32nd annual National Waste Disposal Day, Helsinki

Landfill Mining: Lessons learned in Estonia

Tutkimuskokemuksia täysimittaisesta landfill miningista

Mait Kriipsalu
Estonian University of Life Sciences
mait.kriipsalu@emu.ee

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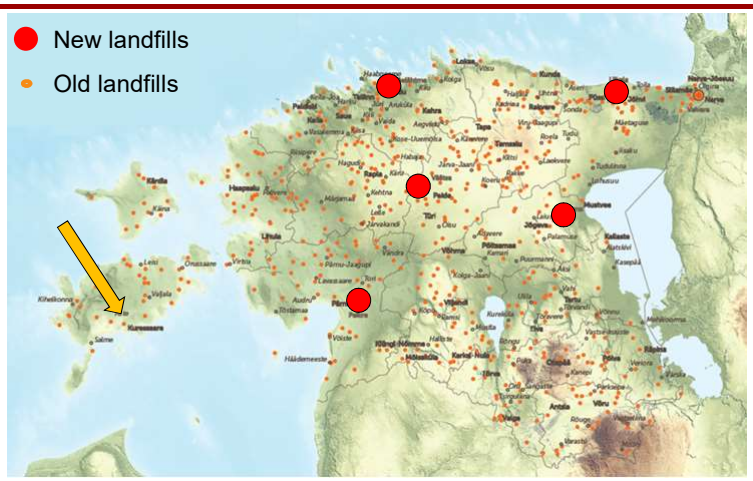
Landfills in Estonia



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Case study: Kudjape

Kudjape dumpsite, Saaremaa, Estonia

- In operation 1970–2009, most active during last two decades;
- Estimated volume 200.000 m^3;
- Municipal waste;
- By law had to be capped 2013;
- Main issue: Landfill gas
  - Gas collection? Passive ventilation?

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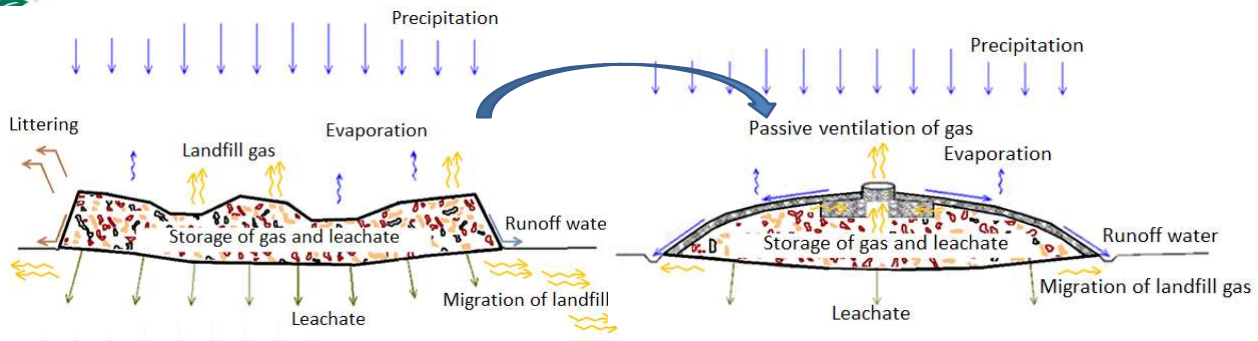
Typical cover design in small dumpsites



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Kudjape case was different

- Simple closure design of a LF was **not agreed** by authority;
  - Fear of gas → 1,5 m cover layer was prescribed;
- Cover material was not available.
  - Excavating 60.000 t locally → 'big hole in ground'.
  - To transport it from distances/overseas?
  - Is it ethical to force LF to use virgin soil and cover waste with it?
- What if we take cover material from the same landfill?
  - This technology is called Landfill Mining (LFM)

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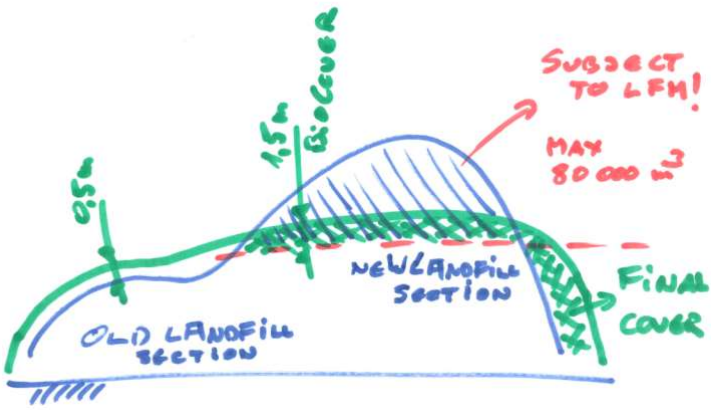
Master plan



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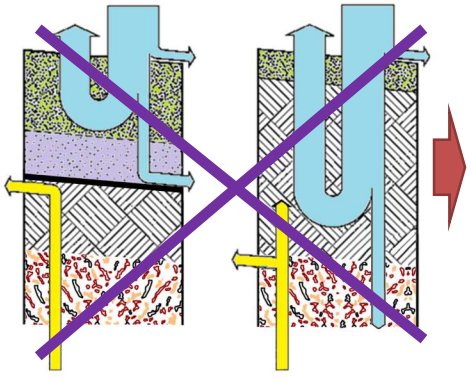
Design of a cover layer

Impermeable cover layer Semi-permeable cover layer



Methane degradation layer (taken from LF)

Mineral gas distribution layer (taken from LF)

(Modified after Tchobanoglous et al., 1993)

Methane degrades: $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

Closure of the Kudjape landfill

- Cover design which was accepted by Environmental Board:
  - No clay or synthetic geomembrane;
  - No active or passive gas collection system;
  - Alternative final cover for landfill – biocover;
  - Biocover consists of 1.2 m methane degradation layer + 0.5 m gas distribution layer;
  - Extraction of RDF if feasible.

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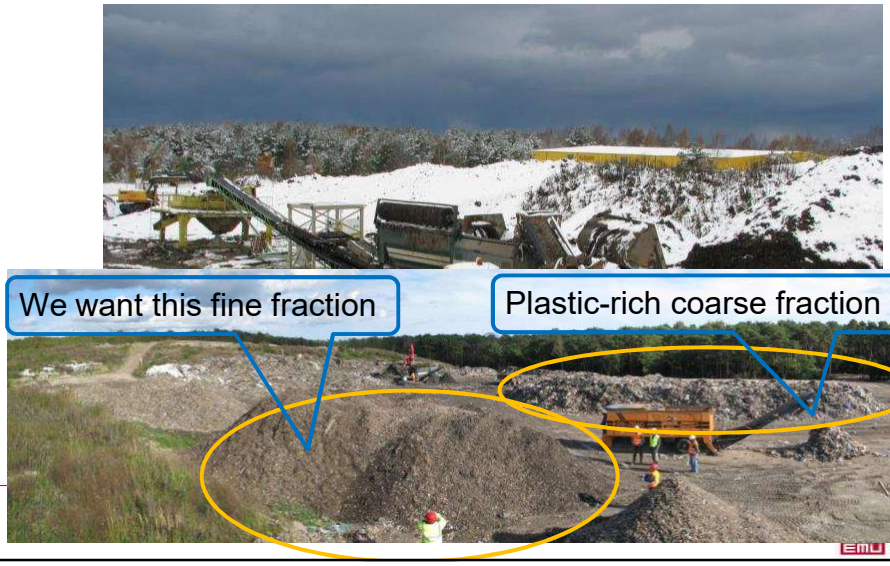
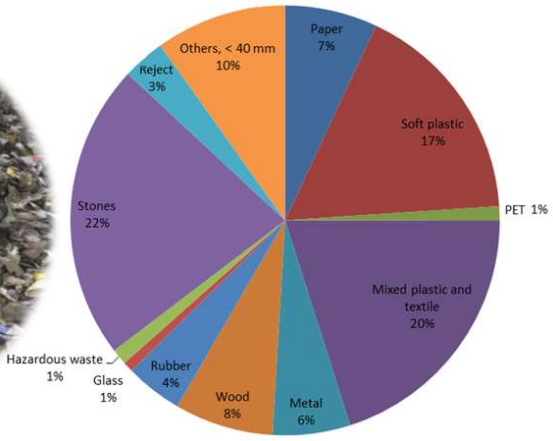
Excavation in progress



Characterisation of wastes

Coarse fraction



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Oversize fraction

- Waste-to-energy in Tallinn Mass-burn facility

- Waste-to-SRF for Kunda Cement factory

- Waste-to-plastic product at Rexest/Elegro
  - Now Elegrotech-WIPA GmbH

- Waste-to-oil in Oil Shale Research Centre

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Undersize fraction → biocover

- Is it possible to extract material with prescribed bicover properties from the landfill?

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Properties of biocover

Metal	n	unit	Fine fraction	Limit value	Target value
Arsenic (As)	17	mg/kg DM	5.0 ± 0.9	By law: 50	
Cadmium (Cd)	17	mg/kg DM	1.0 ± 0.4	20	
Chromium (Cr)	17	mg/kg DM	77 ± 44	800	
Nickel (Ni)	17	mg/kg DM	34 ± 13	500	
Lead (Pb)	17	mg/kg DM	241 ± 232	600	
Zink (Zn)	17	mg/kg DM	1590 ± 843	1000	
Copper (Cu)	17	mg/kg DM	257 ± 181	500	
Mercury (Hg)	1	mg/kg DM	0.89	10	
Carbon / Nitrogen (C/N) ratio	2		31±4	BAT	
Dry matter	18	% DM	65.4±4.3		50–70
Loss of Ignition LOI	18	%	19.3±3.7		>15
pH	18		7.80±0.26		6.5–8.5
Electrical Conductivity EC	18	mS/cm	2.62±1.25		<4
Total Organic Carbon TOC	2	% DM	12.7±3.8		>7
Respiration activity (7 d)	18	mgO_2/g DM	5.92±3.86		≤8

Bottleneck:

- Water Retention (soil moisture characteristics)
- Hydraulic Conductivity

BAT: Huber-Humer et al., (2009)

Tailoring of cover layer

Fine Fraction, FF (40 mm)
100 %

✓ OK, except Zn

Low capillary fringe, biocover could dry out too quickly. High respiration. Not enough FF available.
→ **add soil**

FF + soil
83 % + 17 %

✓ OK except TOC (was 5.1 % DM, but required >7 % DM)

Poor source of carbon for bacteria.
→ **add carbon**

FF + soil + sludge compost
60 % + 20 % + 20 %

✓ Chemical parameters OK
✓ TOC & respiration OK
✓ Hydrophysical parameters OK
✓ Mass balance OK, soil and sludge compost locally available
→ **good**

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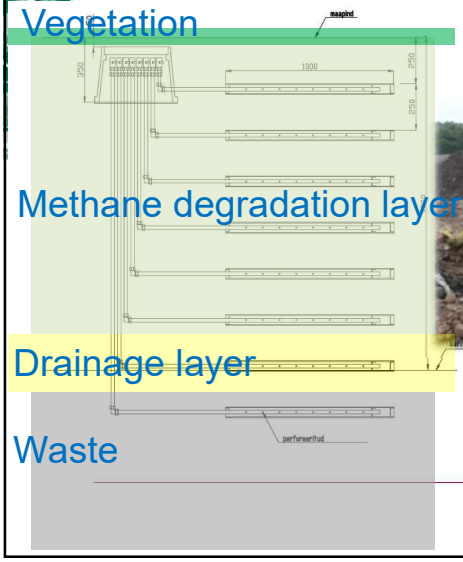
Construction of a methane degradation layer

Vegetation



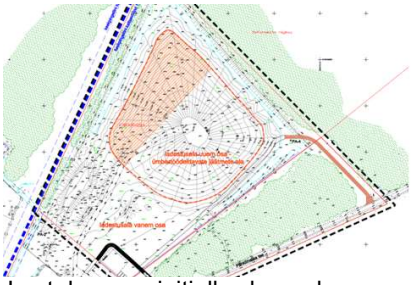
Methane degradation layer

Drainage layer

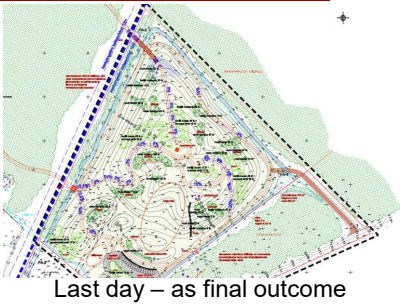
Waste

First day – last day

First day



Last day – as initially planned



Last day – as final outcome

Final outcome is a public park

Kudjape landfill in service of the society





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Is the cover layer functional?

- Stability of remediated landfill, settlings
- Gas emissions from surface
- Gas from deep layers
- Water pollution
- Vegetation

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Kudjape landfill in service of science

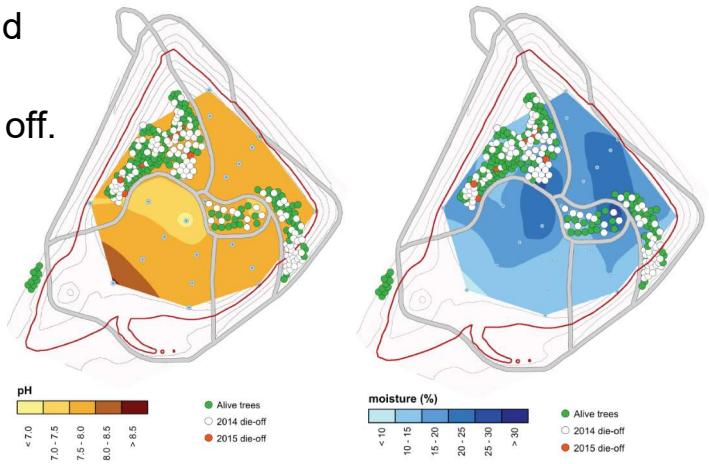





Pehme, MSc 2014 & PhD 2019; Heinsoo, MSc 2016; Tamjärv, BSc 2016; Tooding, MSc; Lääne, MSc; Sapelkov, MSc; Kure, MSc; Hoop, MSc; Böckler & Keskküla BSc; Kupits, MSc. Two Int. MSc/PhD courses + research by local school

Monitoring: trees

- We planted 338 trees and 959 shrubs.
- Many of them have died off.
- Why?



Pehme, K.M., Kriipsalu, M. 2018. Full-scale project – from landfill to recreational area. Detritus, 1:174-179.

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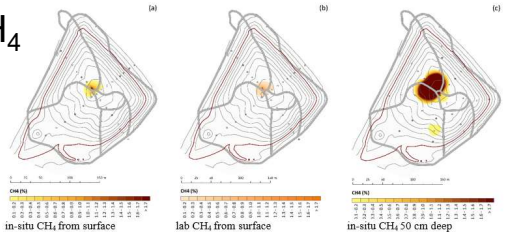
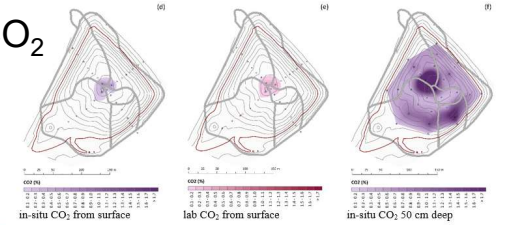
Monitoring: surface emissions

- 6 measurement events 2015-16.
- CH_4 and CO_2 emissions through the surface of the landfill were missing or very low.
- Did we measure correct?

CH_4



CO_2



Submitted to Waste Management.

Method: In-situ (surface) | Lab (surface) | In-situ (50 cm deep)

Monitoring: microbiology

- I do not see methane emissions into the atmosphere. WHY?
  - There is no methane?
  - Methane is degraded or immobile?
  - We measure wrong?
- Who is living in my cover layer?
  - Methanogens are microorganisms that produce methane
  - Methanotrophs are microorganisms that degrade methane

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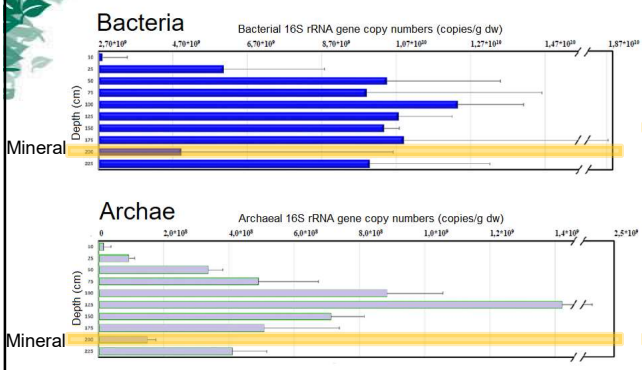
Monitoring: microbiology

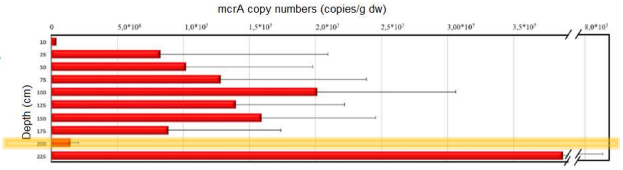
Monitoring: microbiology

Abundance of microorganisms

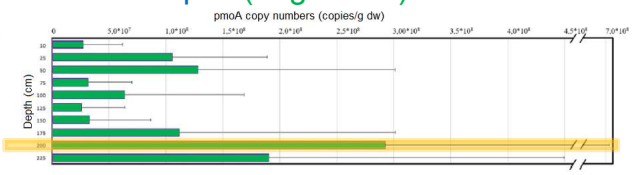


Bacteria $10^{9\text{-}10}$ > Archae $10^{8\text{-}9}$

Methanogens (producers)



Methanotrophs (degraders)



Producers $10^{6\text{-}7}$ < Degraders $10^{7\text{-}8}$

MSc Krista Kupits 2018, sup Marika Truu & Hiie Nõlvak

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Monitoring: water

- In-situ monitoring of 4 groundwater wells + ditch
  - Data: 5 years before excavations; monthly during LFM; every year until today
  - In-situ (pH, t, EC, O_2)
  - Ex-situ: (BOD, COD, F, NH_4, NO_3, NO_2, N_{tot}, Cl, Mn, Fe, P_{tot}, DS, Metals, PAH, BTEX, $TPH_{10\text{-}40}$, phenols)
- Leaching of fine fraction
- Toxicity of fine fraction

Unpublished data

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Conclusions

- Compared to active gas extraction and flaring, microbial methane oxidation in semi-permeable final cover layer offers an alternative option to reduce greenhouse gas emissions from (small?) landfills.
  - Simple design, locally available materials, cheap, effective.
- Fine fraction which was extracted from landfill by Landfill Mining was suitable for constructing methane degradation layer.
  - Consider adjusting properties of excavated material.
- In our study, (nearly) no gas leakage was detected from surface.
- There are both microorganisms: Methanogens and Methanotrophs.
  - It is 'ME' who has to create favourable environment to activate Methanotrophs.

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Acknowledgements: teamwork!

- EMU, Dept of Water Management: MSc Enriko, Kaarel and Kaur-Mikk for hard work on site; Dept of Env and Agri: sup Kaja Orupõld, MSc Kertu and Allar for their work with fine fraction; sup Valdo Kuusemets and MSc Merilin for gas study; Dept of Land Surveying: Harli Jürgenson and BSc students, Dept of Forestry: Andres Jäärats and BSc Kati for survey of trees; University of Tartu: Marika Truu, Hiie Nõlvak and MSc Krista for 16S rRNA; Supervisors of undergraduates: Mari Ivask, Ülle Soom, Maie Meius
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- Prof William Hogland and Dr Fabio Kaczala, Linnaeus Uni, Sweden.

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What next?

MSc 2019 & MSc 2020

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Let us help the nature to help itself!

Thank you!

Mait Kriipsalu
mait.kriipsalu@emu.ee

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