Final Storage Landfills: Key Element of Sustainable Waste Management

Vertederos de almacenamiento finales – elemento clave de todo sistema de gestion sostenible de los residuos

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Resources, cycles and flows to sinks

Resource → Anthroposphere → Waste
Stock

Recycling
Environment
Development of resource extraction

Coal mining then ...
Unlimited progress of technology

... and now

240.000 t/d

Thyssen Krupp Excavator 288
"Input equals output"

**Anthroposphere**

**Input** 240.000 t/day → **Anthroposphere** Stock +/- 0 → **Output** 240.000 t/day

**CO₂**
- Input: 300 ppm
- Output: 150 ppm
- Increase: +75%

**CH₄**
- Input: 500 ppb
- Output: 1500 ppb
- Increase: +300%

**Graphs:**
- CO₂ concentration over time from 160,000 to 0 years before today, showing a significant increase from 160 to 20 years ago.
- CH₄ concentration over time from 160,000 to 0 years before today, showing a dramatic increase from 160 to 20 years ago.
Consequences of resource extraction at the “back-end”

Muir and Riggs Glaciers
CO$_2$ not the only example: CFCs et al.

„Planet earth“ as a limited sink

Atmosphere 4.200 [Mio. km³]

Hydrosphere 1.400 [Mio. km³]

nach A. Nieman ergänzt durch G. Döberl
Global production 1950-2010

- **Ammonia**: 7 → 200x10^6 t/y
- **Concrete**: 1.5 → 30x10^9 t/y
- **Automobiles**: 7 → 70x10^6
- **Chlorinated paraffins**: 20 → 600x10^3 t/y
- **Cadmium**: 5 → 20x10^3 t/y

Financial crisis of 2008
Substance flows to sinks are invisible (Cu)

Vineyard and railway
Ballast as a “sink” for Cu from railroads

Quality criteria:
- Landfill ordinance
- Recycling material
- Anthropogenic Cu
- Geogenic Cu

Cu in ballast recycling residue [mg/kg]

Time [y]

2010

total Cu in ballast residue
Investigating into Cu metabolism
~ 20% of Cu flow to recycling and landfilling

~ 80% of Cu flow uncontrolled into the environment

Change in copper stocks [kg/km·year]

-9.6 kg/km·year
-2.7 kg/km·year
+2.6 kg/km·year
+9.7 kg/km·year

Losses to environment and possibly others

Rolling stock components
Track ballast

From sources to sinks – the full picture
Just a railway issue? Cf. urban surfaces...

where is the zinc?
Global Zinc flows to sinks

Import: 12.8 Mt/a
Change in stock + 6.4 Mt/a
Export: 6.4 Mt/a

Zinc from mines 12.8
production & manufacturing 21.3
Gross flow to market
utilization Stock 300 + 6.4
Recycled Zinc 8.5
Zinc losses 6.4

System boundary “Zinc, 2006”
Flows [Mt/a] Stock [Mt]
From inorganic to organic substances

Eol vehicles 0.6 t/y

consumption
stock 76 t (-3.2)

plastics in c&d wastes 2.6 t/y

waste management
stock ?? (+2.6)

recycling

export

key control process

City of Vienna, 2010

Vyzinkarova et al, 2013
The need for sinks and final sinks

ANTHROPOSPHERE

resource management

production and utilization phase

recycling flows

off-flows

collection & recycling

waste management

ANTHROPOGENIC SINKS

landfill

underground fill

soil

water

ENVIRONMENT

resources

emissions

emissions

ENVIRONMENTAL SINKS

Intermediate sink

final sink
Incineration: perfect sink for organics

Source: SGP-VA
Resource recovery from WTE-bottom ash

Center for Sustainable Waste Recovery and Resource Use
Recovery of NF-metals from separated ash

<table>
<thead>
<tr>
<th>Metal</th>
<th>Concentration [g/100g]</th>
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<tbody>
<tr>
<td>Aluminum</td>
<td>70</td>
</tr>
<tr>
<td>Copper</td>
<td>15</td>
</tr>
<tr>
<td>Silver</td>
<td>0.06</td>
</tr>
<tr>
<td>Gold</td>
<td>0.003</td>
</tr>
<tr>
<td>Palladium</td>
<td>0.001</td>
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</tbody>
</table>

Recovery-Efficiency

<table>
<thead>
<tr>
<th>Generation</th>
<th>Recovery-Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st generation</td>
<td>62 %</td>
</tr>
<tr>
<td>2nd generation</td>
<td>95 %</td>
</tr>
<tr>
<td>3rd generation</td>
<td>&gt;98 %</td>
</tr>
</tbody>
</table>

Source: Center for Sustainable Waste Recovery and Resource Use
The landfill: a “Final Sink” for wastes?

Organic waste (MBT) landfill

- \( \text{CH}_4 \), \( \text{CO}_2 \), TOC, \( \text{NH}_4 \), Cl etc.

Bottom ash landfill

- \( \text{H}_2 \), SO\(_4\), Cl etc.

Filter ash landfill

- \( \text{SO}_4 \), Cl etc.

Emissions of leachate, gas, TOC and N

Large ⇔ Small
"Reactor" versus "Final Storage" landfill

**Barriers**
1\(^{st}\): Treated (mineralized) waste -> *After care free!!!*
2\(^{nd}\): Top and bottom landfill liners to keep out water and for control
3\(^{rd}\): Geogenic barrier ("natural attenuation")
Conclusions

1. Sinks as ultimate resource?
2. Zero waste is not feasible!
3. New role and priorities for waste management:
   -> „clean“ cycles and „safe final sinks“
4. “Design for sinks” as a new objective of WM
5. WM must signal sink constraints!
6. WM must supply sinks: incineration and landfills
7. New knowledge base for planning:
   -> “Metabolism of the anthroposphere”!
Recycling is not... is the final sink.

the end

...is the final sink