TREATMENT OF LOW-CONTAMINATED SOIL WITH BIOCHAR PRODUCED FROM ORGANIC WASTE FOR SUSTAINABLE RESOURCE USE AND CIRCULAR ECONOMY

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Acknowledgements

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FORMAS

NSR

STATENS GEOTEKNISKA INSTITUT

RE: SOURCE

HELSINGBORG

ÖREBRO UNIVERSITET

SLU

Conclusions

Ups

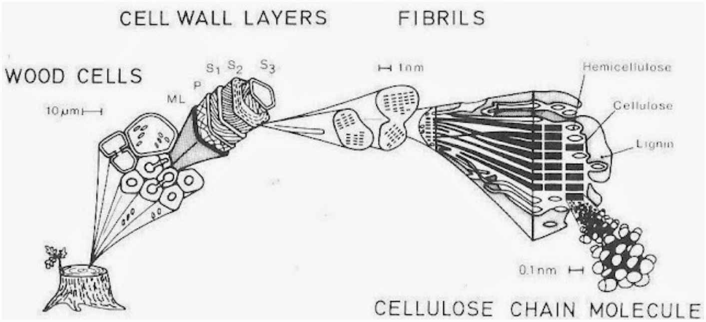
- Substantial immobilization of PAH
- Biochar can reduce solubility of cat ionic compounds like Cu, Hg, Pb, Zn but the choice of biochar is crucial
- Soil health improved significantly
- A climate positive sustainable remediation option that can be used in situ, on site or off site

Downs

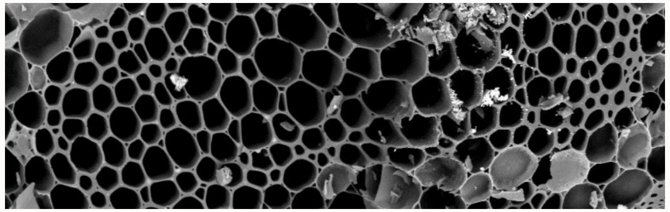
- No effect or even increased solubility on anionic elements such as As, Cr, Mo, Sb and V (likely due to increase in pH from ash)
- It does matter how biochar is produced
- Regulators often wants “braces and belts” and stabilization methods will always be viewed more conservative

Important properties for the biochar

- Biochar made from a feedstock rich in lignine and hight temperature (600-900 C)
- Large surface area and high micro porosity, which is good properties for stabilization of hydrophobic organic toxins like PAH or hydrocarbons but can also work for heavy metals.
- Biochar produced at a lower temeperature and with green stems and leafs can give a good reduction of heavy metals, especialy for lead but it remains to evaluate if the effect is persistent with a normalized pH
- Biochar can be tailored to meet specific property demand



Source; doctor-biochar.blogspot.com

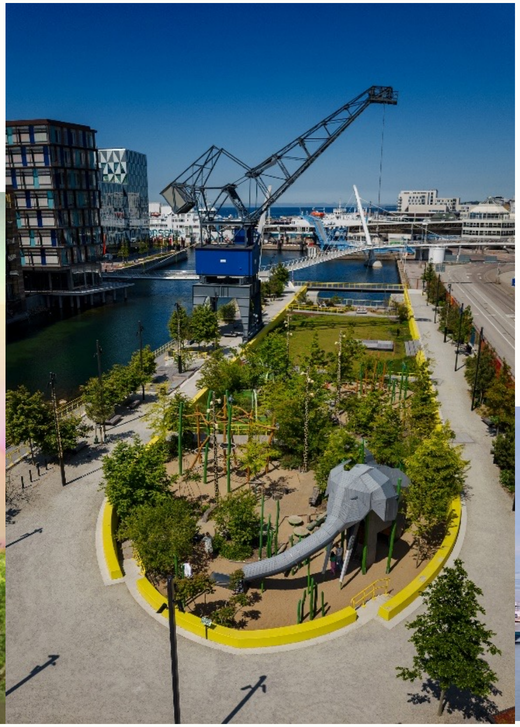


Source; biocharmalaysia.com

Urban (re-)development

Urban development – Helsingborg Sweden





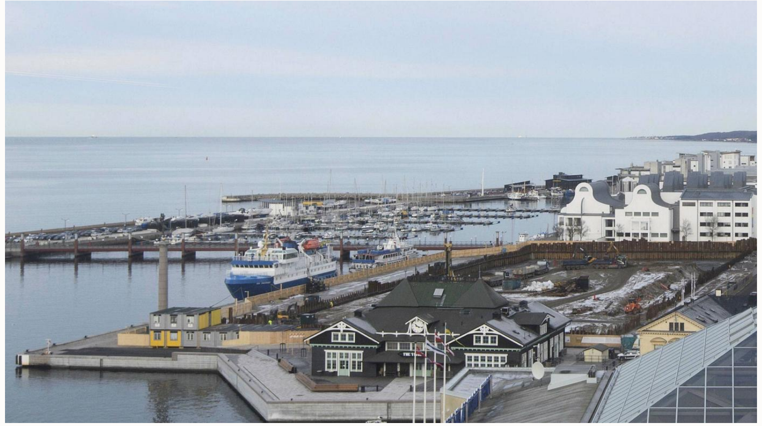

An industrial site

A vision(ary)

Re-development

Urban development

Railway yard



- 60 000 cu yd of soil

= A biochar Summit

Contaminated land (briefly)

Contaminated Soil in breif

- Lightly contaminated soils are a major cost driver in urban development projects

- Most urban development in brownfield areas involves dig & dump (landfilling)

- in Stockholm 28% of the emissions from heavy traffic derives from transportation of soils

- Majority of all contaminants consists of PAHs and 10-12 metals

- Few sustainable remediation alternatives exist today

CDC Centers for Disease Control and Prevention

National Biomonitoring Program

Polycyclic Aromatic Hydrocarbons (PAHs) Factsheet

Polycyclic aromatic hydrocarbons (PAHs) are a class of chemicals that occur naturally in coal, crude oil, and gasoline. They result from burning coal, oil, gas, wood, garbage, and tobacco. PAHs can bind to or form small particles in the air. High heat when cooking meat and other foods will form PAHs. Naphthalene is a manmade PAH used in the United States to make other chemicals and mothballs. Cigarette smoke contains many PAHs.

PAH Exposure in People

Exposure to PAHs can occur by:

- Breathing air containing
  - Motor vehicle exhaust
  - Cigarette smoke
  - Wood smoke
  - Fumes from asphalt roads
- Consuming grilled or charred meats or foods
- Eating foods on which PAH particles have settled from the air
- In some cases, passing through the skin.

After PAHs enter a person, the body converts PAHs into breakdown products called metabolites. The metabolites pass out of the body in the urine and feces.

Contaminated soil is not a small deal

In urban/brownfield development the cost for remediation is significant

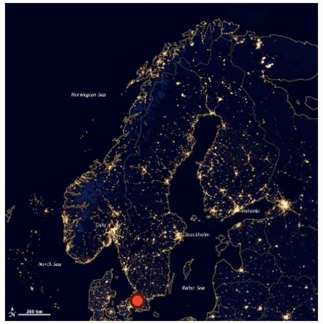
President Biden's Fiscal Year 2024 budget requests $12.083 billion, supporting the EPA's essential work to protect human health and the environment.

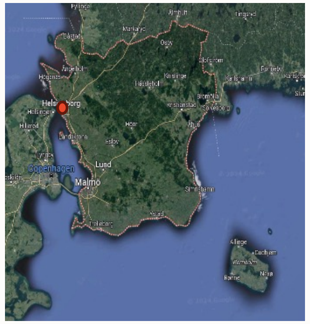
- **Protecting Communities from Hazardous Waste and Environmental Damage.** The prevention and cleanup of harmful environmental damage that poses a risk to public health and safety continues to be a top priority for EPA. In addition to an estimated $2.5 billion in Superfund tax revenue that will be available to EPA in 2024, the Budget provides over $350 million for the Superfund program to continue cleaning up some of the Nation's most contaminated land and respond to environmental emergencies and natural disasters. The Budget also provides over $215 million for EPA's Brownfields program to provide technical assistance and grants to communities, including overburdened and underserved communities, so they can safely clean up and reuse contaminated properties, as well as $20 million for the Alaska Contaminated Lands program. These programs support the President's Cancer Moonshot initiative by reducing human exposure to harmful contaminants that are correlated with an increased risk for cancer.

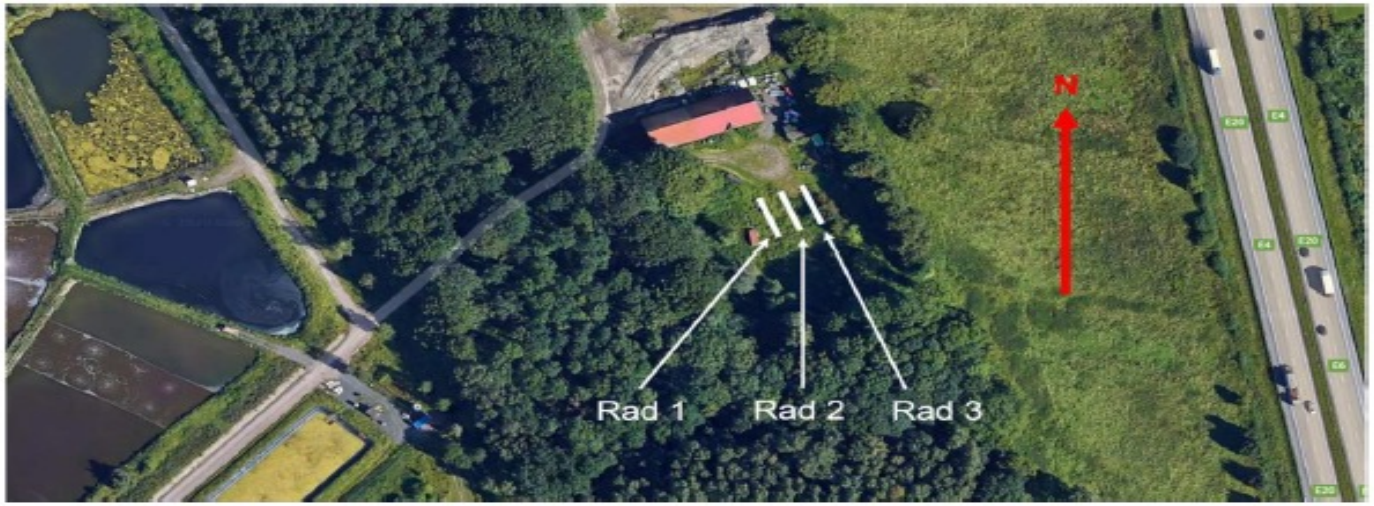
$3.1 Billion

The project(s)

Helsingborg Sweden







The Projects:

Project 1

- ✓ Lab and field trials
- ✓ Life Cycle Assessment
- ✓ Local production from waste assessment
- ✓ Legal perspectives

Project 2 (Balance)

- ✓ Lab and field trials – Long term effects
- ✓ Vapour intrusion trials
- ✓ Life cycle assessments
- ✓ Framework for an urban mass balance and circular material flows

Project objectives

- detoxification,
- soil quality improvement and
- environmental impact of various alternatives in a life cycle perspective.
- Feasibility for a public company to invest in production of biochar from the citizen's green waste

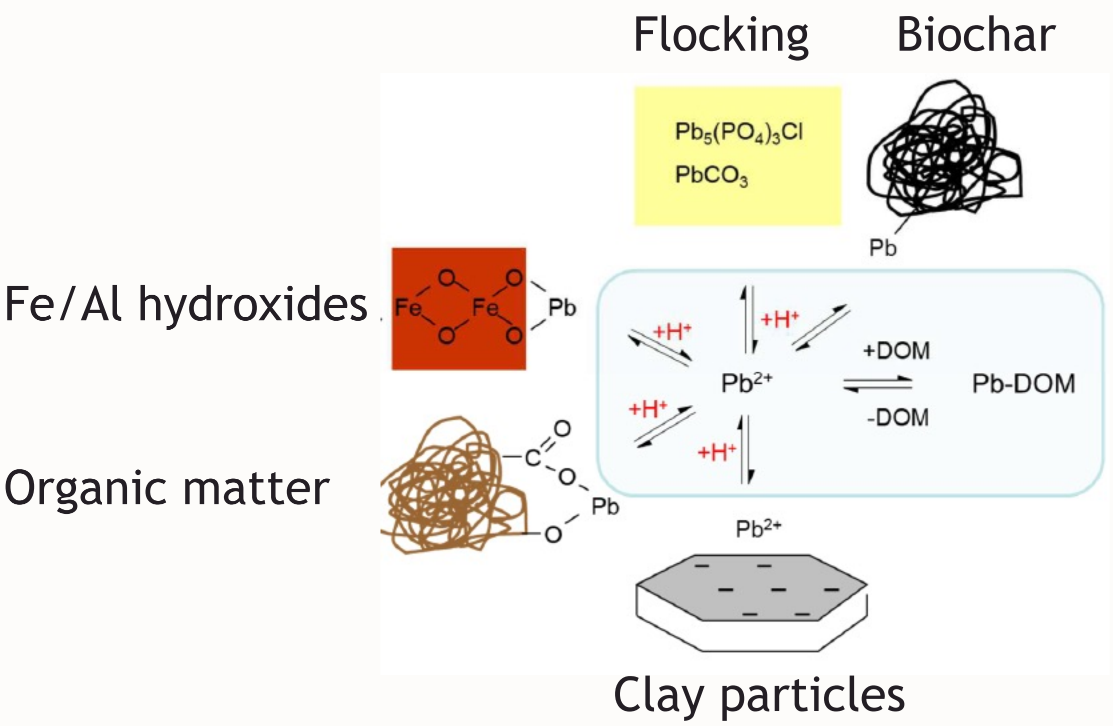
Field study:

1. When is a treatment suitable?
2. What type of soils can be treated?
3. How much biochar is need to see effect?

The Project results:

1) addition of 3% w/w biochar can decrease contaminant mobility and uptake in biota, making the soil less toxic
2) The greatest positive treatment effects in relative terms is achieved in soils with low soil quality (low organic carbon, low clay content and pH<7
3) the remediation technique have a large potential as a sustainable soil remediation option, bringing a climate positive (carbon negative) option to an industry with a very high carbon footprint.
4) There is even data that the environmental impact of the contaminants are lesser than if the soil is landfilled

Why is Biochar good for sorbtion stabilization and solidfication?



The effects of biochar;

- ✓ Addition of sorbion surface
- ✓ Increase of pH that increase sorbtion
- ✓ Increased pH add salts that leads to mineral flockings
- ✓ Affects solubility with dissolved organic matter

Field Trials

Spiking the soils

PAH contaminated soil from gas works.

Metal contaminated soils from harbour exploitation

Mixing spiked soils

Field Trials in Helsingborg

	Soil no 1			Soil no 2			Soil no 3		
	Pile 1	Pile 2	Pile 3	Pile 4	Pile 5	Pile 6	Pile 7	Pile 8	Pile 9
P	0%			1,5%			3%		
BC	0%	3%	6%	0%	3%	6%	0%	3%	6%

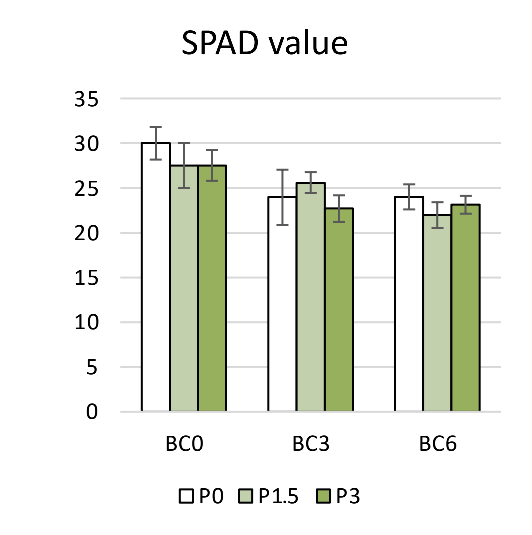
Field and lab trials Biomass analysis

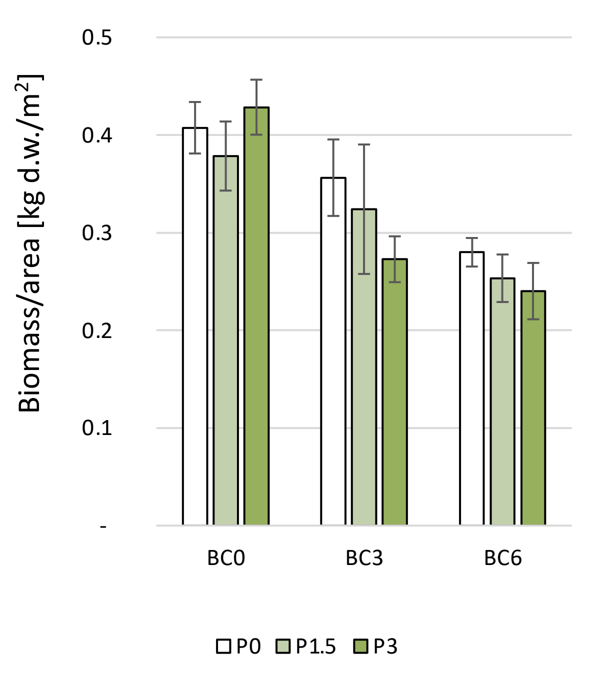
- Chlorophyll
- Biomass
- Uptake of N, P, K, micro elements, metals and PAHs

Results Biomass production

Biochar and peat increased the soil quality for the microorganisms and for the earthworms...

But the biochar reduced the availability of nitrogen, resulting in lower conc of chlorophyll in grass and less biomass production.





Increased amount of biochar

Conclusions in grass and earthworks

Grass;

- Reduced up-take of PAH, Cu and Zn, but no difference for Pb

EARTHWORM:

- Reduced up-take of PAH, Cu, Zn, Pb

Biochar and peat reduced the toxicity and increased reproduction!

- Peat had bigger positive effect than biochar
- Addition of 3% biochar better than 6%

Photo: Branzén, SGI

Photo: Enell, SGI

Field and lab trials Soil parameters

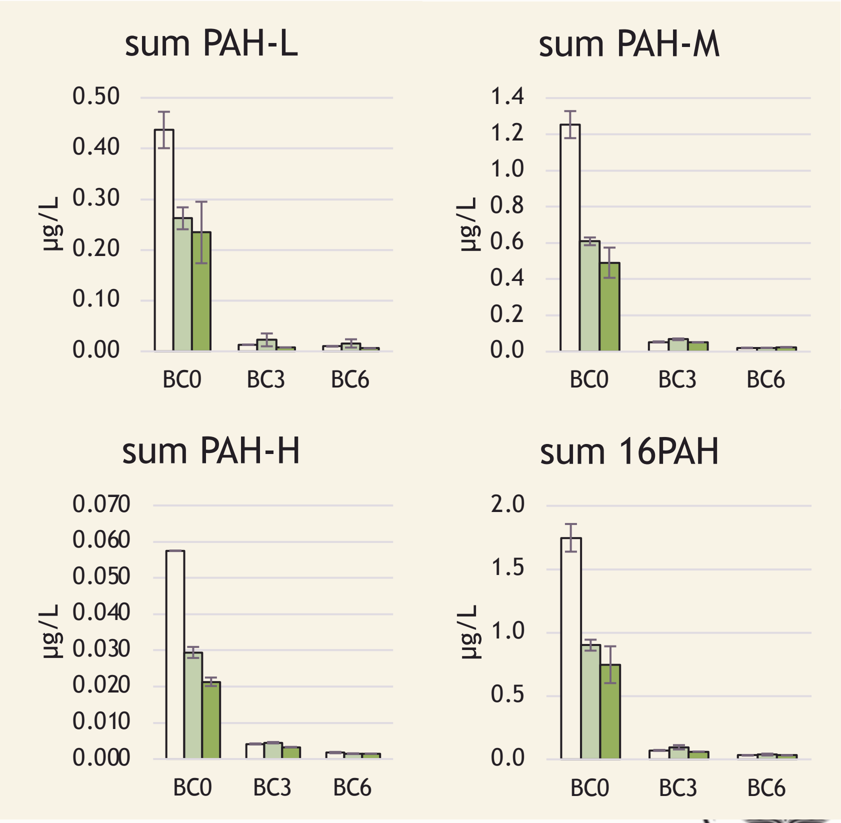
- Texture (grain size distribution)
- Cultivation parameters (water retaining capacity, pH, Nutrients, TOC and TIC)
- Metals (total concentrations ofr calculation of K/D)
- PAH (PAH16)
- Carbon mineralization
- Nitrogen cycle
- Eco toxicity (mortality of earth worms, reproduction of earth worms

Results leaching of PAH

Leaching of PAH (freely dissolved in water) from treated soil in relation to untreated soil

Addition of BC:	PAH-L	PAH-M	PAH-H	SOIL
0%	100%	100%	100%	Nbr1 Low amount of NOM (1% compost)
3%	3%	4%	7%	
6%	2%	2%	3%	
0%	100%	100%	100%	Nbr 2 Medium amount of NOM (1% compost+1.5% peat)
3%	9%	11%	15%	
6%	6%	3%	5%	
0%	100%	100%	100%	Nbr 3 High amount of NOM (1% compost+3% peat)
3%	3%	10%	15%	
6%	3%	5%	7%	

Concentration in leachates (freely dissolved)

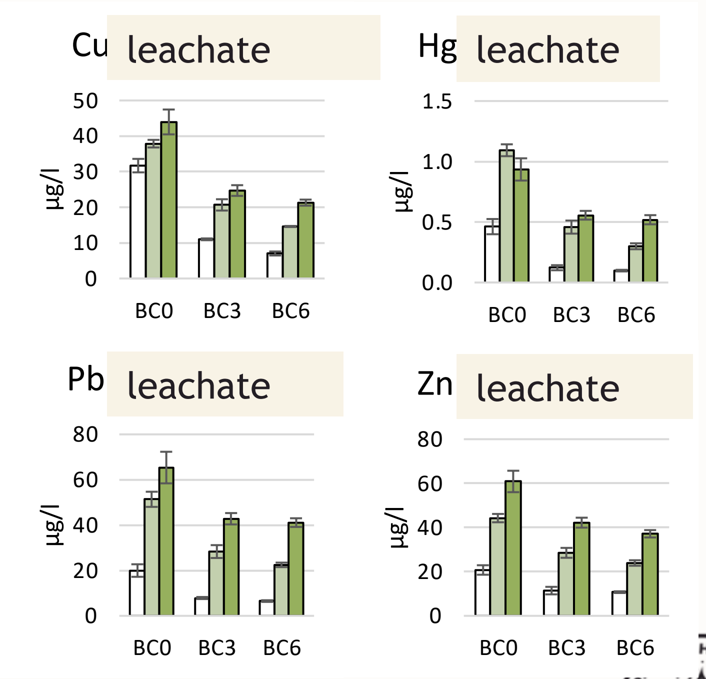


Results – Leaching of metals

Leaching from treated soil in relation to untreated soil

Addition of BC:	Cu	Hg	Pb	Zn	Soil
0%	100%	100%	100%	100%	Nbr1 Low amount of NOM (1% compost)
3%	35%	26%	39%	55%	
6%	22%	21%	33%	52%	
0%	100%	100%	100%	100%	Nbr 2 Medium amount of NOM (1% compost+1.5% peat)
3%	55%	42%	55%	64%	
6%	39%	27%	44%	54%	
0%	100%	100%	100%	100%	Nbr 3 High amount of NOM (1% compost+3% peat)
3%	56%	59%	65%	69%	
6%	48%	56%	63%	61%	

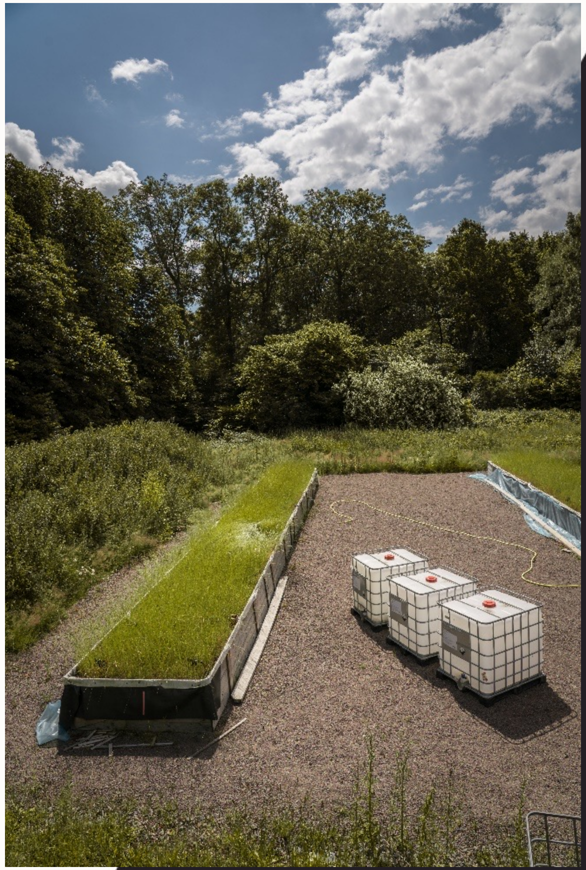
Concentration in leachates



NOM = natural organic matter

Continuation – The Balance Project

- New research project ongoing until 2022-2025
- Follow up on long term effects
- New aspect with human health exposure (vapour intrusion reduction)

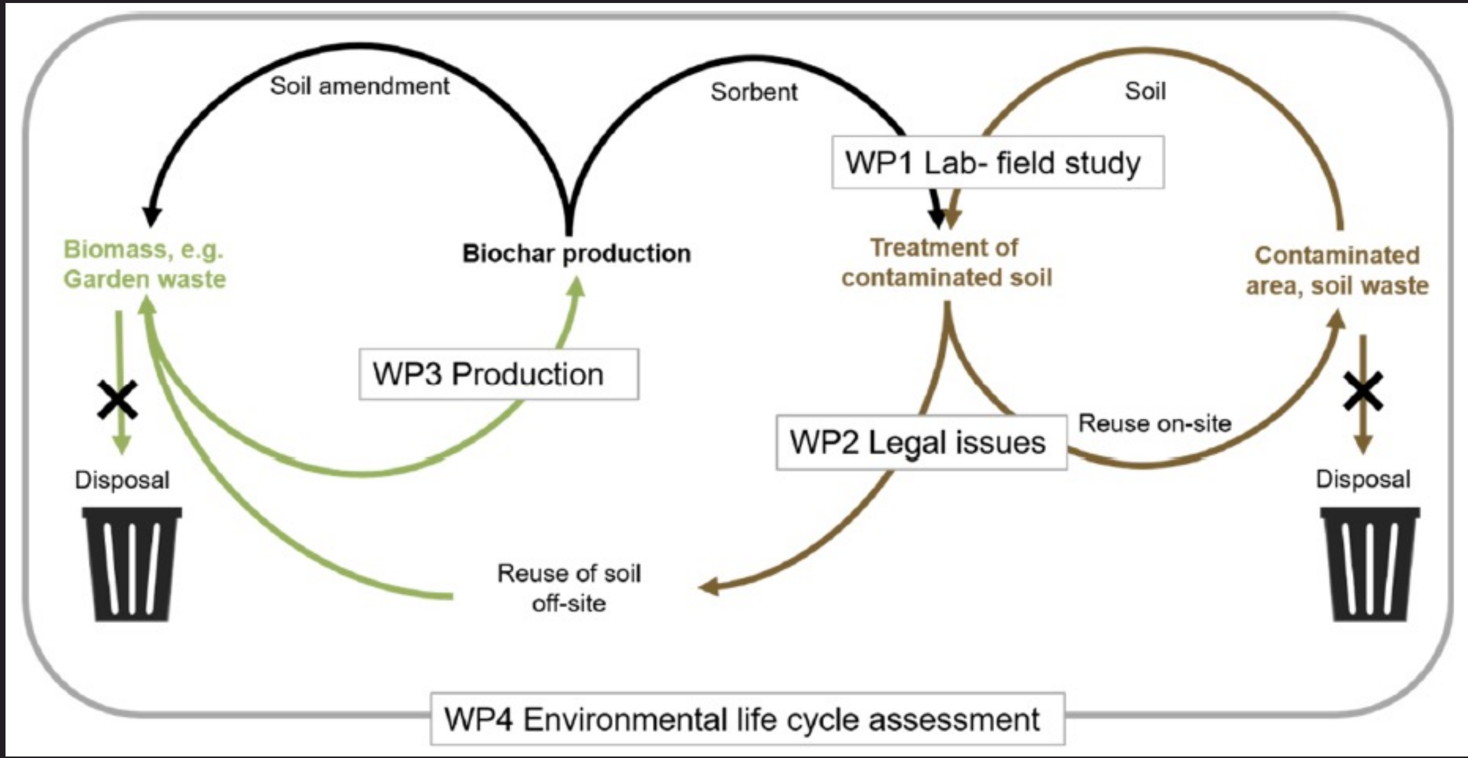


Environmental system analysis

Life cycle assessment

Three scenarios

1. Dig & Dump (landfilling)
2. Treatment off site
3. On site / in situ treatment



Environmental system analysis

"Dig and dump"

Off-site treatment with biochar and re-use of the treated soil at new locations

On-site treatment with biochar

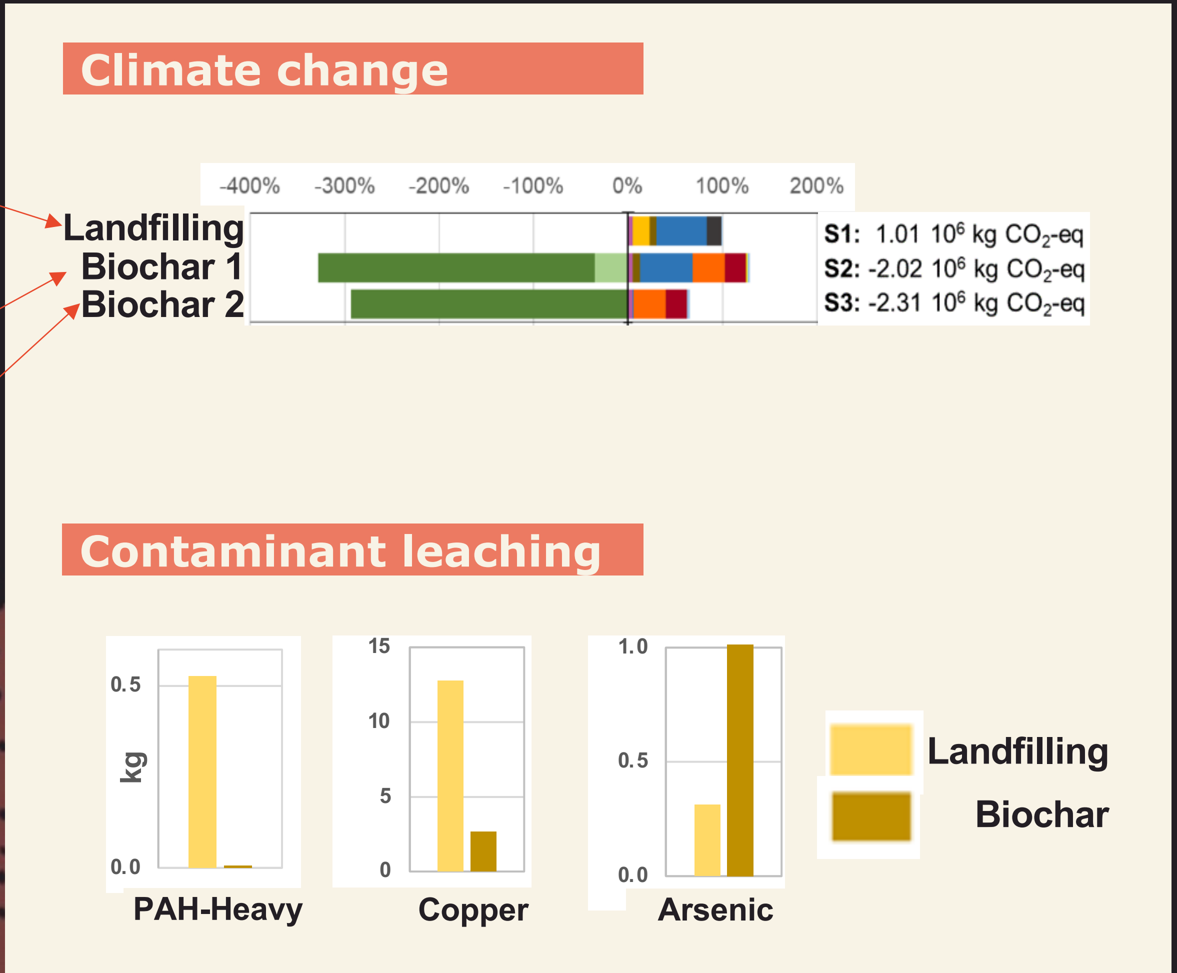


Figure: "Graphical abstract" in Papageorgiou, et al. (2021)

The LCA conclusions ;

- Biochar treatment has a significantly lower environmental impact compared with landfilling.
- Treatment on-site as well as off-site, results in negative CO_2 emissions under prevailing Swedish conditions!

The substance flow analysis showed that

- Using biochar results in significantly smaller amounts of leached PAH and copper (seen over a 100-year period).
- For other metals, the same simple conclusion cannot be drawn. Which alternative is best (disposal or treatment) is governed by site-specific conditions and the choice of biochar.

Life cycle assessment

- ISO 14040 and 14044
- Base case 100 years
- Production of 1250 tons of biochar
- Treatment of 12000 tons of soil

Local Production Feasibility

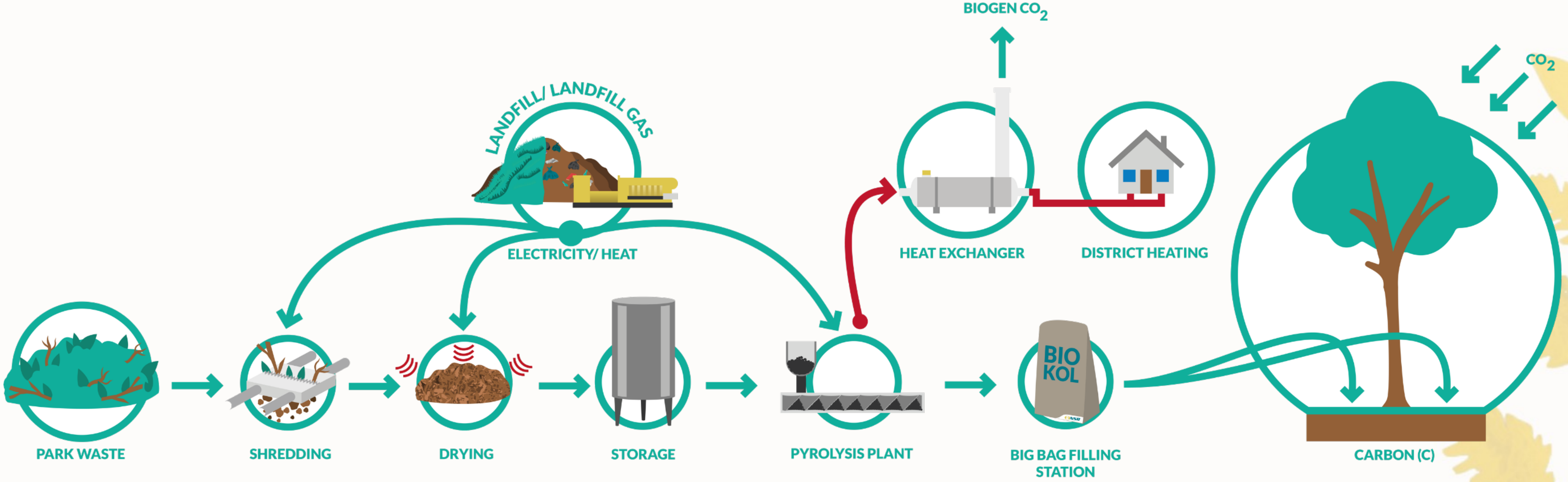
Local production feasibility

The Helsingborg Biochar Journey

- 2019-2022 – First Project
- 2020-2023 – Production process tendering and installation
- 2022- Bloomberg Philanthropies sponsored Biochar Competence Centre
- 2023- The Balance project (part 2)
- 2023 – The Biochar Summit
- 2023 – National innovation cluster project to form an innovation lobby organization funded by the Swedish Energy Agency
- 2024 – Full production (hopefully)

Local production feasibility

Conceptual site model



Local production assessment

- ✓ 25 000 - 30 000 tons of garden waste shredded.
- ✓ 7500 tons of wood chips are produced
- ✓ The process will in full operation make 1500 tons of biochar
- ✓ Energy for the process is produced locally by landfill gas
- ✓ 15 Gwh of heat is supplied to the local heat grid
- ✓ Total investment including excluding CHP engines is roughly USD 5M
- ✓ A bench scale pyrolysis test unit is installed in the competence centre, and a lab including BET for members of the network

Publications

- Papageorgiou (2021). Emerging technologies for climate-neutral urban areas: An Industrial Ecology perspective. Dissertation. diva2:1543263
- Papageorgiou, A., Azzi, E. S., Enell, A., & Sundberg, C. (2021). Biochar produced from wood waste for soil remediation in Sweden: Carbon sequestration and other environmental impacts. Science of The Total Environment, 776, 145953. https://doi.org/10.1016/J.SCITOTENV.2021.145953
- Flyhammar, P., Hermansson, S. och Ohlsson, Y. (2020), Report in Swedish: Biokol i lätt förorenade jordar, Kritiska juridiska frågeställningar, Statens geotekniska institut, SGI, Linköping, 2020 08 31. http://urn.kb.se/resolve?urn=urn:nbn:se:swedgeo:diva-914
- Sippel, F. (2020). A Comparative Assessment of the Availability and Suitability of different types of Biomass Feedstock in Skåne and Sweden for the Production of Biochar. Ertl, F. (2019). Summary of Different Types of Pyrolysis Concepts http://projects.swedgeo.se/biokol/index.php/publikationer-och-presentationer

Thank you

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