the release levels of pollutant?

MAIN OBJECTIVE OF THE PRESENT RESEARCH

What is the effect of different conditions between lab-on site?

- When materials are tested by conventional leaching tests:
  - The exposition to the leachant is **high and continuous**
  - The material is **not physically altered**
- However, when construction materials are used at work:
  - The exposition to the leachant is not continuous ***rain episod***
  - The material is **compacted** for increasing its bearing capacity.



- Comparative between release levels under laboratory / at work conditions

BIOMASS BOTTOM ASH

- Two BBA come from the combustion of the following biomass mixtures, were studied:

BBAO
33% olive tree + 33% olive oilcake + 33% vegetable waste from olive oil industries

BBAG
70% seed grape + 30% oil cake

- Basic characterisation:

		BBAG	BBAO
Density-SSD (kg/m³)		1.75	1.80
Water absorption (%)		37.00	28.40
Sand equivalent		72	49
Organic matter content (%)		1.29	6.55
SiO_2/Na_2O (at 24, 48, 72 h)		0.037 - 0.060 - 0.079	0.046 - 0.072 - 0.088
Soluble sulphate content (SO_3%)		0.67	0.75
Elemental content (%)	Na	1.28	1.67
	K	9.49	15.35
	Ca	16.37	20.15
	Mg	2.36	4.64
	Fe	1.57	2.52
	Si	18.78	48.88
	Al	1.63	2.02
	Mn	0.05	0.04
	S	0.12	0.75
	P	2.19	5.31

Olive oil cake is characterized by an average heating value around 21,000 kJ/kg (wood 17,000 kJ/kg)

EXPANSIVE CLAY SOIL (ES)

- Basic characterisation:

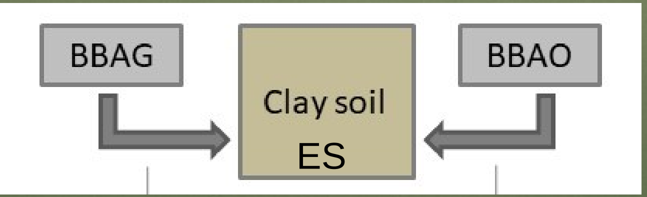
- The soil studied is a clayey expansive soil obtained during the construction works of the encirclement road west of Cordob

- Basic characterisation:
  - plastic index (PI): 30.30
  - Free swelling: 11.54 %
  - classified as high plastic clay-CH

(according to ASTM D2487–11 of Unified Soil Classification System, USCS).

- Mixtures of expansive soil (ES) and ashes (BBAG and BBAO): 8%, 12% and 16%

ES-8G
ES-12G
ES-16G



ES-8O
ES-12O
ES-16O

LEACHING TESTS FOR GRANULAR MATERIALS

- **LEVEL 1: BATCH LEACHING TEST (UNE-EN 1**

 basic characterisation

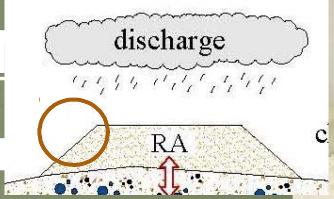
2 steps

2 and 10 L/kg

particle size <4 mm

- **LEVEL 2: COLUMN LEACHING TEST (NE**

 percolation phenomena throught mate



7 steps

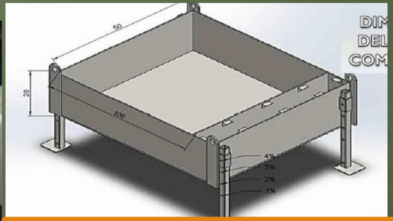
0.1, 0.2, 0.5, 1, 2, 5, and 10 L/kg

particle size <4 mm

CONVENTIONAL METHOD

- **LEVEL 3: UNDER COMPACTION LEACHING TEST**

 percolation phenomena throught material simulating real application conditio



7 steps

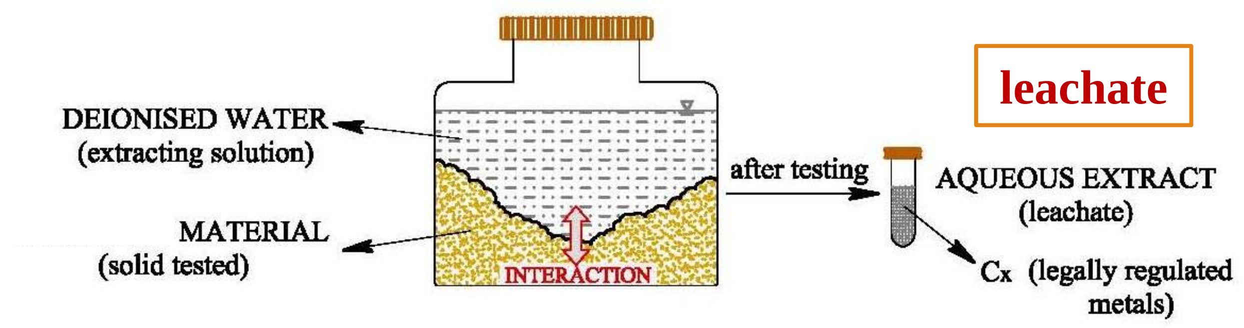
0.1, 0.2, 0.5, 1, 2, 5, and 10 L/kg

Real commercial grain size

PROPOSED METHOD

BASIC CHARACTERISATION

- **Leaching** as a method of characterisation of pollutan release of hazardous elements.



L/S ratio = LIQUID / SOLID (l/kg)

Metals inductively coupled plasma mass spectrometry
Anions ion chromatography (UNE-EN ISO 10304-1: 2009)

- Concentration on leachate

List of hazardous elements?

Landfill Directive of European Comission

12 metals	Cr	Ni	Cu
	Zn	As	Se
	Mo	Cd	Sb
	Ba	Hg	Pb
3 anions	Cl^-	F^-	SO^{-2}_4

Comparison with LEGAL LIMITS

(green)	Inert waste
(yellow)	Non-hazardous
(red)	Hazardous

DATA FROM LEACHING TESTS

LEVEL 1: ▶ **COMPLIANCE TEST BASIC CHARACTERISATION**

Leachate concentrations (mg/kg)

Inert | Non-hazardous | Hazardous

	ES		BBAG		ES-8G		ES-12G		ES-16G	
	LS2	LS10	LS2	LS10	LS2	LS10	LS2	LS10	LS2	LS10
pH	8.18	8.38	[illegible]	[illegible]	10.92	10.22	11.69	10.64	12.4	11.11
Cr	[illegible]	[illegible]	[illegible]	[illegible]	0.128	0.105	0.193	0.154	0.300	0.238
Ni	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Cu	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.260
Zn	[illegible]	[illegible]	[illegible]	[illegible]	0.013	0.261	0.015	0.061	0.024	0.079
As	[illegible]	[illegible]	[illegible]	[illegible]	0.014	0.046	0.021	0.061	0.035	0.091
Se	[illegible]	[illegible]	0.072	0.146	0.075	0.0552	0.0780	0.064	0.078	0.079
Mo	[illegible]	[illegible]	[illegible]	[illegible]	0.105	0.099	0.142	0.121	0.184	0.149
Cd	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Sb	0.005	0.012	0.001	0.002	0.005	0.014	0.006	0.014	0.007	0.016
Ba	0.060	0.196	0.100	19.861	0.067	0.083	0.042	0.057	0.027	0.044
Hg	n.d.	n.d.	0.002	0.001	0.002	0.003	0.000	0.006	0.001	0.001
Pb	n.d.	n.d.	0.047	0.047	n.d.	n.d.	n.d.	n.d.	0.002	0.003
Fluorurate	2.000	9.900	9.000	10.000	11.000	10.000	12.000	10.000	33.400	20.000
Chloride	99.000	83.000	25.000	40.000	37.000	50.000	277.800	271.000	320.000	301.000
Sulfate	3316.000	4170.000	4233.000	4420.000	4088.000	4420.000	3902.000	4420.000	3598.000	4420.000

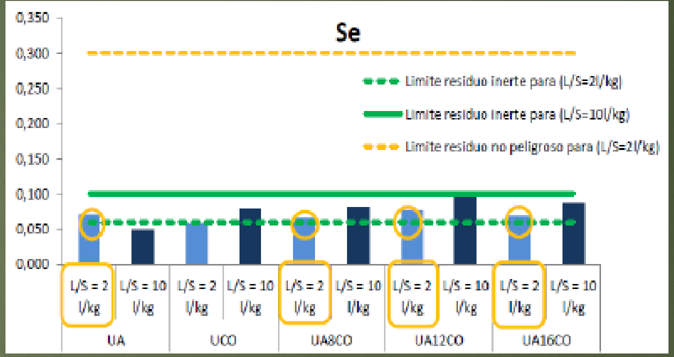
Expansive SOIL

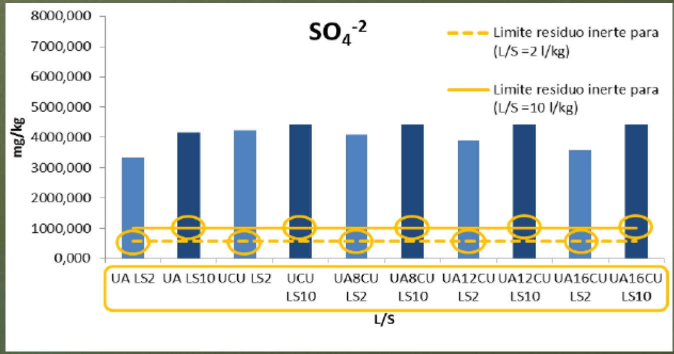
ASH-GRAPE

MIXTURES OF STABILISED SOIL

After comparing with the legal limit of Landfill Directive

ALL SAMPLES CLASSIFIED AS **NON-HAZARDOUS MATERIALS**





DATA FROM LEACHING TESTS

LEVEL 1:

▶ **COMPLIANCE TEST BASIC CHARACTERISATION**

Leachate concentrations (mg/kg)

Inert | Non-hazardous | Hazardous

	ES		BBAO		ES-80		ES-120		ES-160	
	LS2	LS10	LS2	LS10	LS2	LS10	LS2	LS10	LS2	LS10
	[illegible]	[illegible]	[illegible]	[illegible]	9.7	10.1	10.4	10.5	10.12	10.67
Cr	[illegible]	[illegible]	[illegible]	[illegible]	0.119	0.040	0.164	0.068	0.218	0.120
Ni	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Cu	[illegible]	[illegible]	[illegible]	[illegible]	0.088	0.149	0.119	0.208	0.190	0.330
Zn	[illegible]	[illegible]	[illegible]	[illegible]	0.019	0.079	0.019	0.065	0.021	0.081
As	[illegible]	[illegible]	[illegible]	[illegible]	0.012	0.093	0.015	0.106	0.017	0.099
Se	[illegible]	[illegible]	[illegible]	[illegible]	0.067	0.0810	0.0770	0.098	0.069	0.087
Mo	[illegible]	[illegible]	[illegible]	[illegible]	0.104	0.138	0.117	0.137	0.135	0.151
Cd	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Sb	0.005	0.012	0.005	0.010	0.004	0.015	0.004	0.017	0.003	0.017
Ba	0.060	0.196	0.015	0.050	0.089	0.163	0.083	0.127	0.071	0.095
Hg	n.d.	n.d.	0.001	0.050	n.d.	n.d.	0.004	0.001	0.006	0.001
Pb	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Fluorurate	2.000	9.900	59.900	47.600	2.016	5.000	1.692	5.000	12.465	5.000
Chloride	99.000	83.000	1140.000	1200.000	279.200	176.000	322.000	183.000	396.500	215.000
Sulfate	3316.000	4170.000	1884.000	2080.000	3240.000	3400.000	3148.000	3100.000	3045.000	2940.000

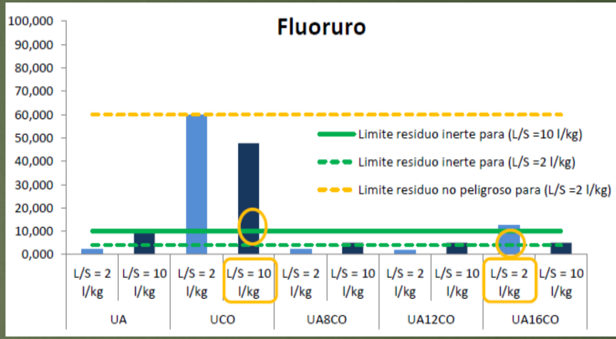
Expansive SOIL

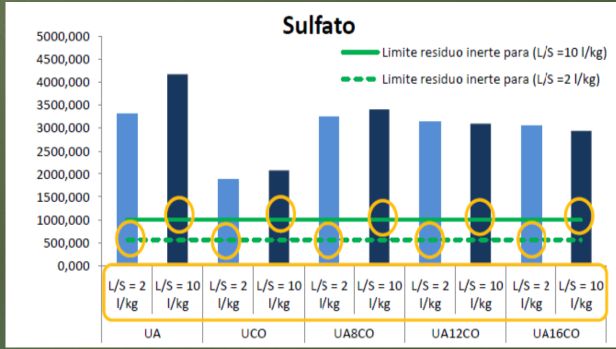
ASH-OLIVE

MIXTURES OF STABILISED SOIL

After comparing with the legal limit of Landifll Directive

ALL SAMPLES CLASSIFIED AS **NON-HAZARDOUS MATERIALS**





Assessment of environmental aspects of using biomass bottom ashes as stabilising agent of expansive clays

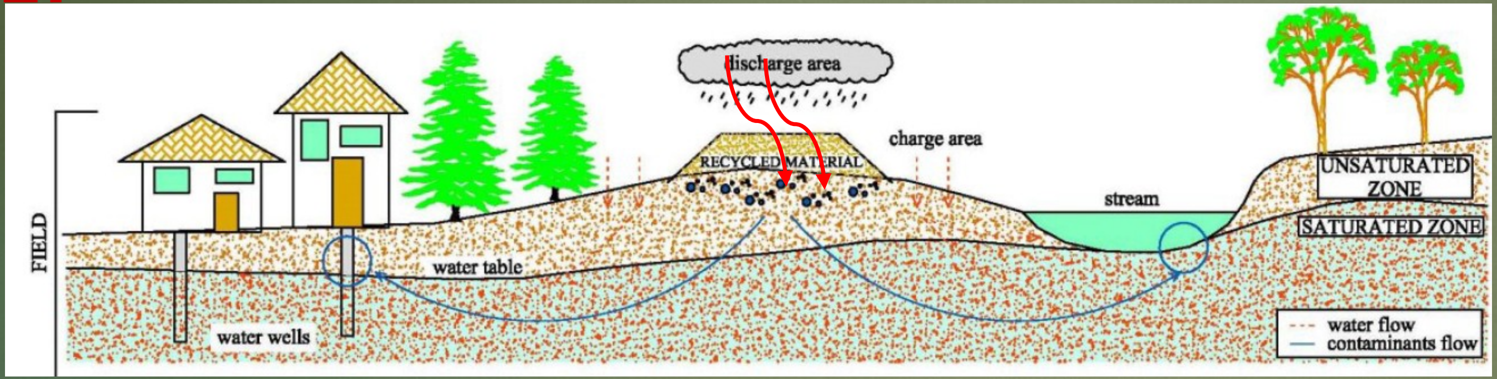
RESULTS AND DISCUSSION

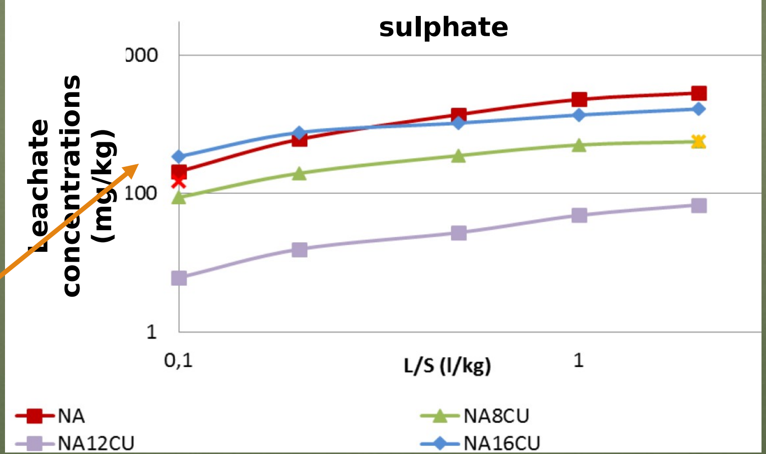
DATA FROM LEACHING TESTS

LEVEL 2:

- **PERCOLATION TEST AT LONG TERM?**

Material used in civil works





Legal limit of Landifll Directive

At L/S = 0.1 l/kg

Concentration curves from conventional leaching columna test

DATA FROM LEACHING TESTS

LEVEL 2:

- **PERCOLATION TEST AT LONG TERM?**

STABILISED SOIL with **GRAPE** ASH

	ES	ES-8G	ES-12G	ES-16G
	LS0.1	LS0.1	LS0.1	LS0.1
Cr	0.000	0.000	0.000	0.000
Ni	0.002	0.003	0.006	0.012
Cu	0.010	0.010	0.020	0.040
Zn	0.073	0.003	0.003	0.004
As	0.0003	0.002	0.002	0.003
Se	0.0003	0.000	0.0002	0.003
Mo	0.000	0.000	0.000	0.01
Cd	0.000	0.000	0.000	0.000
Sb	0.002	0.000	0.001	0.0003
Ba	0.0021	0.001	0.008	0.0015
Hg	0.000	0.000	0.000	0.000
Pb	0.001	0.000	0.000	0.000
Fluorurate	0.050	0.050	0.170	0.090
Chloride	2.920	0.940	0.110	9.800
Sulfate	208.000	88.000	90.700	343.000

INERT MATERIALS

NON-HAZARDOUS MATERIALS

STABILISED SOIL with **OLIVE** ASH

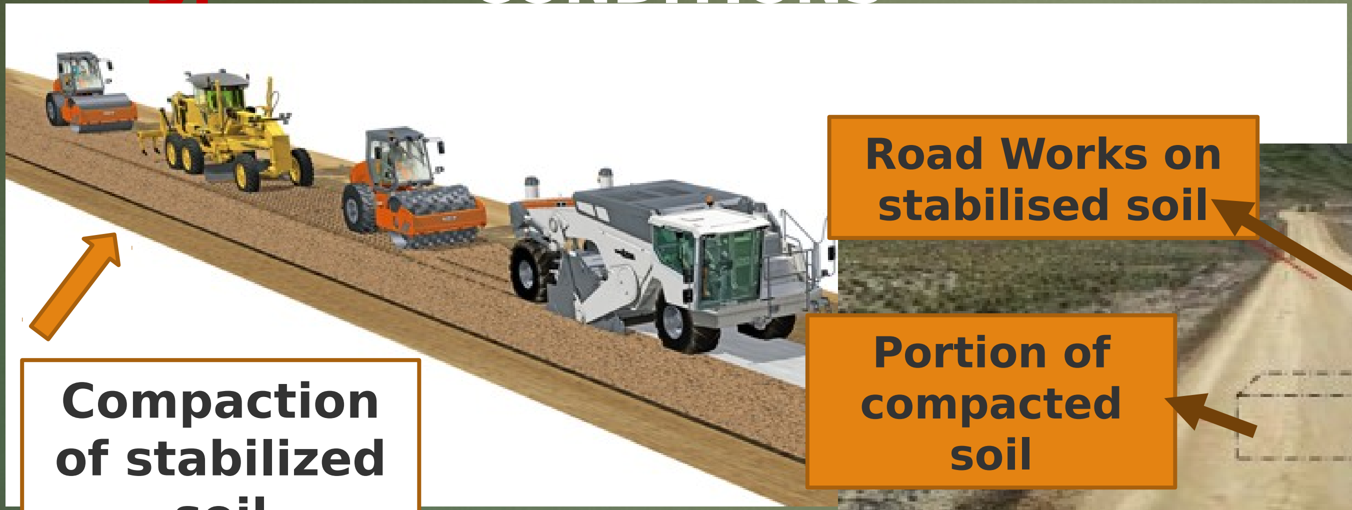
	ES	ES-8O	ES-12O	ES-16O
	LS0.1	LS0.1	LS0.1	LS0.1
Cr	0.000	0.002	0.001	0.002
Ni	0.002	0.011	0.009	0.009
Cu	0.000	0.000	0.000	0.000
Zn	0.000	0.010	0.020	0.012
As	0.0100	0.060	0.050	0.024
Se	0.0000	0.000	0.0003	0.000
Mo	0.003	0.016	0.013	0.0156
Cd	0.002	0.004	0.003	0.005
Sb	0.001	0.000	0.000	0
Ba	0.0002	0.000	0.000	0.0001
Hg	0.000	0.0001	0.0001	0.0001
Pb	0.073	0.036	0.002	0.002
Fluorurate	0.050	1.150	1.150	0.250
Chloride	2.920	46.000	39.500	20.850
Sulfate	208.000	423.000	292.000	176.000

NON-HAZARDOUS MATERIALS

DATA FROM LEACHING TESTS

LEVEL 3:

- **DESIGNED LEACHING PROCEDURE □ ON SITE CONDITIONS**



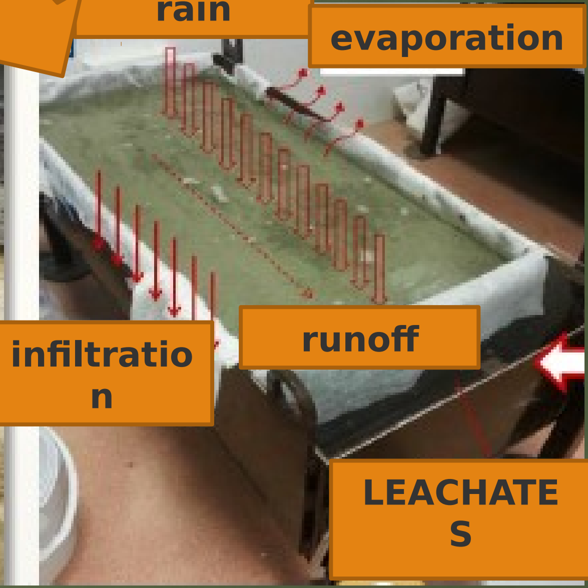
Compaction of stabilized soil

Road Works on stabilised soil

Portion of compacted soil

Laboratory – on site

Experimental design



rain

evaporation

infiltration

runoff

LEACHATES

UNDER COMPACTION LEACHING TEST (UCLT)

DATA FROM LEACHING TESTS

LEVEL 3:

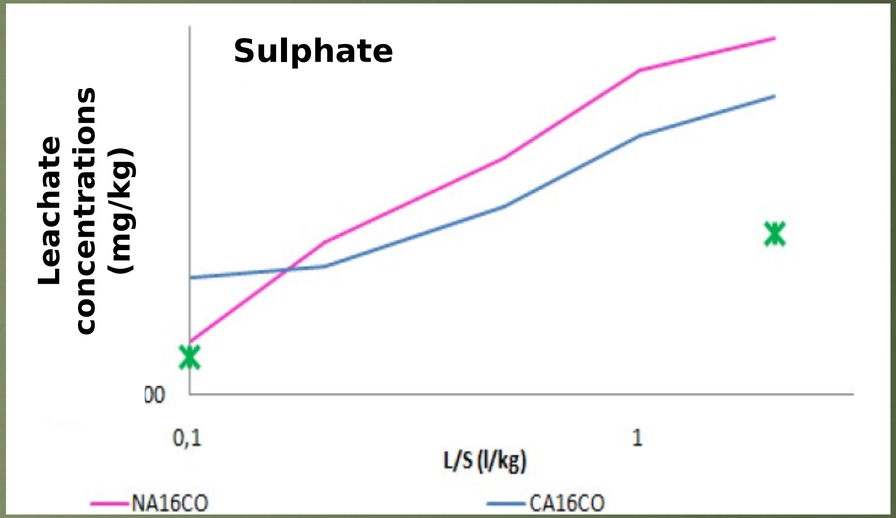
DESIGNED LEACHING PROCEDURE ON SITE CONDITIONS

	ES-12G
	LS0.1
Cr	0.0099
Ni	0.0015
Cu	0.0039
Zn	0.0026
As	0.0007
Se	0.0039
Mo	0.0091
Cd	0.0000
Sb	0.0000
Ba	0.0045
Hg	0.0000
Pb	0.0000
Fluorurate	0.1420
Chloride	0.2450
Sulfate	86.0000

	ES-16O
	LS0.1
Cr	0.0012
Ni	0.0071
Cu	0.0000
Zn	0.0090
As	0.0129
Se	0.0010
Mo	0.0108
Cd	0.0021
Sb	0.0000
Ba	0.0001
Hg	0.0002
Pb	0.0011
Fluorurate	0.0011
Chloride	0.9830
Sulfate	76.5000

Reduction on release levels

INERT MATERIALS



upper

lower

CONCLUSIONS

- Eco-friendly agents for stabilizing of expansive soils can be used in civil infraestructures
- According to compliance test all mixtures were classify as **NON-HAZARDOUS**
- When materials are tested by percolation test **simulating the percolation of rain** through a granular layer concentration levels **were reduced**
- When materials are **compacted** as occurs in civil infrastructures concentration levels **were even lower**
- Release levels are directly related with:
  - the **density** and **porosity** of the material (influenced by the compaction stage)
  - Contact time water-aggregate

In materials used in civil infrastructures as roads

THE POLLUTANT POTENTIAL COULD BE OVERESTIMATE WHEN ON-SITE CONDITIONS ARE NOT TAKEN INTO ACCOUNT

MITIGATING THEIR POTENTIAL USE AS ECO-STABILISER

THANK YOU FOR YOUR ATTENTION

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Presenting author: Adela P. Galvín.

"The greatest threat to our planet is the belief that someone else will save it."

Robert Swan

Alpine skier. He is currently an advocate for the protection of Antarctica and renewable energy.