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Chemical or natural?

Including LCA in social CBA comparing remediation alternatives of a dry cleaning case study

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Case study

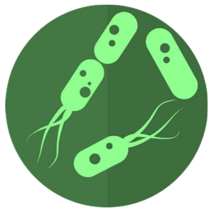
Contamination and remediation due to dry cleaning activities

- Contaminated with volatile chlorinated hydrocarbons
  - Tetrachlorethylene
- Two potential remediation alternatives

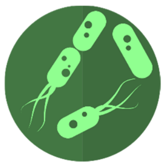
"***Chemical option***"

- Soil Vapour Extraction + In-Situ Chemical Oxidation
- Introducing hydrogen peroxide in the soil
- Potential impact on local residents

"Natural option"



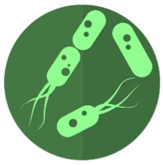
- Soil Vapour Extraction + stimulated biological degradation
- Stimulate the biodegradation with lactate



1. Prelimanary works and PID measuring
2. Excavation and pipe work
3. Pump and Treat for groundwater remediation
4. Soil vapor extraction
5. **In-situ chemical oxidization with hydrogen peroxide**
6. **Stimulated biological degradation with lactate**
7. Monitor of site and groundwater

Remediation alternatives

- Initial excavation
- Pump and Treat
- SVE
- ISCO
  - Introducing H_2O_2
  - Production of oxidant has an impact on the environment
  - Can inhibit microbial activity
- Limited extent of biological degradation



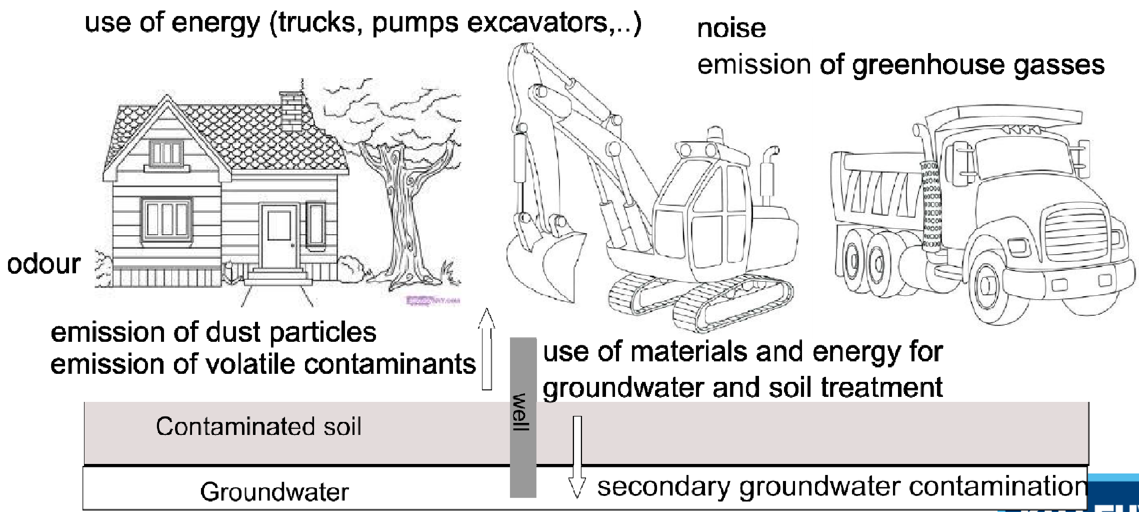
- Initial excavation
- Pump and Treat
- SVE
- ISCO with limited amount of wells
- Biological degradation
  - Introducing lactate
  - Enhances the biological activity

Methods

- Life cycle assessment (LCA)
  - Quantify environmental and health impacts of both remediation alternatives
- Social cost benefit analysis (CBA)
  - analyze the social profitability of both remediation alternatives.
  - Including all impacts to society: the direct and indirect financial costs and benefits as well as the health and environmental benefits and other relevant impacts
  - environmental impact in the CBA is based on the LCA results, using a monetization technique (Stepwise 2008) to translate the environmental impact into a monetary value.

Life cycle assessment

- LCA is used to calculate environmental impact of products and processes over their entire life cycle
- Environmental impact of soil remediation?



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Life cycle assessment

- LCA is used to calculate environmental impact of products and processes over their entire life cycle

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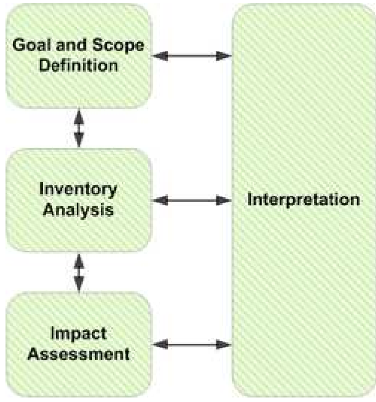
Life cycle assessment

4 essential steps

- Goal and scope definition (including functional unit)
- Life Cycle Inventory
  - Data collection
  - Database use
- Impact assessment
  - Midpoint indicators: according to used method
  - Endpoint indicator(s): aggregation
- Interpretation and communication



Software: SimaPro and Ecoinvent database

Life Cycle Inventory

Processes included:

- Occupation of the site
- Use of electricity, water, hydrogen peroxide (ISCO) and molasses
- Excavation and pipe work
  - Excavation
  - Foil to cover grounds after excavation
  - Transport of contaminated soil
  - Cleaning of contaminated soil
- Coil drilling all necessary wells
- Groundwater treatment during Pump and Treat
- Air treatment during SVE
- Transport of workers during work and monitoring

Cost Benefit Analysis

- Overall costs before during and after remediation
  - Soil inspection report
  - For example
    - Costs for preparation of site,
    - Cost of groundwater purification,
    - Costs of treatment and transport of contaminated soil, …
- Environmental and health costs and benefits
  - Cost of CO_2 emissions (and other air pollutants)
  - Costs of transport (emissions other than CO_2, congestion, …), noise and odour
  - Health benefits (30 years)

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Stepwise 2006

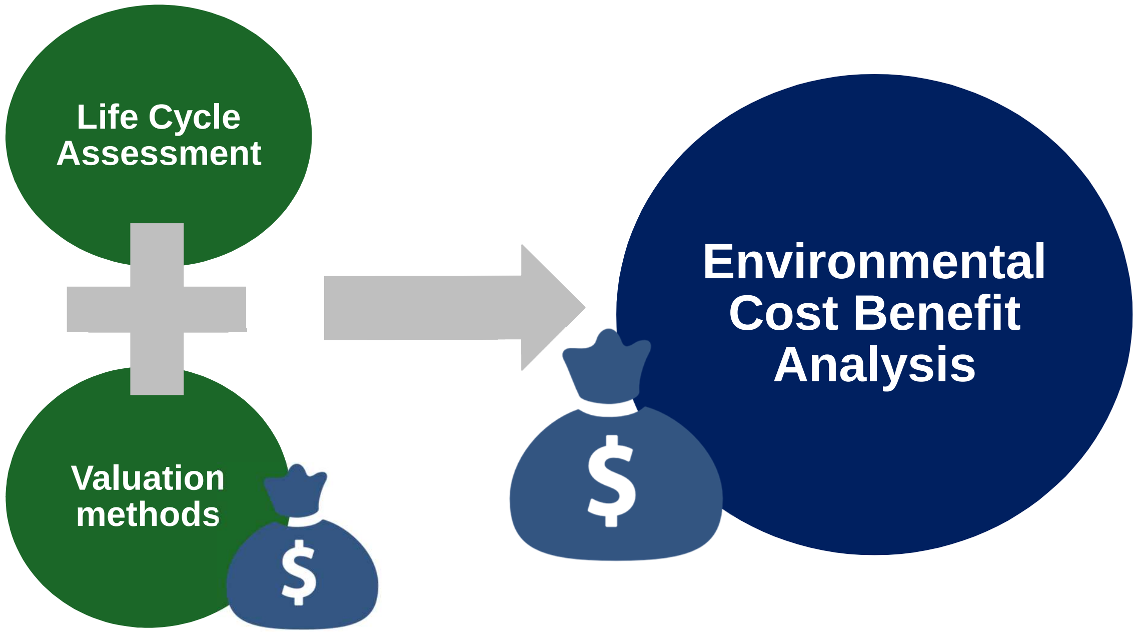
- monetization technique which can be fully implemented in the SimaPro software
- provides users with values on three overall safeguard subjects
  - Human well-being,
  - Biodiversity
  - Resource productivity

⇒ *linked to the three pillars of sustainability (people, planet, profit).*

- The initial calculation of the environmental impact is based on the LCIA (Life Cycle Inventory Analysis) method Ecoindicator99 and the results are expressed in
  - Quality Adjusted Life Years (QALY) for human well-being,
  - Biodiversity Adjusted Hectare Years (BAHY) for biodiversity a
  - euros for resource productivity.

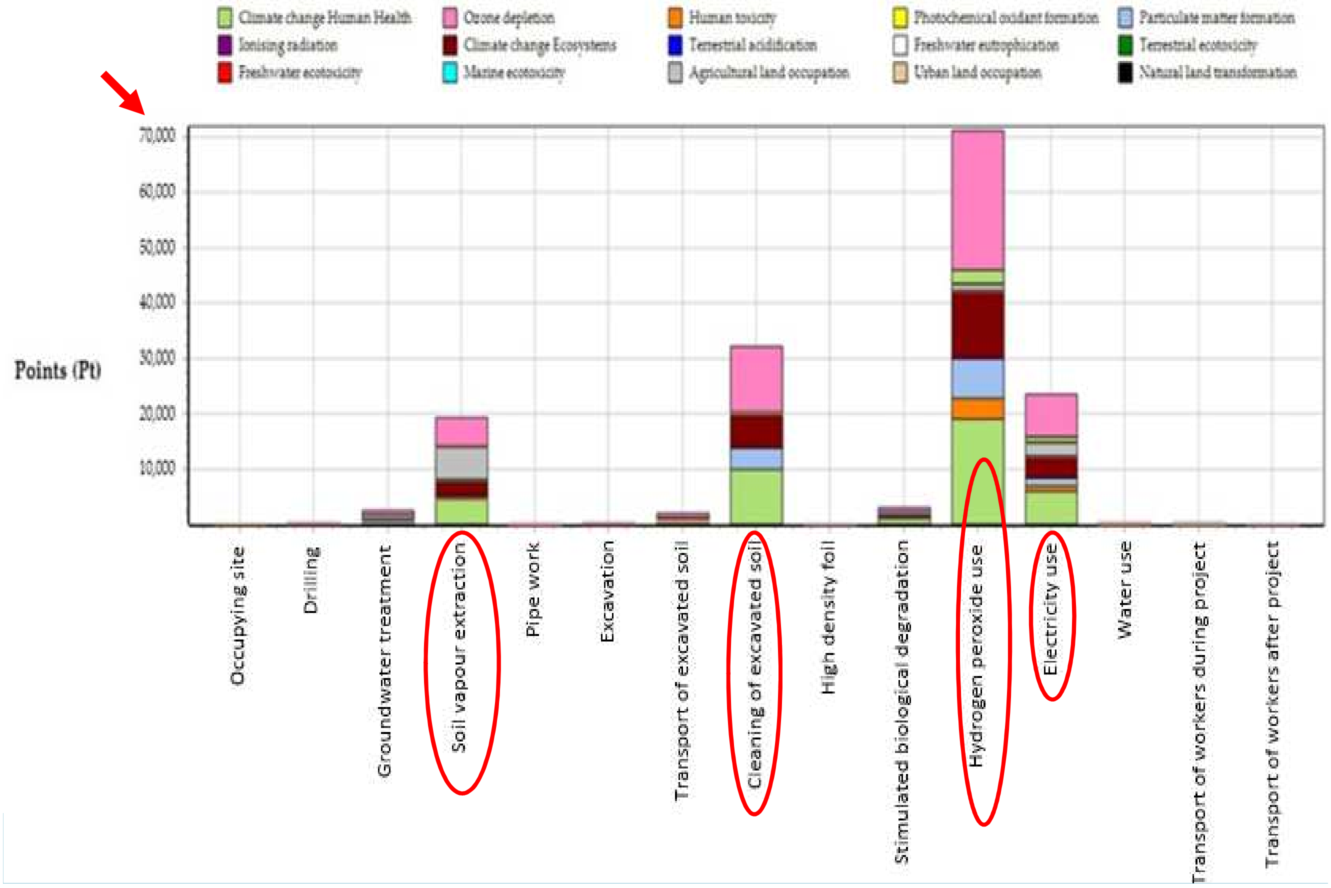
Weidema, B.P.,Wesnae, M., Hermansen, J., Kristensen, I., Halberg, N., 2008. Environmental Improvement Potentials of Meat and Dairy Products. JRC European Comission, Spain https://doi.org/10.2791/38863.

Results

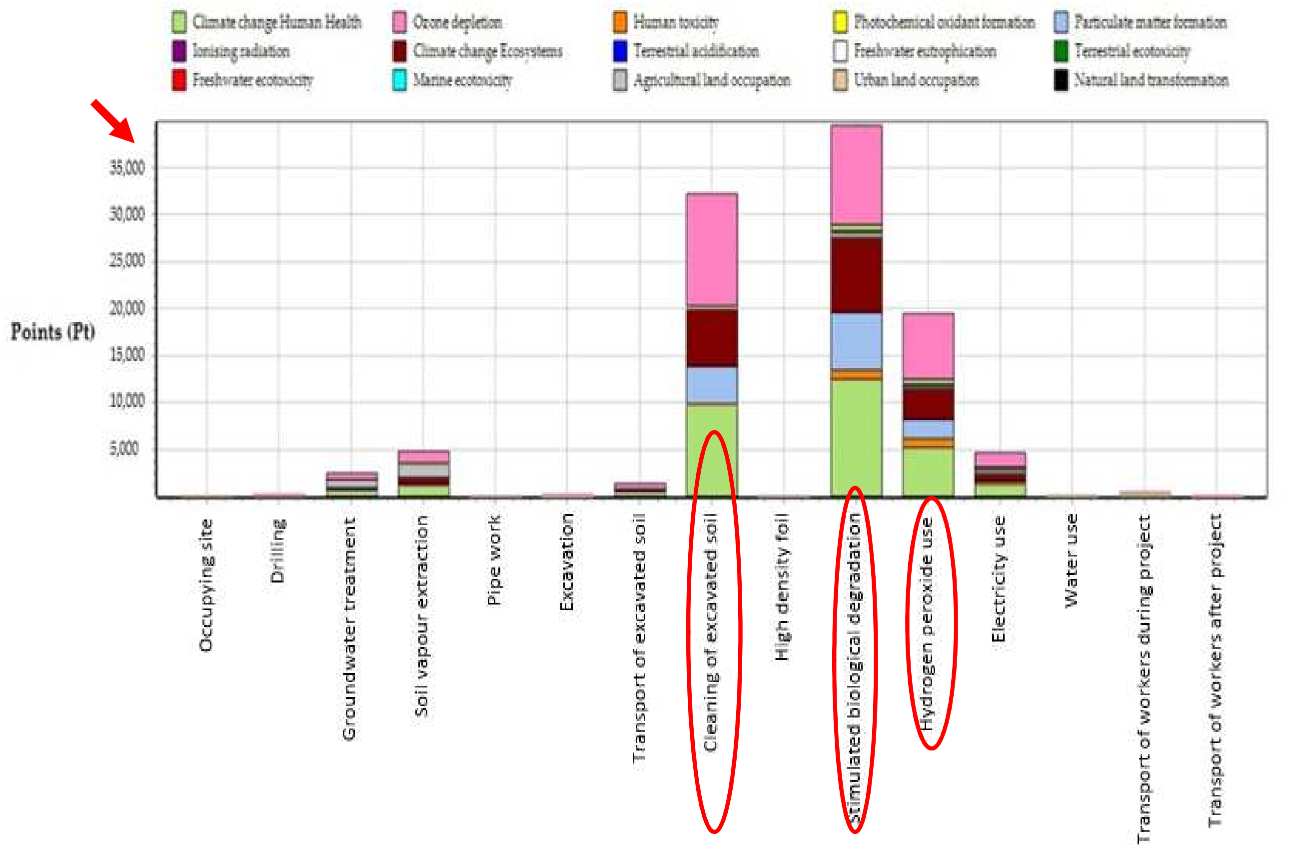


Products and processes	Input	"Chemical alternative"		"Natural alternative"	
		Amount	Unit	Amount	Unit
Site use	Occupation (urban)	2 987	m^2a	2 987	m^2a
Electricity use throughout project	Electricity (low voltage)	806 400	kWh	160 000	kWh
Water use throughout project	Water	9 216	m^3	2 400	m^3
Hydrogen peroxide use throughout project	Hydrogen peroxide (50%)	528	m^3	144	m^3
	Water	1 232	m^3	336	m^3
Excavation	Hydraulic digger	1 533	m^3	1 533	m^3
Transport excavated soil	Transport freight lorry	119 300	tkm	79 736	tkm
Cleaning excavated soil	Diesel	105 000	l	105 000	l
	Electricity	11 400	kWh	11 400	kWh
Foil to cover after excavation	Polyethylene granulate	663	kg	663	kg
	Extrusion to plastic film	663	kg	663	kg
Pipe work	Hydraulic digger	2 765	m^3	875	m^3
Pump and Treat	Activated carbon	2 000	kg	2 000	kg
Soil vapor extraction	Activated carbon	16 000	kg	4 000	kg
Coil drilling throughout the project	Diesel	7 235	kWh	7 996	kWh
Stimulated biological degradation	Water	228	m^3	3 000	m^3
	Organic carbon source (molasses)	456	m^3	6 000	m^3
Transport of workers during project	Transport passenger car	10 890	km	17 010	km
	Transport bus	5 130	perskm	6 660	perskm

LCA ‘chemical’ alternative



LCA ‘natural’ alternative



Private costs (EUR)

Activity	"Chemical alternative"	"Natural alternative"
Preparatory works	245 950	215 700
Electricity use throughout project	217 780	43 210
Water use throughout project	51 850	13 500
Hydrogen peroxide use throughout project	104 930	28 620
Excavation	244 030	244 030
Pipe work	98 540	63 240
Pump and Treat	45 980	45 980
Soil vapour extraction	165 480	113 210
In-situ chemical oxidization	558 200	155 900
Stimulated biological degradation	16 770	1 652 300
Environmental guidance	164 580	249 339
Unforeseen expenses	185 870	281 590
Total	2 099 960	3 106 620

Estimated discounted (3% discount rate) private costs in EUR (2017) of the chemical and natural remediation alternatives

Monetized environmental costs (EUR)

Activity	Stepwise including biogenic C		Stepwise excluding biogenic C	
	"Chemical alternative"	"Natural alternative"	"Chemical alternative"	"Natural alternative"
Site use	371	371	371	371
Electricity use throughout project	32 385	6 426	32 552	6 459
Water use throughout project	670	175	672	175
Hydrogen peroxide use throughout project	203 875	55 602	203 007	55 366
Excavation	484	484	488	488
Transport excavated soil	4 090	2 734	4 093	2 736
Cleaning excavated soil	66 833	66 833	66 862	66 862
Foil to cover after excavation	0.38	0.38	0.39	0.38
Pipe work	425	24	425	24
Pump and Treat	2 520	2 520	3 094	3 094
Soil vapour extraction	20 156	5 039	24 754	6 188
Coil drilling throughout the project	695	768	695	768
Stimulated biological degradation	-3 764	-49 530	6 421	84 489
Transport of workers during project	733	1 111	734	1 113
Total	329 474	92 556	344 168	228 133

Other extrenal costs and benefits (EUR)

costs of transport:

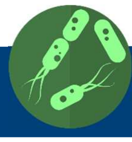
- cost of congestion,
- cost of noise,
- cost of possible traffic causalities
- cost of infrastructural damage due to additional traffic

benefits: avoided impact of a specific substance on human health, ecosystems, buildings and machines, resources and well-being

External costs	“Chemical alternative”	“Natural alternative”
Transport excavated soil	2 210	1 500
Transport of workers	5 740	8 250
Noise of excavation and coil drilling	154 090	155 020
External benefits	“Chemical alternative”	“Natural alternative”
Upper bound benefits per year	49 530	49 530
Lower bound benefits per year	23 360	23 360

Costs and benefits of external impacts in EUR (2015) of the chemical and natural remediation alternatives

Externalities and health benefit

	Activity		
Environmental impact	Stepwise 2006 excl biogenic C	344,168	228,133
	Stepwise 2006 incl biogenic C	329,474	92,556
Health benefit	Reduced health risk (per year)	49,530	49,530
Externalities	External impact of transport soil	2210	1500
	External impact of transport workers	5740	8250
	External impact noise	154,090	155,020

Net Present Value		
NPV of Baseline scenario	−1,889,390	−2,765,110
NPV including timeline benefits to 50 years	−1,627,490	−2,503,210
NPV including timeline benefits to 100 years	−1,376,720	−2,252,440
NPV including lower bound benefit valuation	−2,331,980	−3,207,700
NPV including discount rate of 2%	−1,744,320	−2,656,370
NPV including discount rate of 4%	−2,001,500	−2,842,180
NPV including reduction of private costs with 20%	−1,517,650	−2,201,930
NPV including reduction of private costs with 30%	−1,331,780	−1,920,350
NPV including reduction of private costs with 40%	−1,145,910	−1,638,760
NPV including environmental impact including biogenic carbon	−1,872,140	−2,610,941
NPV including non-use benefit of groundwater	−1,833,410	−2,709,120

Conclusions

- Natural attenuation has the lowest environmental impact
- But the lower environmental impact does not cover the large increase in private costs
- In this case study both alternatives are NOT socially profitable from a scientific point of view

➢ The effect of waiting and risk averse behaviour
➢ The effect of potential substitutes
➢ The impact of biogenic carbon

sustainability

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Article

Chemical or Natural? Including LCA in Social CBA to Compare Remediation Alternatives for a Dry-Cleaning Facility

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Abstract: The choice between remediation alternatives for contaminated sites is complicated by different elements, e.g., the occurrence of multiple contaminants, the extent of the contamination, or the urban location, complicate the choice between remediation alternatives. This paper addresses this challenging choice by analyzing a case study of an extensive soil and groundwater contamination by a dry-cleaning company. For remediating this site, two alternatives were proposed. The first remediation alternative combines several techniques with in-situ chemical oxidization being the most important one. Due to the potential negative impact of this alternative on local residents a second remediation alternative was drawn up, in which the focus lies on the use of stimulated biological degradation. A Life Cycle Assessment (LCA) was performed on both alternatives and showed that the second alternative had a lower environmental impact. The inclusion of monetized LCA results in the calculation of a social Cost-Benefit Analysis (CBA) provided a more extensive view of the secondary environmental costs and benefits of the remediation alternatives. The results of the social CBA allow to conclude that both alternatives are not socially desirable, the chemical alternative however is socially less disadvantageous than the more natural remediation alternative.

Keywords: Life Cycle Assessment; social Cost-Benefit Analysis; dry cleaning; soil remediation; groundwater remediation; monetization

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