CIRAIG

Centre Interuniversitaire de Référence sur l'Analyse, l'Interprétation et la Gestion du cycle de vie des produits, procédés et services

ÉCOLE POLYTECHNIQUE MONTRÉAL

LCA of Aboveground Bioremediation of Diesel-Impacted Soil

L. Toffoletto, R. Samson and L. Deschênes

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InLCA/LCM 2003 Seattle

LCA of Aboveground Bioremediation of Diesel-Impacted Soil

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2. **Case study**
3. **Goal and scope**
4. **Life cycle inventory (LCI)**
5. **Life cycle impact assessment (LCIA)**
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1- LCA and contaminated soil management

- In Quebec, three levels of criterial values for site use (A : residential, B : commercial and C : industrial) have been set out for contaminated soil. These generic criteria do not consider the impacts of decontamination, however:

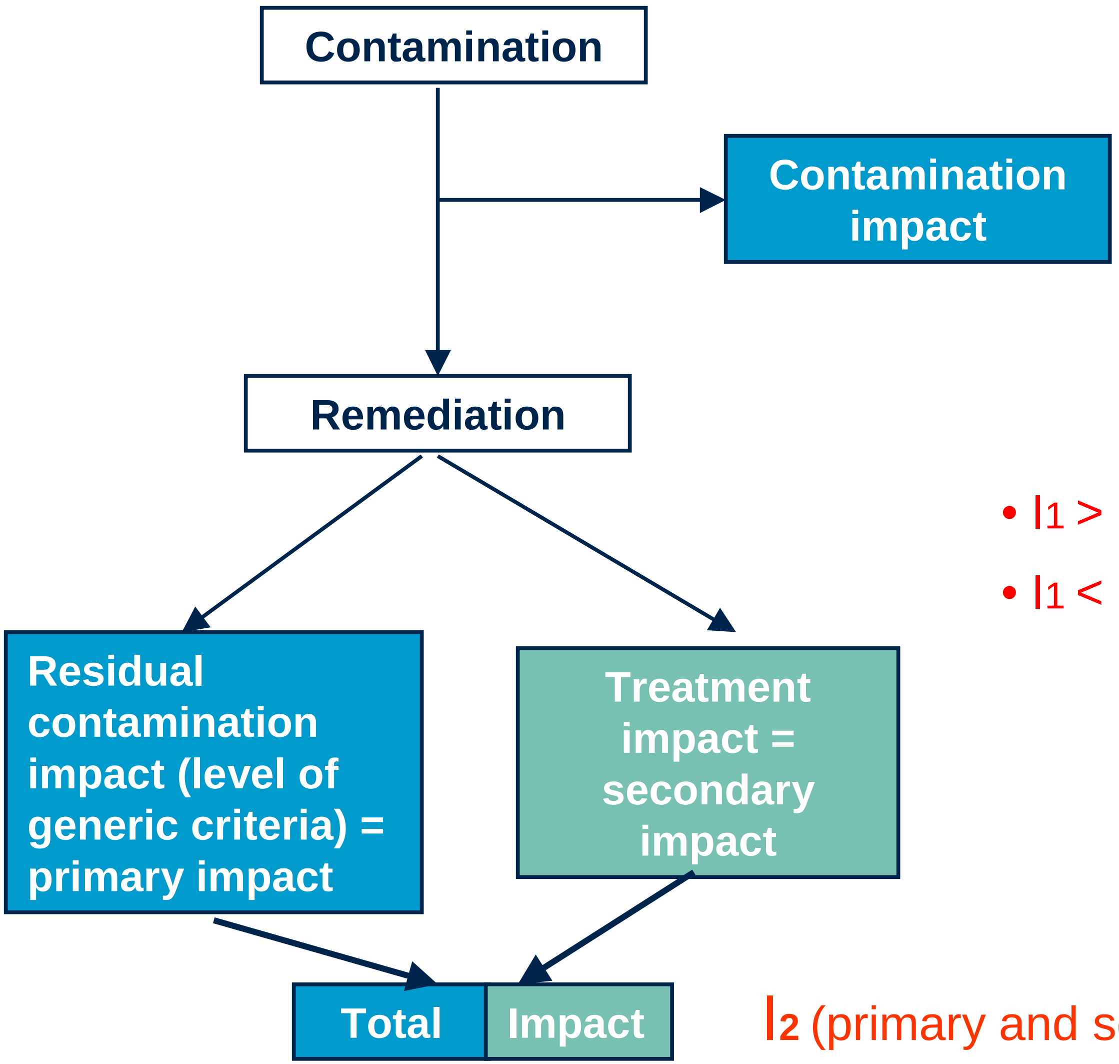
While decontamination technologies reduce the concentration of pollutants, they can generate other impacts

- LCA can be a useful tool to assess these two kinds of impacts as well as evaluating if remediation is the best environmental option

- 4 previous studies have already applied LCA to soil management:
  - Volkwein et al., 1999
  - Page et al., 1999
  - Diamond, et al., 1998
  - Beinat et al., 1997

1- LCA and contaminated soil management

Primary impact vs secondary impact (Volkwein et al., 1999)



I_1 (primary impact)

- $I_1 > I_2$: remediation is needed
- $I_1 < I_2$: another management should be chosen

I_2 (primary and secondary impact)

2 – Case study

A diesel contamination in Quebec

- The case study considered is a diesel-contaminated site located in Quebec (Canada).

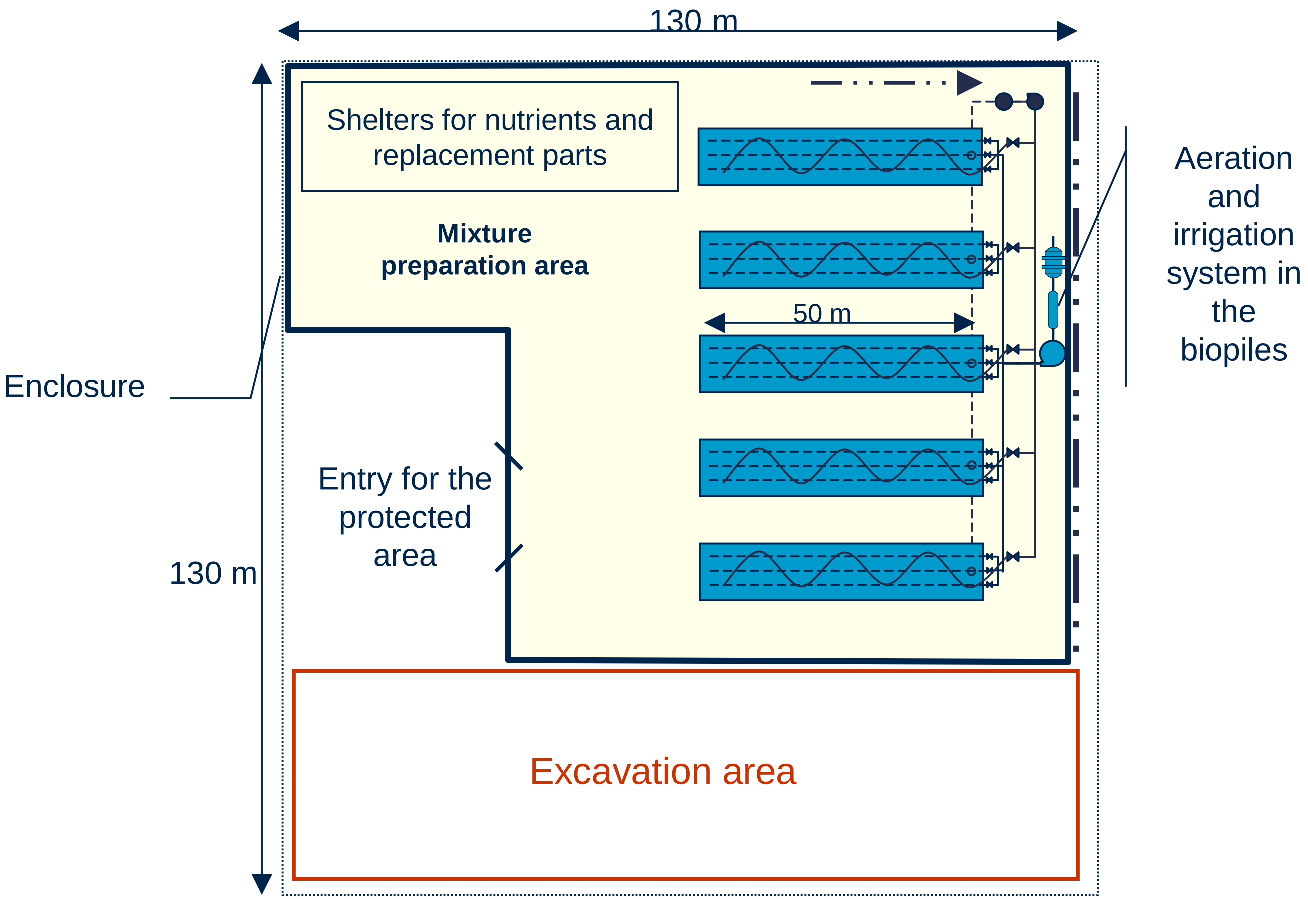
- A volume of 8000 m^3 was impacted with diesel
- Level of contamination : 6145 mg/kg (2 times the B criterion for industrial use)

- The remediation project took place in the late 90’s and consisted in excavating the soil and treating it using an ex-situ biopile treatment located near the contaminated area (single-use treatment center)
- The target was 700 mg/kg (B criterion for commercial use)

2 – Case study

A diesel contamination in Quebec

5 biopiles were constructed near the contaminated area :



3 – Goal and Scope

Objectives

To assess the primary and secondary impacts of the biopile treatment's life-cycle as a function of the duration of treatment and the achievement of regulatory criteria

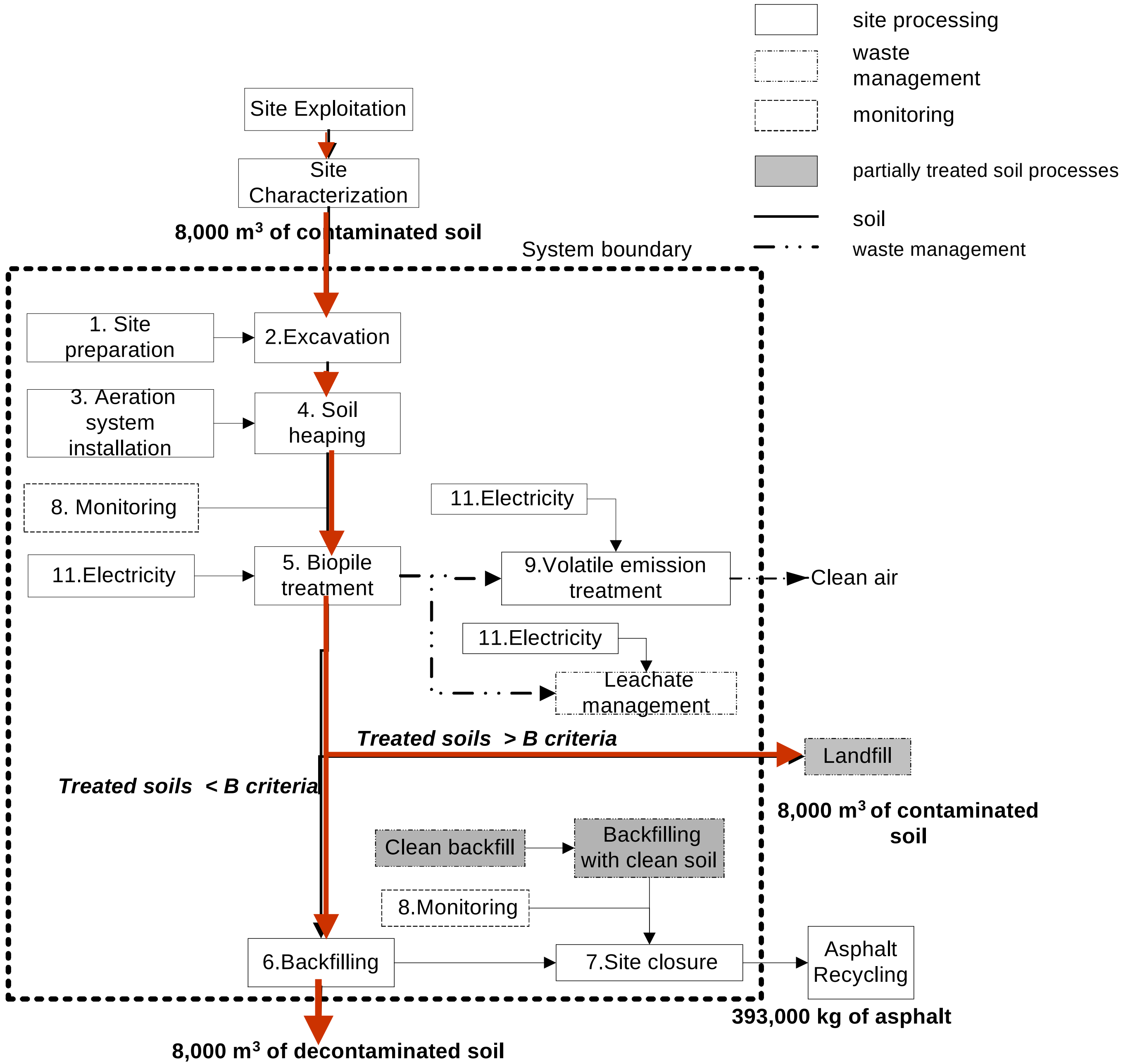
Functionnal unit and reference flow

The remediation, during a two-year period, of 8000 m^3 of diesel contaminated-soil (6145 mg C_{10}-C_{50} / kg) to the B generic criterion (700 mg C_{10}-C_{50} / kg) using a biopile treatment

Scope

- All activities occurring during the remediation were included ;
- The electric energy consumption considered pertained to the pumps ;
- All transportation to and from the site were included ;
- Ex-situ monitoring activities were not taken into account ;
- Landfilling of soils was excluded from the system boundary.

4 - LCI
Life cycle flow diagram



4 - LCI

Some inventory data …

Inputs	Mass (kg)	%	Life cycle stage
Steel	25,644	1.30	(1) Site preparation
Aluminum	151	0.01	
Clay	880,866	44.57	
Asphalt	786,000	39.77	
Wood	4904	0.25	
HDPE	1305	0.74	
LDPE	7375	0.09	
Zinc	4	0.00	
Wood chips	189,600	9.59	(4) Soil heaping
Diammonium phosphate	1644	0.08	
Urea	7525	0.38	
Water	40,486	2.05	(8) Monitoring
Latex	5	0.00	
Glass	552	0.03	
Manure	6402	0.32	(9) Volatile emission treatment
Gravel	4272	0.22	
PVC	11,473	0.58	
Peat	15	0.00	
Total	1,976070	100	

5 – LCIA

Diesel characterization factors

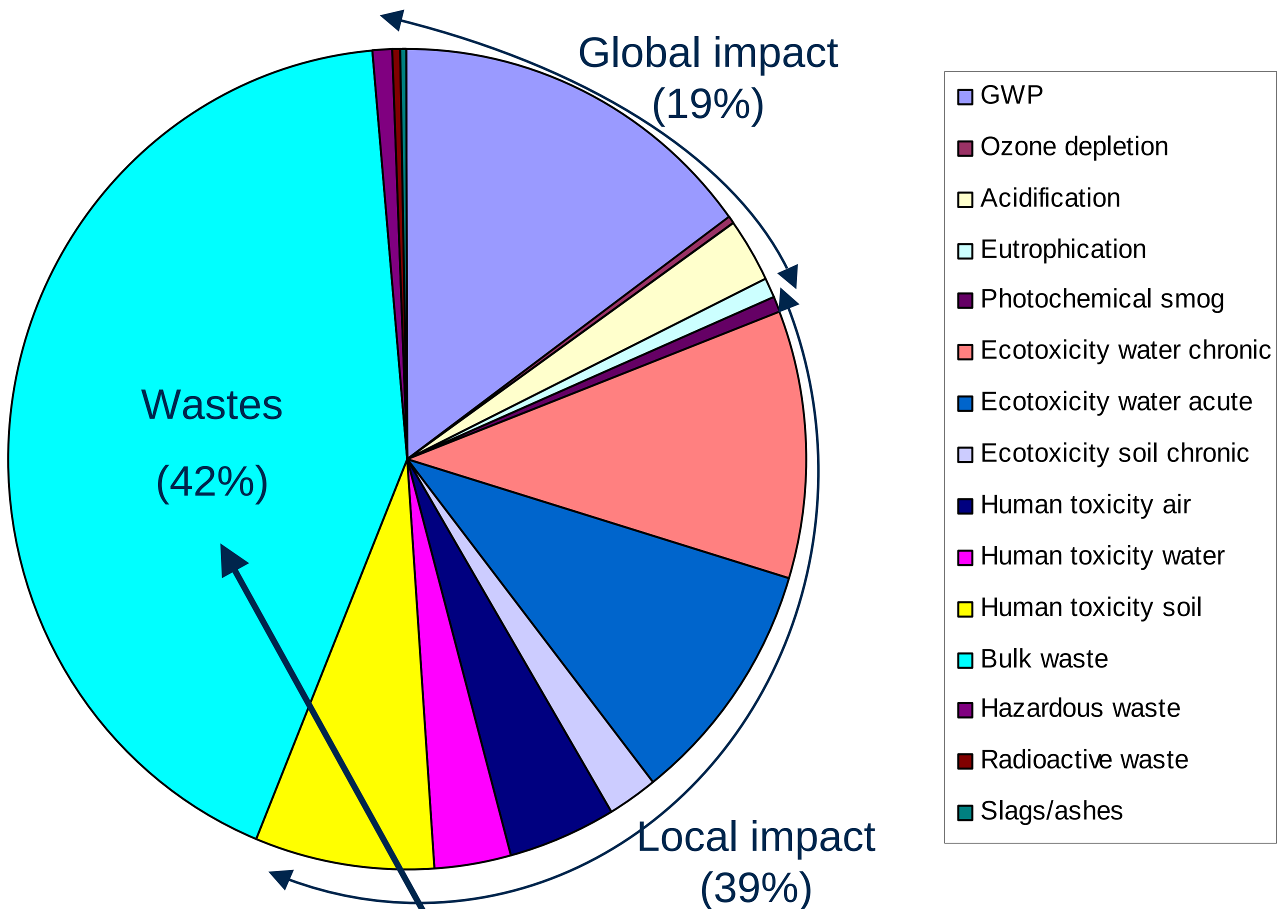
- Characterization factors for each emitted susbstance come from SimaPro databases (EDIP97).
- Characterization factors for diesel were calculated for the three main fractions (Gustafson et al., 1997) according to the EDIP methodology (Hauschild et al., 1998).

	% of diesel mass	EF_{soil}	EF_{water}	HTF_{soil}	HTF_{water}	HTF_{air}
	AROMATIC					
C_6- C_{10}	14	5.63E-01	1.39E00	3.05E-05	2.4E-02	2.52E00
C_{11}- C_{16}	**25**	5.80E-02	1.39E00	1.57E-06	2.67E00	5.02E00
C_{17}- C_{21}	0.03	4.63E-03	0.00E00	1.03E-07	1.59E01	NA
	ALIPHATIC					
C_6- C_{10}	1.3	1.85E-02	5.56E-01	3.05E-5	2.67E-03	5.02E-02
C_{11}- C_{16}	14	7.35E-05	5.56E-01	2.72E-07	1.35E01	1.12E00
C_{17}- C_{21}	**46**	1.47E-07	5.56E-01	1.42E-04	NA	NA

EF: Ecotoxicity Factor

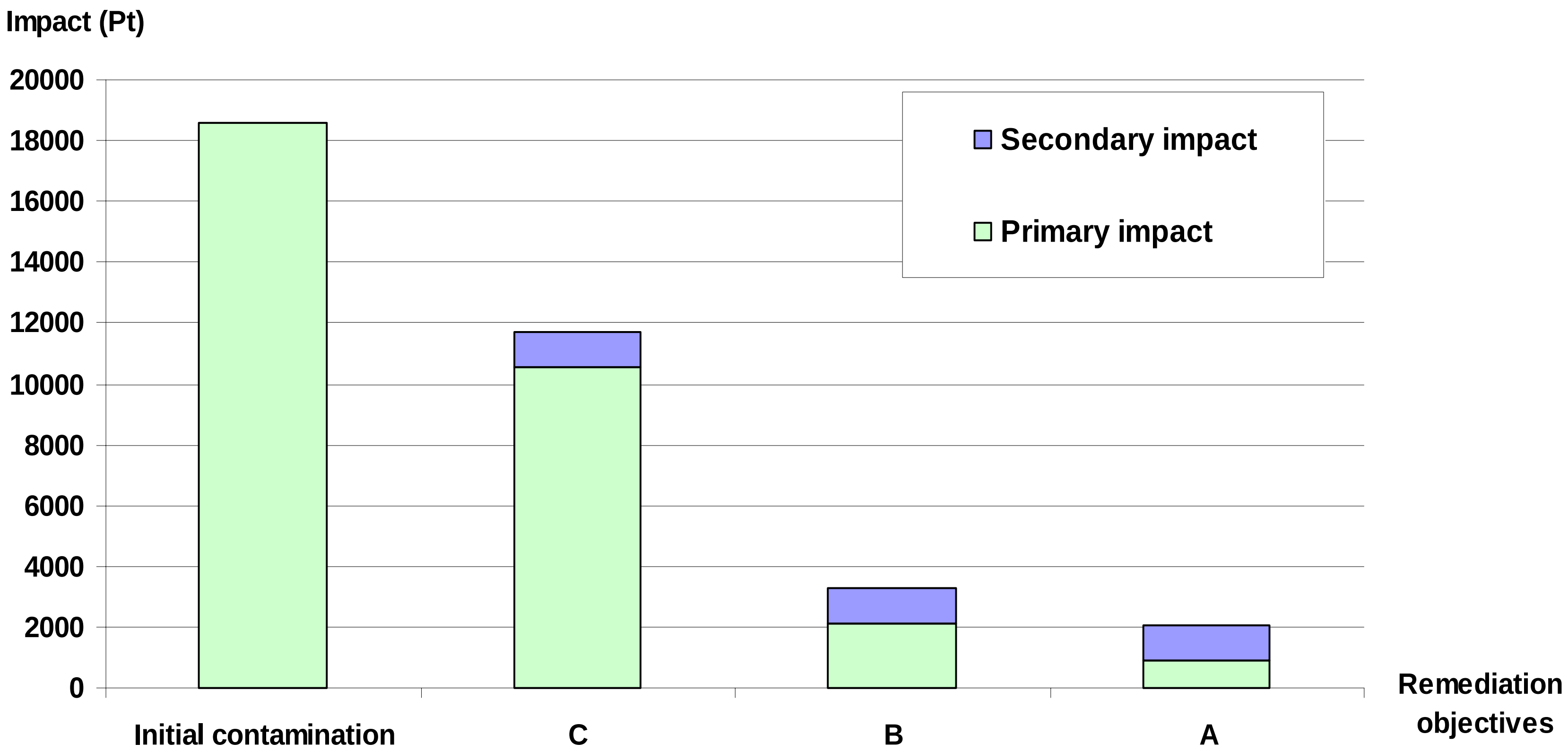
HTF : Human Toxicity Factor

6- Local impact is superior to global impact



The impact associated to the wastes category is generated by the asphalt and wood end-of-life (burial in landfills)

6 - Decontamination generates less impact than the initial contamination



- Treatment efficiency (criteria level reached) does not influence the level of secondary impact ;
- As lower levels of contamination are reached during decontamination (A and B generic data), the less significant the bioremediation's total impacts becomes.

6 - Decontamination generates less impact than the initial contamination

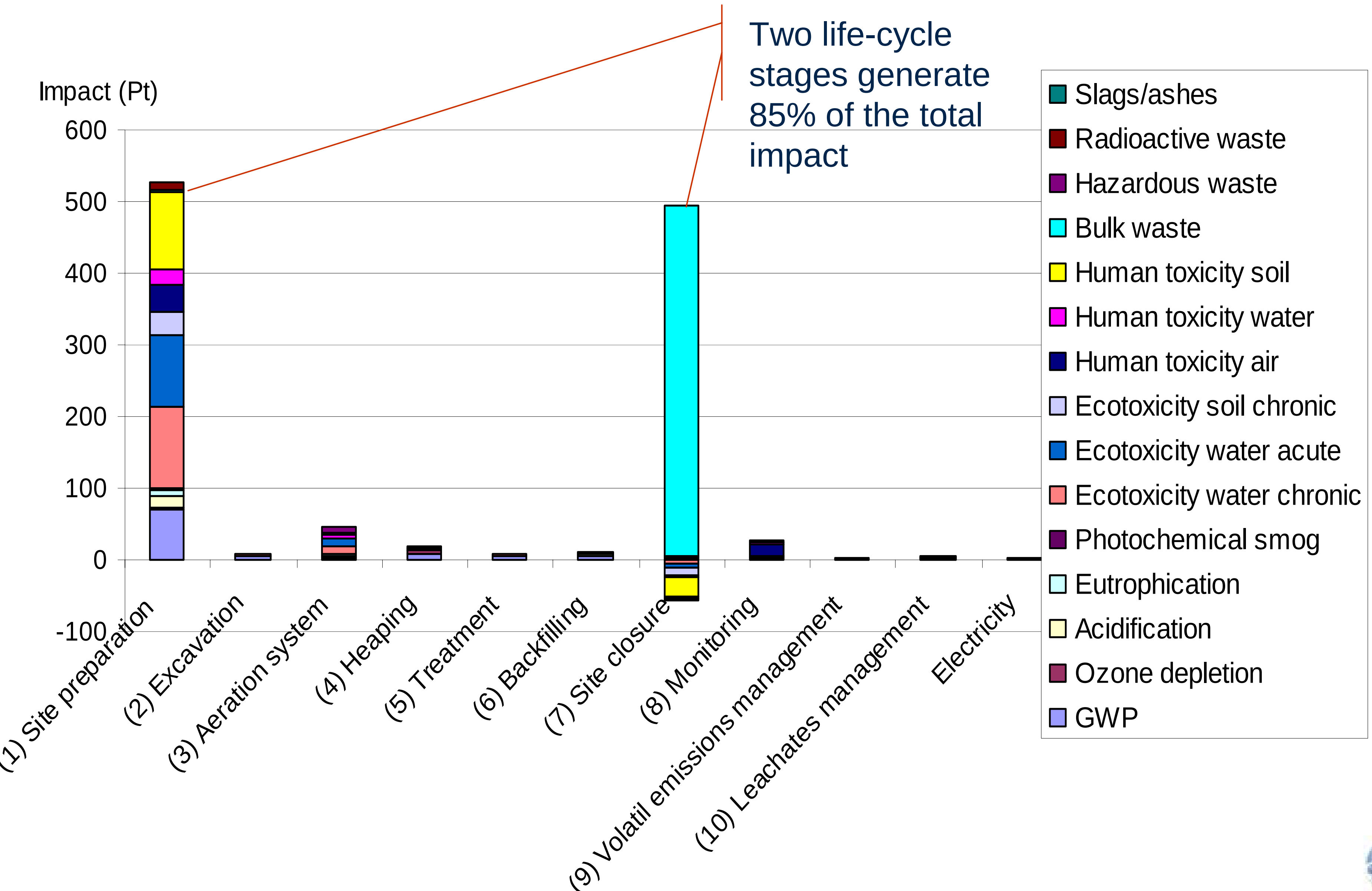
This LCA showed that the remediation that occurred in the late 90's has probably generated less impact than the contamination.

In a sustainable development perspective, this decontamination was necessary.

Total impact of bioremediation	<	Impact of the initial contamination

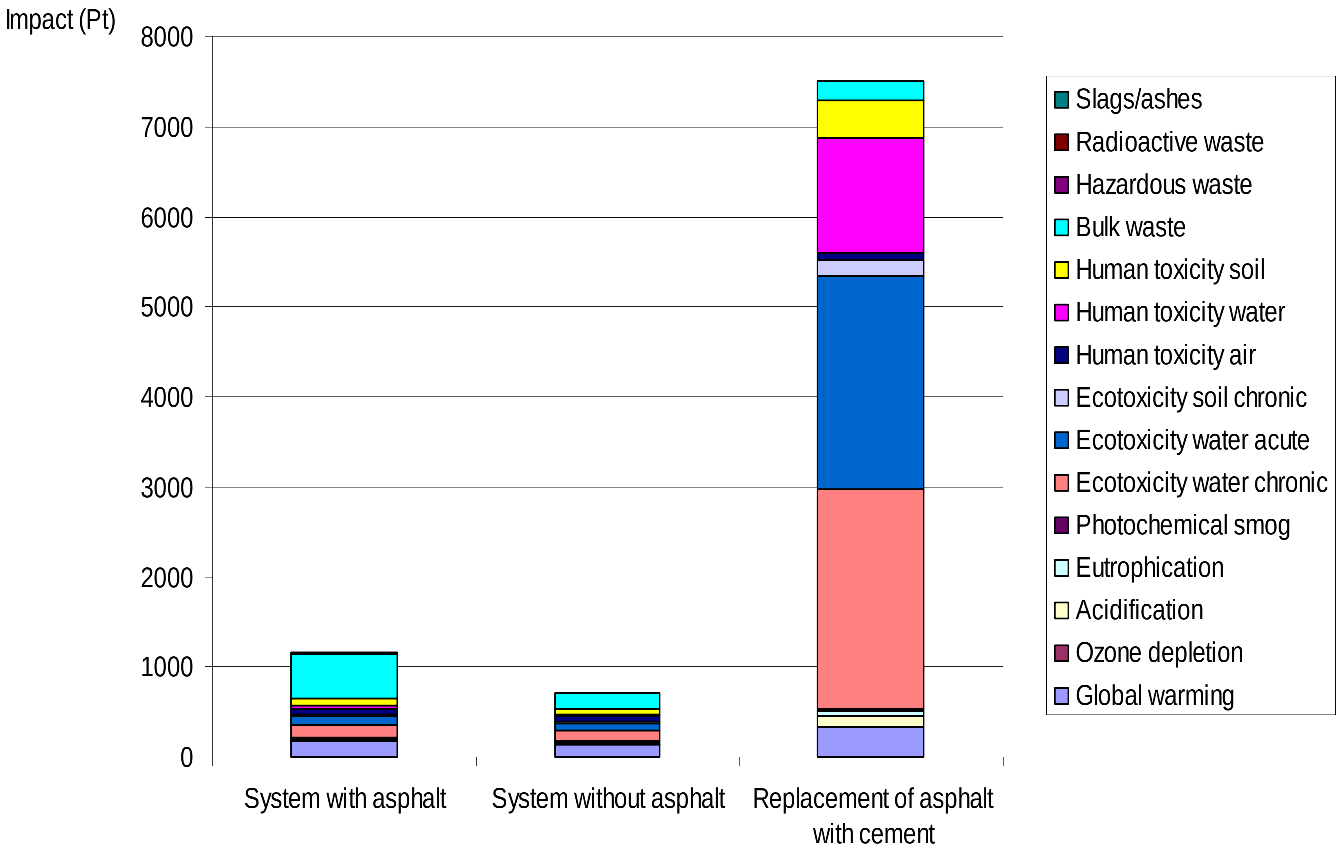
For initial contamination > 350 ppm

6- Site preparation and site closure are the main life cycle stages that generate environmental impact



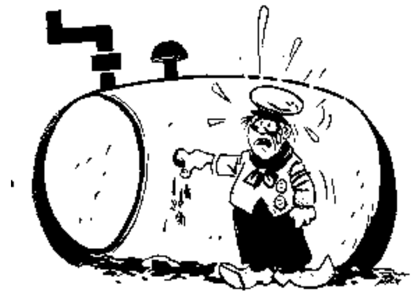
6- Replacement of asphalt with cement

Asphalt is a material input which generates a high impact (during its production and its end-of-life burial in a landfill).



Concrete paving does not represent a better environmental alternative to asphalt since its impact is higher than asphalt paving (Blomberg, 2000; Horvath et al., 1998).

6- Single-use treatment center or permanent facilities ?



Single-use treatment center

- Site preparation and closure
- Soils remain on site

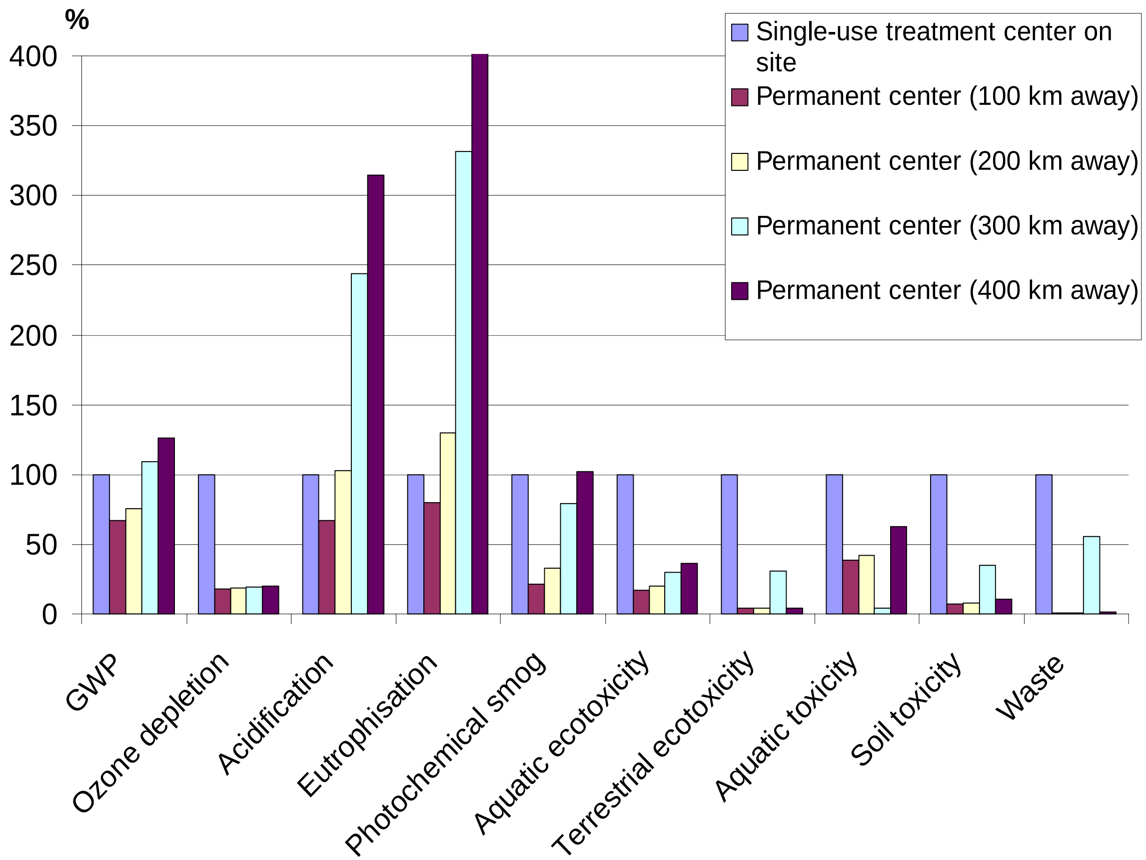
Comparative LCA

Permanent facilities

- Allocation of the impact of site preparation and site closure to the total quantity of soil treated during the center's operation time
- Transport of soils from the contaminated site to the permanent treatment center

6- Global impact increases if the permanent center is far away from the site

For a permanent treatment center treating 20,000 m^3 of soil / year during 10 years global impacts become superior to the ones of a single-use treatment when the distance to the contaminated site becomes greater than 200 km.



The environmental advantage of a permanent treatment center depends on its distance from the contaminated site.

7 - Conclusions

for decision makers

- To reduce the overall environmental impact, contaminated soil should be treated to achieve the lowest level of residual contaminants;
- Decontamination can generate more impact than the contamination itself when the initial contamination is below a certain limit value (350 ppm for this case study);
- Depending on the volume of contaminated soils treated each year, the duration of permanent installations and the contaminated sites' geographical location, permanent installations can be a very interesting alternative to reduce the environmental burden.

7 - Conclusions

LCA and contaminated soil management

The use of LCA proved to be useful for the assessment of site remediation but has also revealed several challenges :

- Over-estimation of the primary impact values obtained from the EDIP method:
  - many physical and chemical properties of the soil and the diesel were not taken into account during the characterisation factor calculations ;
  - no sorption phenomena were integrated ;
  - the model assumes a one-shot release of the contaminant ;
  - all diesel is considered available to produce ecotoxicologic and toxicologic effects ;
  - no site-specific considerations.

- Low data quality :The databases used were predominantly European; A significant proportion of the data taken from the databases is not well documented

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