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HOW TO CONSIDER SOIL ECOSYSTEM SERVICES IN LCA

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OUTLINE

1. Background: soil ecosystem services

2. Case study 1: Agricoltural soil

3. Case study 2: Urban soil

4. Conclusions and Perspectives

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BACKGROUND

› Defining soil ecosystem services

SOIL ECOSYSTEM SERVICES

- to preserve soil ecosystem services we need to maintain soil ecosystem health in terms of suitability for use (i.e. the provision of ecosystem services)
- suitability for use needs to be addressed through sustainable management practices restoring and maintaining soil ecosystem health
- LCIA = impacts on ecosystem services in terms of e.g. soil quality, carbon sequestering, fertility/biomass yields

SOIL ECOSYSTEM SERVICES

(A) Soil fertility, the capacity to provide nutrients and biomass

(B) Adaptability and resilience, the capacity to adapt, or the fragility upon disturbance and changes in land use

(C) Buffer and reaction function, storage and buffering of water, gasses, chemicals, energy, cation exchange capacity, breakdown and synthesis of chemicals (detoxification, humification)

(D) Disease suppression and pest resistance, the natural capacity to prevent and suppress pests and diseases

(E) Habitat and biodiversity, genetic, functional and structural

(F) Physical support; supportive capacity, historical archive, land-scape identity.

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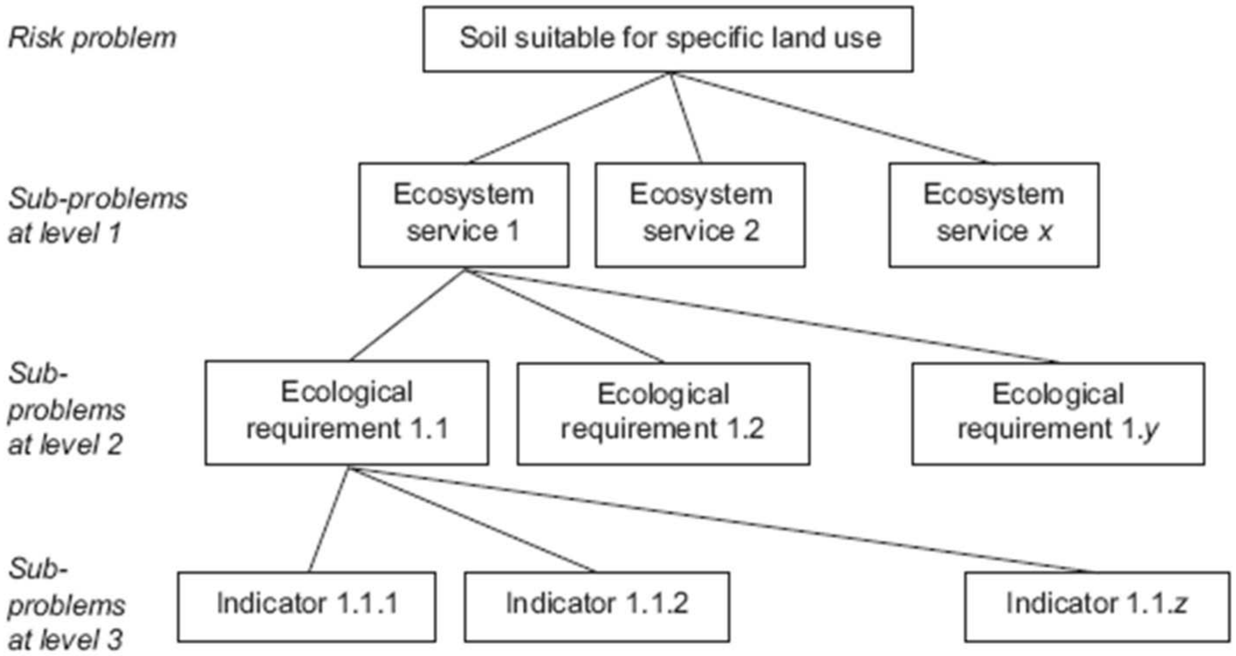
PROBLEM TREE CONFIGURATION FOR SOIL ECOSYSTEM HEALTH



Thomsen, M., et al., Soil ecosystem health and services – Evaluation of ecological indicators susceptible to chemical stressors. Ecol. Indicat. (2011), doi:10.1016/j.ecolind.2011.05.012

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SOIL HEALTH INDICATORS

Sub-problems at level 1: ecosystem service	Sub-problems at level 2: ecological requirements	Sub-problems at level 3: susceptible ecological indicators	
Soil fertility	General biodiversity aspects	1	Biodiversity indices
	Microbial aspects	2	Arginine deaminase activity
		3	Carbon sources utilization diversity
		4	Cellulase activity
		5	Microbial biomass and activity
		6	Mycorrhizal infestation
		7	Nitrification
		8	Phosphatase activity
		9	Soil respiration
		10	Sulphur oxidation
		11	Urease activity
	Plant aspects	12	Dicotyledons biomass (fodder quality)
		13	N content (fodder quality)
		14	Litter standing crop
		15	Root density
		16	Root turnover
		17	Vegetation biomass
		18	Vegetation standing crop
	Fauna aspects	19	Anecic earthworms
		20	Ants
		21	Cattle meat quality
		22	Collembola
		23	Earthworm community structure
		24	Earthworms
		25	Epigeic earthworms
		26	Hoverflies, other dipterans, beetles
		27	Isopods
		28	Millipedes
		29	Mites
		30	Native bees
		31	Nematode community composition
		32	Nematodes
		33	Pollinators
		34	Protozoa
		35	Slugs, snails, beetles
		36	Springtails
		37	Springtails, mites
	Physical/chemical aspects	38	Ionic strength
		39	Loss on ignition
		40	Soil aggregates
		41	Soil bulk density

LAND USE SCENARIOS

› Systems

1) agricultural land use
2) urban top-soil within the build-up area

› Sustainability goals

1) reversal of the decline in soil organic matter and improving soil quality within agro-ecosystems

2) healthy and non-polluted soils in recreational parks and playgrounds

AGRICULTURAL LAND USE SCENARIO

- Impacts on soil ecosystem health and services
- Present trends for cultivated soils
  - aromaticity increasing
  - carbon content decreasing
  - biological activity decreasing
  - water holding capacity decreasing
  - etc. etc.
  - yields have stopped increasing upon increased use of pesticides

- Sustainability goal
  - reversal of the decline in soil organic matter within agro-ecosystems
  - by returning high quality organic matter, minerals and nutrients to the soils

WHAT WE DO NOT MEASURE WE CAN’T MANAGE

- For many years
  - our focus was on monitoring emissions and negative impacts on the climate, environment and human health
- Then we started also to
  - put focus on estimating avoided impacts by reduced emissions
- Let´s imagine that we already started to measure
  - the performance of functional units as part of ecoindustrial networks delivering e.g.net negative or zero emissions
  - intelligent resource exchange and management systems beneficial to those natural environments that provide ecosystem services sustaining human-wellbeing

SOIL NATURAL CAPITAL

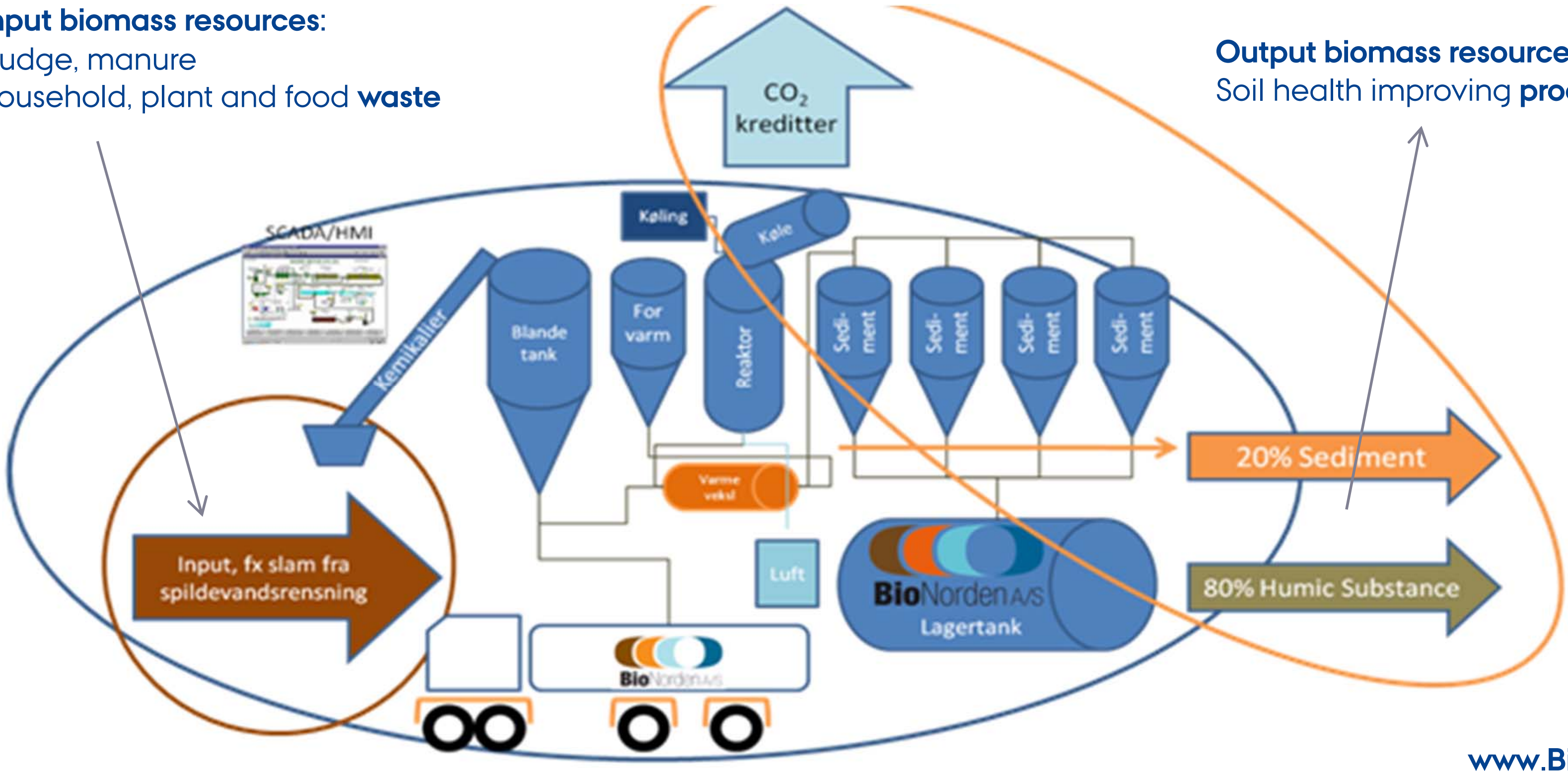
Soil Natural Capital	
MASS	
Solid	Inorganic material: i) Mineral stock and ii) Nutrient stock
	Organic material: i) OM/Carbon stock and ii) Organisms
Liquid	Soil water content
Gas	Soil air
ENERGY	
Thermal Energy	Soil temperature
Biomass Energy	Soil biomass
ORGANISATION	
Physico-chemical structure	Soil physico-chemical organisation, soil structure
Biotic structure	Biological population organisation, food webs and biodiversity
Spatio-temporal structure	Connectivity, patches and gradients

Defined as "the stocks of mass, energy and their organisation (entropy) within soil" (Robinson et al., 2009)

ECOINDUSTRIAL RESOURCE MANAGEMENT SYSTEMS AND TECHNOLOGIES

Input biomass resources:
sludge, manure
household, plant and food **waste**

Output biomass resource:
Soil health improving **product**



www.BioNorden.dk

CASE STUDY 1

› Agricultural soil

1. SLUDGE VERSUS BIOCORRECTED AMENDMENT

› Sewage sludge vs. biocorrected sludge amendment
› Quality of the two biomass resources

[mg/kg dm]	Sludge	BioC-HS	Diff	change [%]
DM (%)	25	8	17	69
Total P	12,300	11,000	1,300	11
Total N	38,000	26,000	12,000	32
Pb	56	2	54	96
Cd	2	0	1	79
Zn	580	37	543	94
Ni	22	14	8	38
Cr	30	1	29	96
Hg	0.5	0.1	0.4	80

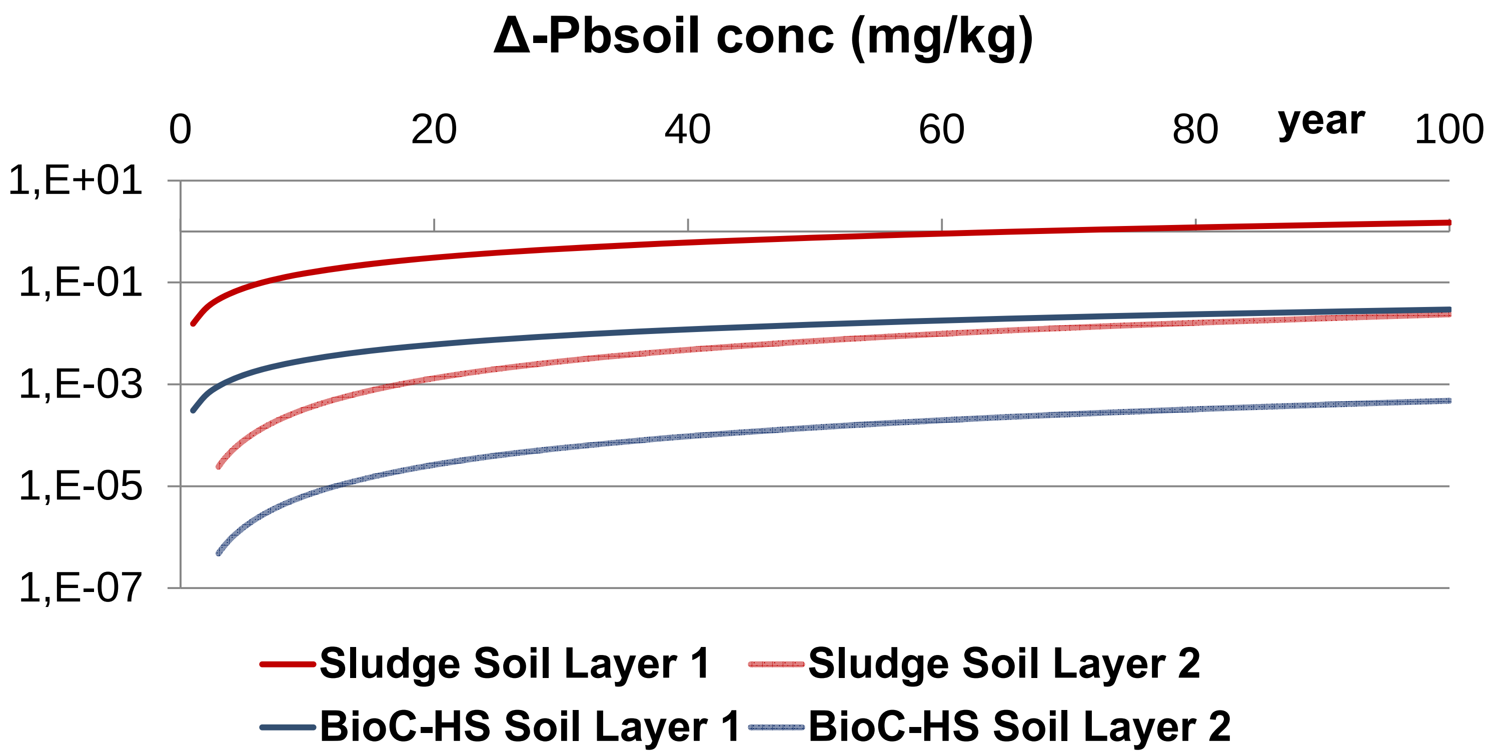
2. REDUCING CHEMICAL STRESS

Agricultural fertilizer scenarios*

[mg/ha]	Sludge from WWTP	BioC-HS	Diff	change [%]
dm [%]	24.5	7.51		69.3
tot-P	24600000	11000000	-13600000	-55.3
tot-N	76000000	26000000	-50000000	-65.8
Pb	111400	2200	-109200	-98.0
Cd	3100	330	-2770	-89.4
Zn	1160000	36700	-1123300	-96.8
Ni	44200	13800	-30400	-68.8
Cr	60600	1300	-59300	-97.9
Hg	1000	50	-950	-95.0
LAS	600000	530000	-70000	-11.7
PAH SUM MF	2600	320	-2280	-87.7
NPE	2600	1100	-1500	-57.7
DEHP	98000	1600	-96400	-98.4

* inorganic fertilizer excluded

3. CUMULATIVE INCREASE IN METAL CONTENT



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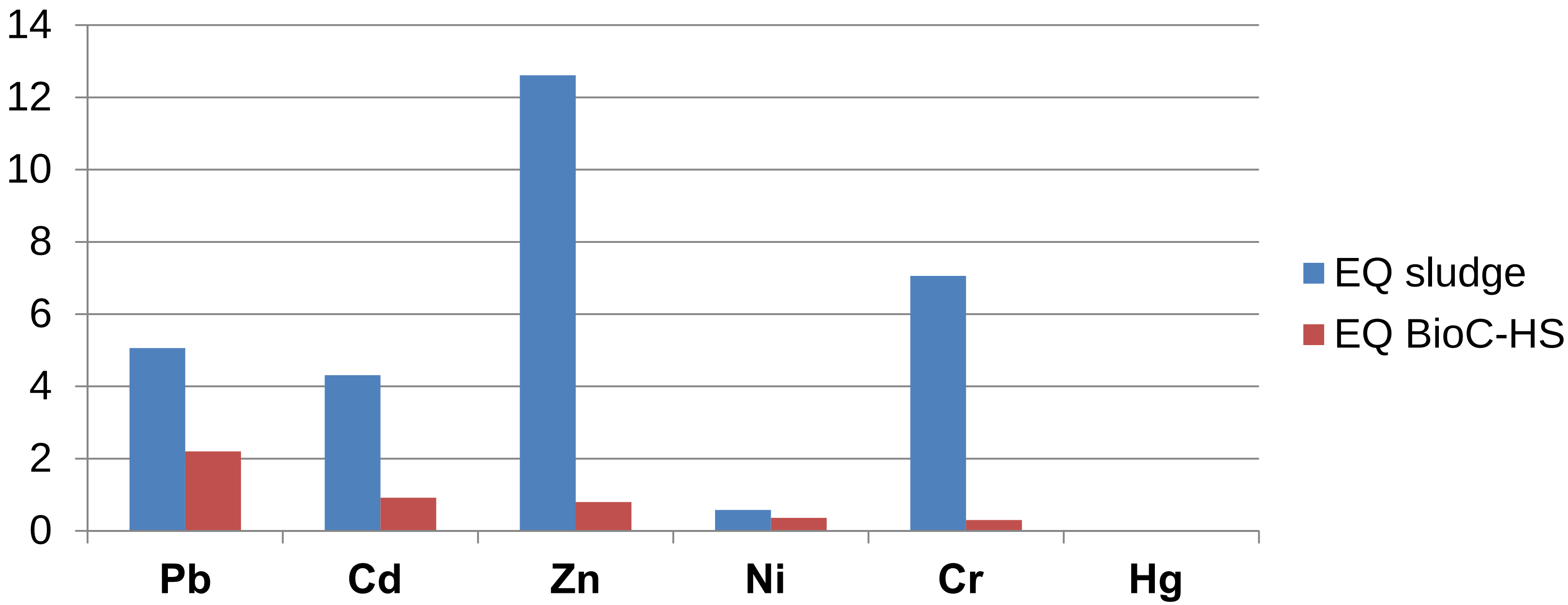
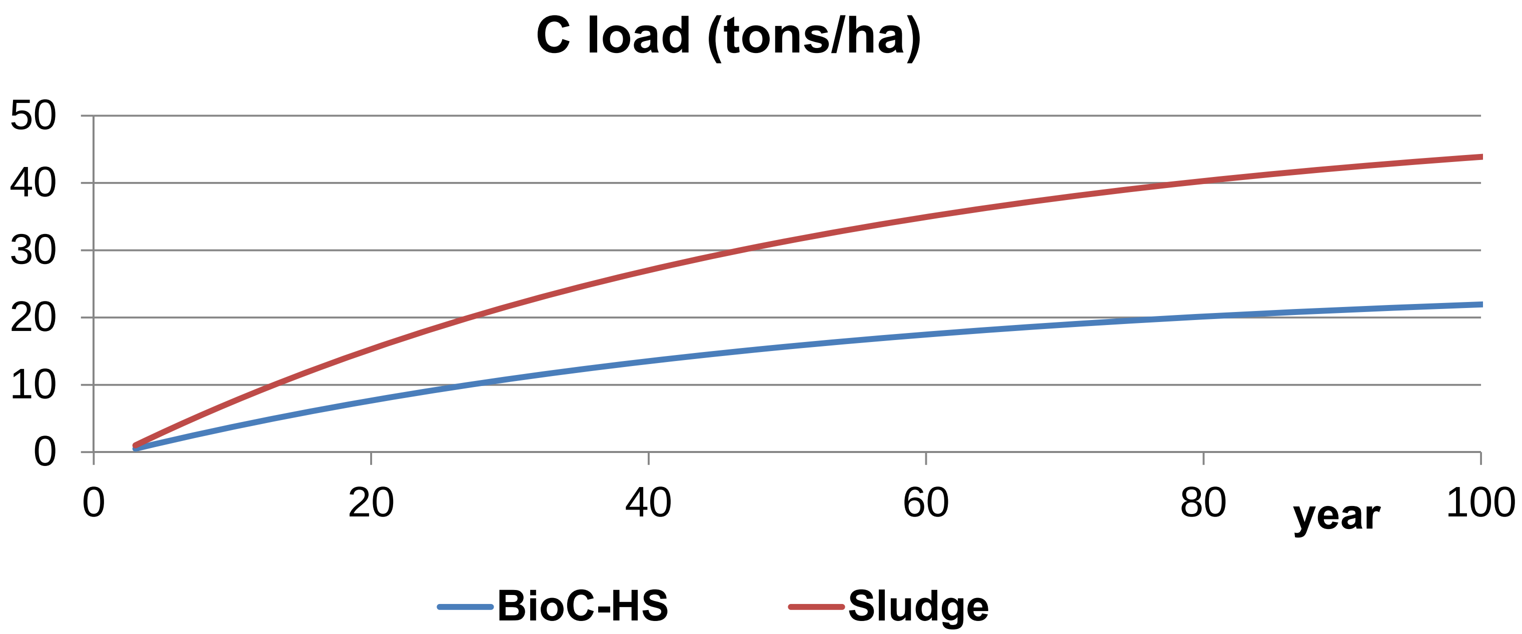
4. FERTILIZER ECOTOXICOLOGICAL RQ



For lead the Ecotoxicological RQ at estimated concentration levels in 2112 scenario would be Sludge = 0,14 and BioC-HS = 0,02.
"Margin of safety" Sludge = factor 7 and BioC-HS = factor 42.

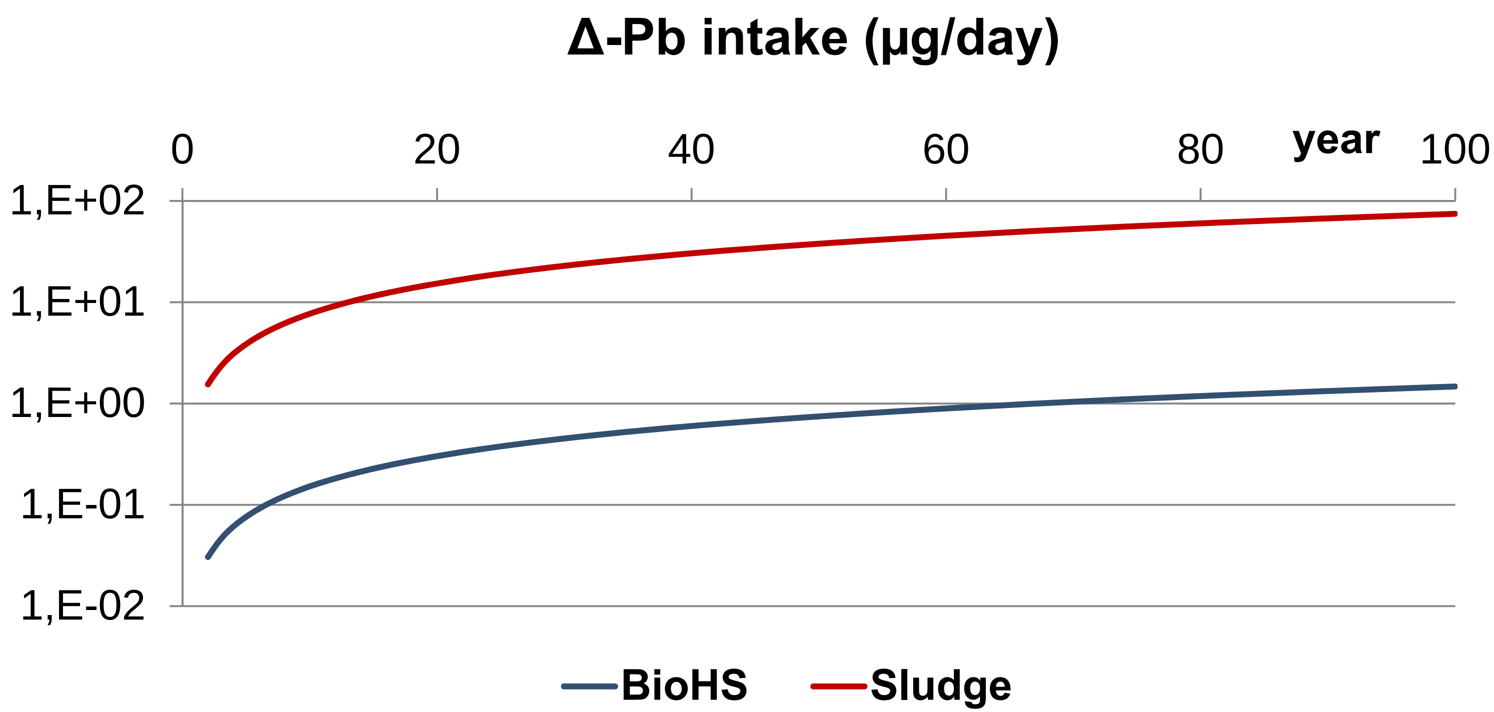
5. ACCUMULATED INCREASE IN TOP-SOIL ORGANIC CARBON



Based on the assumption of 0.14 percent of the organic carbon added to cultivated soils remaining after 100 years

6. POTENTIAL HUMAN INTAKE

Human exposure via soil, farmers workplace



7. CONCLUSIONS (AGRICULTURAL SOIL)

- BioC-HS increases biological activity in top soils as well as fertility (biomass production potentials/yields)

- Difficult to quantify due to complexity of soil ecosystems
- Monitoring, Verification and Reporting

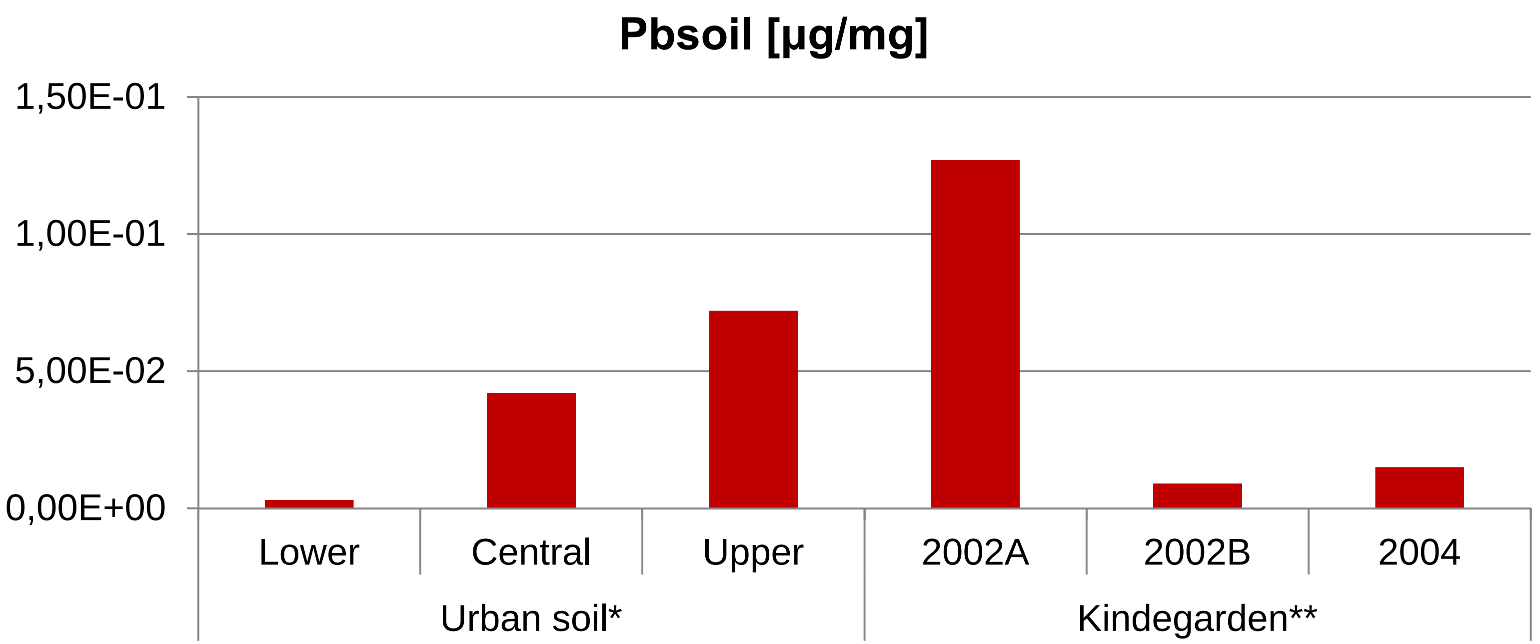
- Positive impacts on soil ecosystem health and services
- restoring the natural biogeochemical cycles

CASE STUDY 2

›Urban soil

1. Pb IN URBAN TOP-SOIL

City soil background concentrations vs. Kindergarden



A, before intervention; B, after intervention (topsoil removal)
*Pizzol et al. 2010; ** DEPA, nielsen et al. 2010

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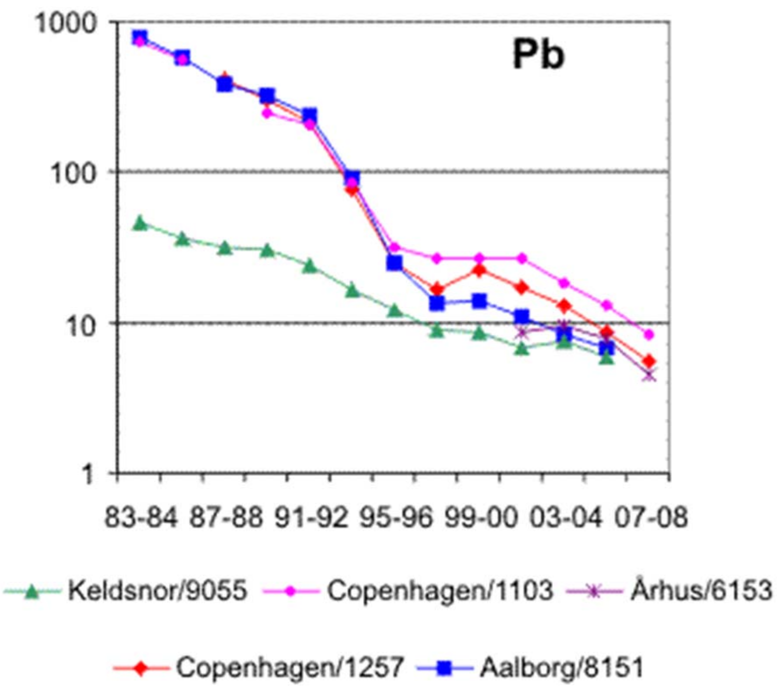
2. SOURCES OF Pb EMISSIONS TO SOIL

Air emissions (DK)

Source (2003)	Quantity (t)
Steel Reclamation	0.51
Foundry	0.1 – 0.3
Waste incineration	**1.2 – 3.7**
Coal	0.2 – 0.3
Bio-fuels	0.1 – 0.2
Others	0.2 – 0.7



3. HOW TO REDUCE Pb EXPOSURE?

AIR POLLUTION CONTROL DEVICES (APCD)

REPLACEMENT OF CONTAMINATED SOIL e.g. kindegardens (DEPA, 2003, 2008)

↔

ACTUAL SOURCES

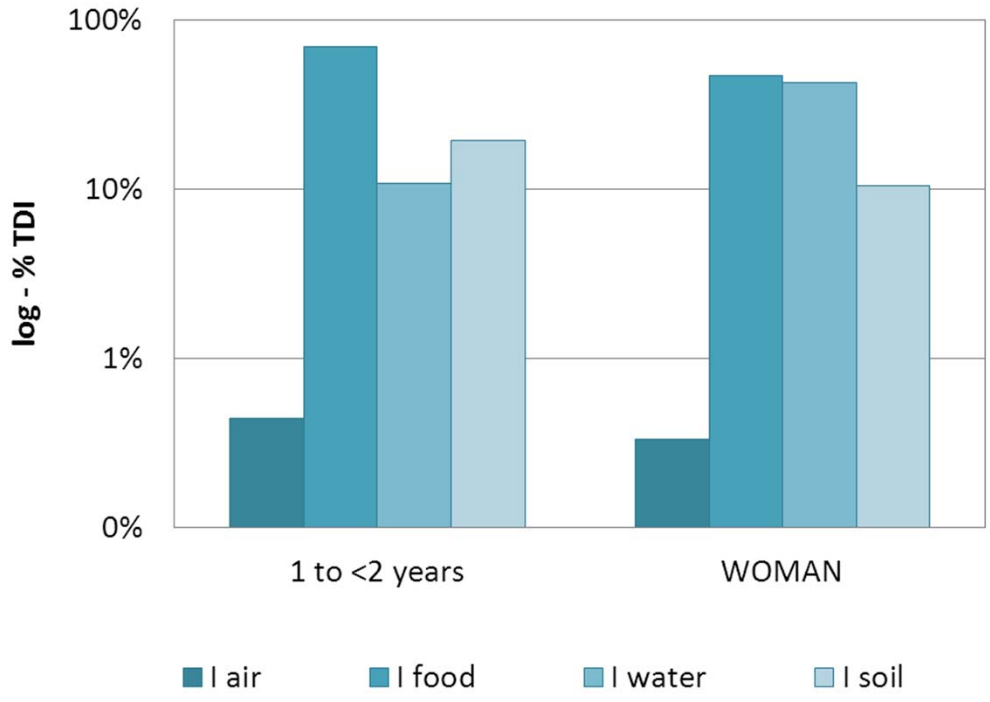
HISTORICAL CONTAMINATION

4. SIGNIFICANT EXPOSURE PATHWAYS

APCD vs. SOIL REMEDIATION - DIFFERENCES

› Population under exposure

› Main exposure pathway (air + soil vs soil only)



5. ECONOMIC VALUATION OF SOIL ECOSYSTEM SERVICES

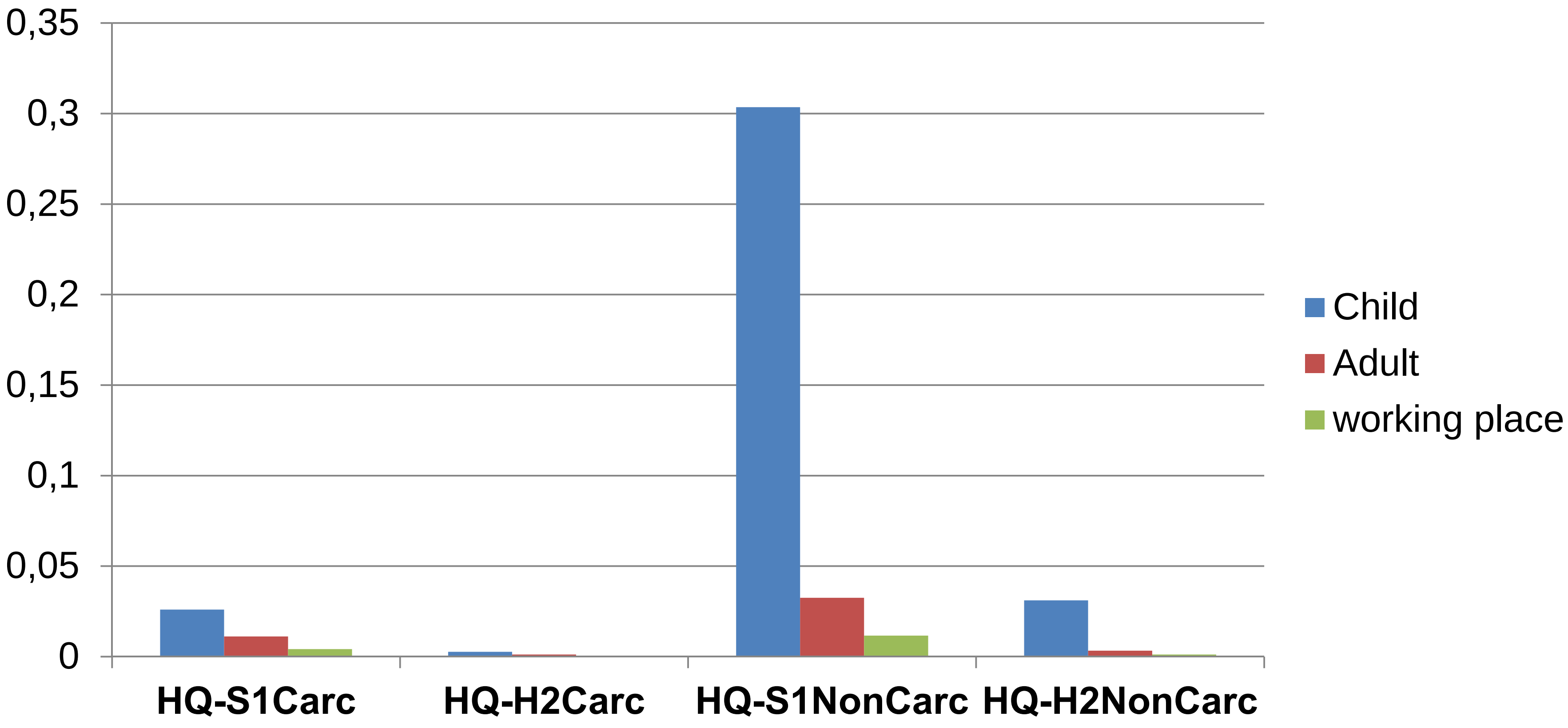
› In terms of avoided external costs
› Based on cost of Pb neurodevelopment

Pb External Cost	APCD	Soil Remediation
€ / kg	€ 35	€ 4,434
€	€ 33,971	€ 44,337

Pizzol et al. (Unpublished results)

› total cost have same magnitude
› differences in cost per kg

6. HUMAN HEALTH HQS



7. CONCLUSIONS (URBAN SOIL)

- Emission – accumulation in soil – exposure - impact
- Soil ecosystem services in monetary value
- Actual vs. historical sources: human exposure from kindegarden exceed the contribution from indirect exposure from waste incineration
- Intelligent ressource management systems may contribute to soil health restoration and lowering of background exposure

FINAL PERSPECTIVES

- Soil ecosystem services in LC thinking perspective

- Extended system boundaries - Ecoindustrial systems

- LCIA based on ecosystem health improving resource flows
- Rebalancing the biogeochemical N, P, C cycle by intelligent circular ressource flows
- End of waste by conversion and upgrading before returning/reuse

- Valuation of ecosystem services
- Future revenue of businesses to include not only the service provided by a single functional unit, but also the contribution to preservation of ecosystem goods and services

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THANKS

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