Assessing the leachate toxicity of materials based on sediments in road sector

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INTRODUCTION & CONTEXT

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Aggregates Need

445 Million tons

2018

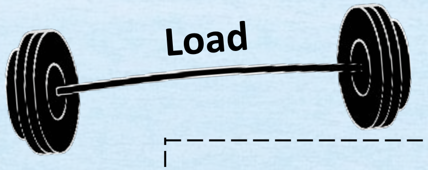
(UNICEM, 2020)*

Main Volume Flows

-2.2 million ton of aggregates as a difference between imports and exports in 2018 (UNICEM, 2020)*

8.9 Mt

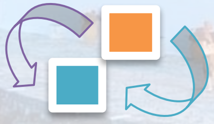
11,1 Mt



Load

€

Alternative Material



That provide a technical substitute for virgin aggregates

* l'industrie française des granulats. edition 2020 - French aggregates industry. 2020 edition

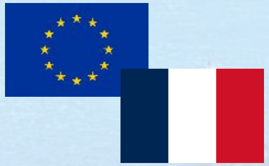
Sediments

50,000,000 m3

(Hayet et al., 2017)*

Classification

Sediments are considered as waste once it is removed from its natural environment (Directive 2008/98/EC)



Valorization

Regulatory Policies

Order that sets out the criteria for the removal of waste status for excavated soil and sediments that have been prepared for use in civil engineering or development

* Hayet et al,, 2017 , Impacts écologiques de sédiments pollués extraits et déposés en milieux terrestres. Etat des connaissances et évaluation des risques pour les écosystèmes

SETRA 2011

Environmental acceptability criteria for any alternative material to be used as a road material in France.

Level 3

Specific Road application

Performing Specific study

Level 2

Covered embankments / underlaying layers

Cumulative released quantity from the up-flow percolation test

Level 1

All Road Application

leaching released quantity
Trace elements (As ,Ba ,Cd ,Cr ,Cu ,Hg ,Mo ,Ni , Pb ,Sb ,Se, Zn), salts, soluble fraction , and total content of organic pollutants

* SETRA , Acceptability of alternative materials in road construction," 2011

Sustainability

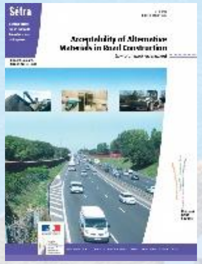
Human, Ecosystem and Environment

Recent Studies

Relating and validating pollutants elements leaching values with their assigned thresholds in the road material matrix. **(environmental acceptability of the treatment method)**.

SETRA Guides

Different methodological and technical guides, the interest in the toxicity field decreased as a single concern.



Previous studies

(Tribout et al. 2011)* that have addressed the toxicity of (Hg, Cd, As, Pb ,Ni ,Cu ,Cr ,and Zn) from dredged sediments , by using METOX index , developed by French water agencies, and used for the calculation of pollution fees with respect to the French environmental code.

* C. Tribout, B. Husson, and A. Nzihou, “Use of Treated Dredged Sediments as Road Base Materials: Environmental Assessment,” Waste Biomass Valorization, vol. 2, no. 3, p. p.337-346, Aug. 2011, doi: 10.1007/s12649-011-9068-4.

Dredged sediments pollutants : agrichemical, urban, industrial, and atmospheric.

Using life cycle assessment characterization models, leaching emissions are translated into sustainability indicators for decision-makers.

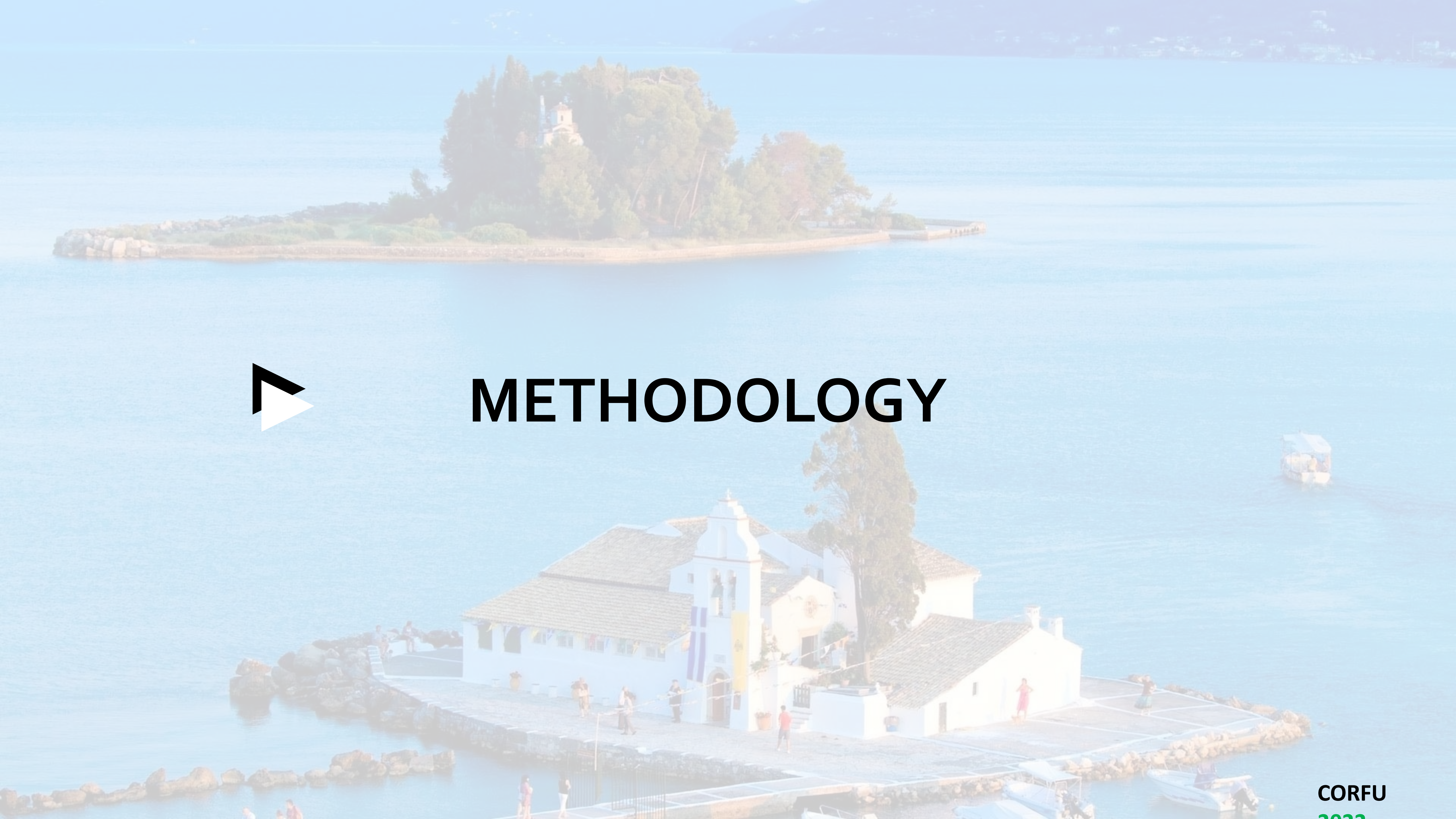
USEtox Model

Contaminants effect → Different Mediums → Potential Environmental Impacts on Ecosystems & Human Health

Study Goal !!

Toxicity impacts for raw dredged sediments for the use as a backfill, and treated sediments for the use as a road foundation at different curing age.

* Acceptability of alternative materials in road construction," 2011



METHODOLOGY

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Case study

Based on the previous study (Achour et al.2014) Dunkirk dredged sediments in one of the most importing dredging sites in France* ,have been granularly corrected with dredged sand, and then treated by using the solidification/stabilization (S/S) technique.

- L. Palumbo, “Sediment Management of Nations in Europe,” in Sustainable Management of Sediment Resources, vol. 2, G. Bortone and L. Palumbo, Eds. Elsevier, 2007, pp. 11–58. doi: 10.1016/S1872-1990(07)80014-6.
- R. Achour et al, “Valorization of unauthorized sea disposal dredged sediments as a road foundation material,” Environ. Technol., vol. 35, no. 16, Art. no. 16, Aug. 2014, doi: 10.1080/09593330.2014.889758.

Functional unit and system boundaries

Due to leaching importance in influencing the total toxicity , only leaching impacts on human toxicity and freshwater toxicity are included and calculated using USEtox model

The functional unit is the unit that allows us to compare different product systems with respect to their provided performance. Then both materials were assessed with a functional unit of 1-ton usage of road material based on dredged sediment with different management possibilities.

Material	Application	I-CBR	Required I-CBR*	Long Term Mechanical classification (Elasticity and Direct Tensile strength)
Dredged Sediments	Backfill	30	5	No requirements
Treated dredged sediments Mix (with sand, cement , and lime)	Road Foundation	70	35	Class T3- Suitable for Foundation

- Réalisation des remblais et des couches de forme (GTR) - Fascicule 1 - principes généraux," Cerema, 2000
- Assises de chaussées en graves non traitées et matériaux traités aux liants hydrauliques et pouzzolaniques." 1998
- NF EN 14227-5 - August 2013 -Hydraulically bound mixtures - Specifications - Part 5 : hydraulic road binder bound granular mixtures

Leaching data

SETRA leaching thresholds where based on environmental modeling for the pollutants' fate with respect to several conditions*. In this study, the leaching behavior of the material was based on SETRA environmental modeling for assessing the acceptability of raw and treated dredged sediments.

Table 2 Pollutants leaching data for raw and treated dredged sediments with their relative SETRA thresholds*

Cumulative amount leached L/S = 10 l/kg (leaching test EN 12 457-4 and NF 12-457-2)								
Elements	Raw Dredged Sediments	Treated Sediments at different days					SETRA Thresholds	
		Crushed Samples			Monolithic Samples		Required value of at least 100% of the samples (mg/kg dry matter)	For Use in Road
		28	60 (Onsite)	90	28	90		
As	*<0.1*	*<0.1*	*<0.1*	*0.2*	*< 0.1*	*0.1*	*1.5*	*2*
Ba	*1.43*	*9.4*	*5.7*	*8.3*	*1.08*	*1.1*	*60*	*100*
Cd	*0.04*	*<0.04*	*<0.04*	*<0.04*	*< 0.04*	*0.04*	*0.12*	*1*
Cr	*0.1*	*0.1*	*<0.12*	*<0.1*	*< 0.1*	*0.1*	*1.5*	*10*
Cu	*0.57*	*1.6*	*1.82*	*0.9*	*< 0.1*	*0.12*	*6*	*50*
Hg	*<0.05*	–	–	–	–	–	*0.03*	*0.2*
Mo	*0.76*	*0.2*	*0.18*	*0.2*	*< 0.1*	*< 0.1*	*1.5*	*10*
Ni	*<0.1*	*0.15*	*0.13*	*0.16*	*< 0.1*	*< 0.1*	*1.2*	*10*
Pb	*<0.1*	*0.1*	*0.1*	*<0.1*	*< 0.1*	*< 0.1*	*1.5*	*10*
Sb	*0.16*	*<0.06*	*<0.06*	*<0.06*	*< 0.06*	*< 0.06*	*0.18*	*0.7*
Se	*0.01*	*0.1*	*<0.1*	*<0.1*	*< 0.1*	*< 0.1*	*0.3*	*0.5*
Zn	*0.34*	*0.1*	*<0.1*	*<0.1*	*< 0.1*	*< 0.1*	*12*	*50*

- Acceptability of alternative materials in road construction," 2011
- R. Achour et al, "Valorization of unauthorized sea disposal dredged sediments as a road foundation material," Environ. Technol., vol. 35, no. 16, Art. no. 16, Aug. 2014, doi: 10.1080/09593330.2014.889758

Characterization & Damage

As a part of the life cycle assessment method, USEtox's final results provide an impact score which represents a comparative unit between different systems at 2 levels

Inventory Flows

Midpoint Level

Serving characterization impacts for human health and freshwater ecotoxicity.

Endpoint Level

Transforming toxicity into damages to human health and ecosystem.

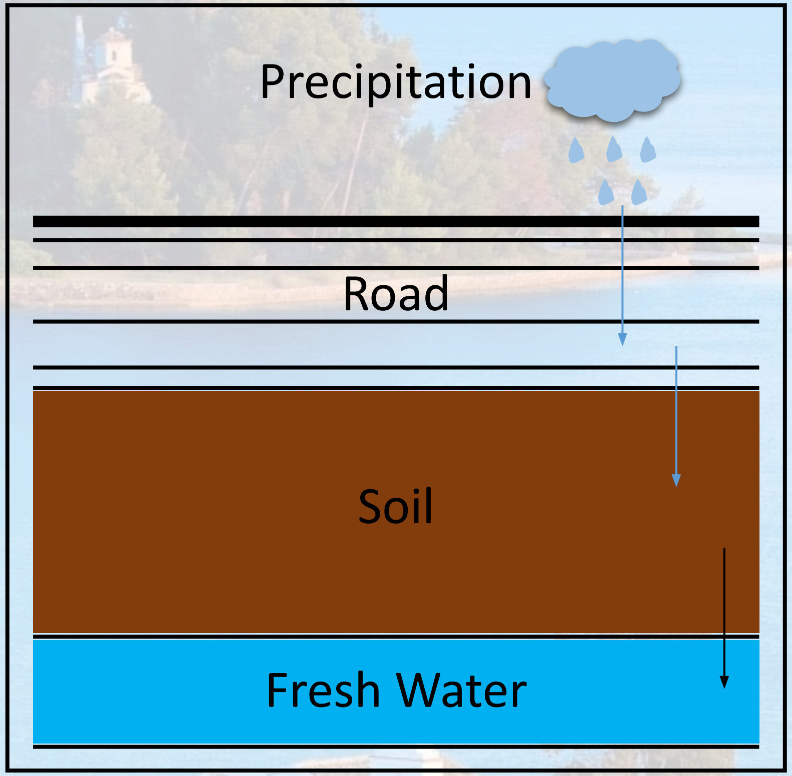
Cases for human health cancer and non-cancer toxicity categories

Disability-adjusted life year (DALY) for the damage endpoint results affecting human health

Potentially affected fraction of species integrated over exposed volume & time (PAF).m3.day

Potentially disappeared fraction of species over exposed volume and time (PDF). m3.day for ecosystems

* M. Bijster et al., "USEtox® 2.0 Documentation (Version 1.1)," 2018, doi: 10.11581/DTU:00000011.



Pollutants leaching scheme

In the USEtox model , the soil compartment is not relevant for the soil under road structure ,then in this study, the leaching impacts were considered directly affecting freshwater despite of the environmental fate modeling used in USEtox for the soil compartment . Assuming that the leachate impacts of the material used will be as a toxicity threat for freshwater in the long-term scenario .

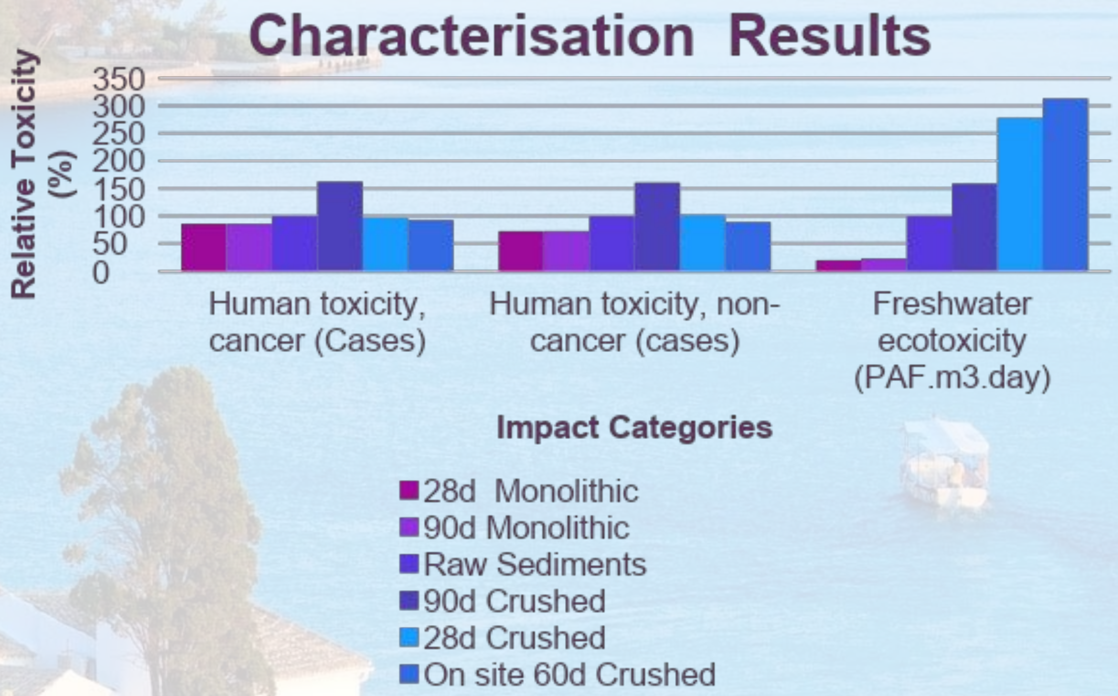
RESULTS

Leachate potential Impacts

For all toxicity categories: the toxicity of treated monolithic material for the use in road foundation at different ages were lower than that of the raw material for the use as a backfill scenario.

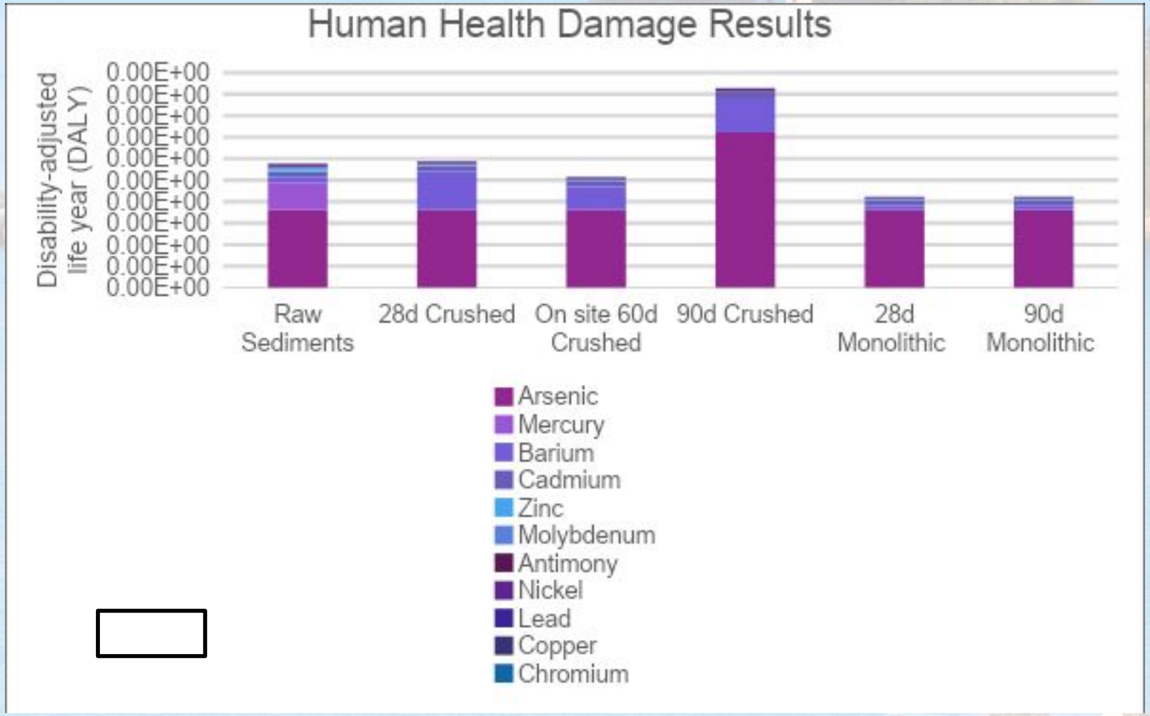
For crushed treated samples the results of freshwater toxicity were higher than the values of raw material impacts in this category.

For human cancer and non-cancer categories:
After 90 days of curing, the treated material showed higher values than those found in the raw material (around 160%).
For material crushed at 60 days (on-site) the values were slightly less than the raw material toxicity impacts.

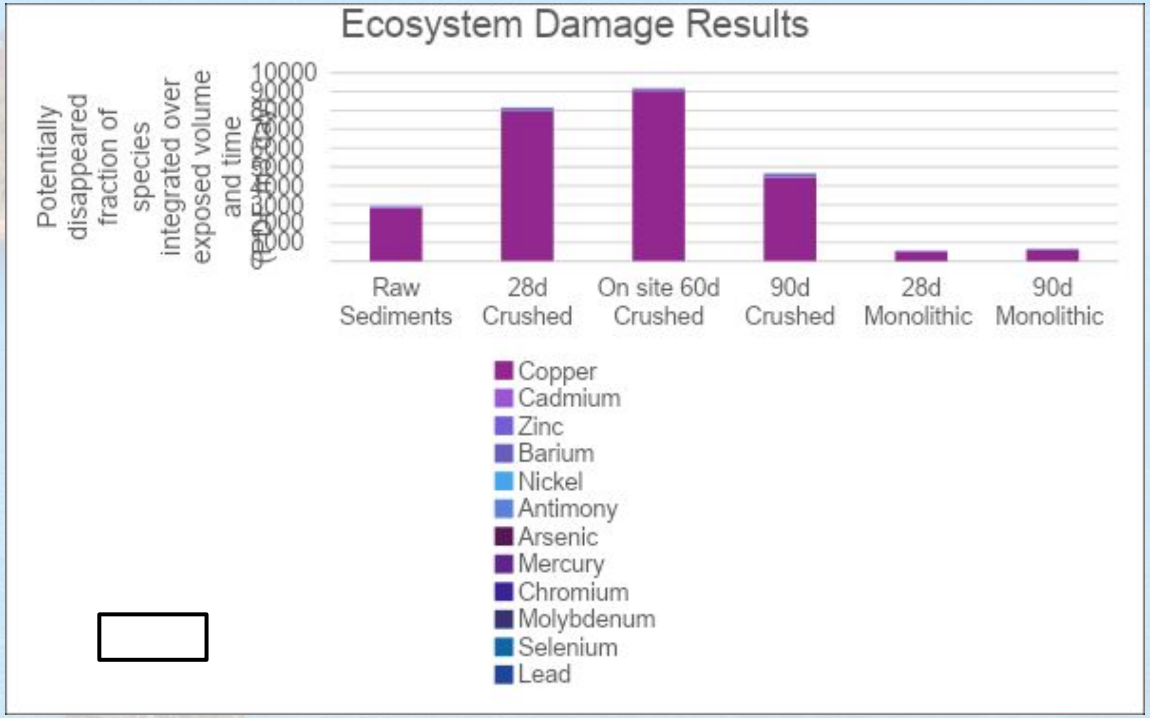


Relative characterization toxicity with respect to raw sediments

Leachate potential Impacts



Human Health Damage Results For Raw & Treated Sediments



Ecosystem Damage Results For Raw & Treated Sediments

Effect of some major toxic elements in terms of magnitude.

Curing time and grain size differences show their effects on elements leaching behavior and consequently on toxicity impacts.

Leachate thresholds and regulations

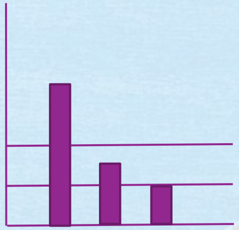
Defining thresholds is the common act of governmental regulations.

Industrial sector gives the economical point of view its priority in its applications

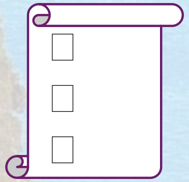
Environmentally acceptable solution that meets their economical view

Feasible Solutions

BUT !!



By providing in parallel certain thresholds with respect to the sustainable development goals , relying on the average natural material application impacts.



Indirectly provide a more sustainable way for waste valorization by their commitment to the laws

CONCLUSIONS & PERSPECTIVE

CONCLUSIONS & PERSPECTIVE

For crushed samples; human cancer and non-cancer toxicity where curing time dependable

Leachate of monolithic treated dredged sediments for the use as a road foundation is less harmful to human health and ecosystem than using raw dredged sediments for the use as backfill

Impacts on freshwater ecotoxicity or ecosystem damages are higher upon leachate of the crushed treated dredged sediments material more than in the case of using raw sediments

PERSPECTIVE

leachate toxicity modeling can serve as primary comparative screening for waste valorization in road ,but will have to be linked to the complete life cycle processes.

PERSPECTIVE

Pilot study that takes real site conditions modeling into account (Pollutants' transfer modeling and liquid to solid ratio effect)

* Acceptability of alternative materials in road construction," 2011

"Conservation is a state of harmony between men and land."

Aldo Leopold

Thank You For Your Attention!!

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