New project types in CDM waste sector:

Landfill aeration
- Current and future applications -

Dr.-Ing. Marco Ritzkowski

Hamburg University of Technology, Institute of Environmental Technology and Energy Economics
Harburger Schloßstr. 36, D - 21079 Hamburg
www.tuhh.de/iue  m.ritzkowski@tuhh.de
Global warming is the result of a change in the atmospheric balance caused by anthropogenic emissions of Greenhouse Gases (GHG).

Methane ($CH_4$) emissions account for $>14\%$ of the total GHG emissions.

- **Ruminant livestock**
- **Paddy fields**
- **Landfills**

85 M tons $CH_4$/year
60 M tons $CH_4$/year
~ 40 M tons $CH_4$/year

Source: IPCC Climate change 2007 – Synthesis report
How to reduce CH₄-emissions from LF?

- Treatment of organic wastes / waste organic fraction
  - Composting / anaerobic digestion
- Recycling and substitution of raw materials (indirect avoidance of CO₂ emissions)
- Incineration / thermal recovery (WTE)
- Gasification (syngas production)
- Landfill gas capture + flaring
- Landfill gas capture + energy generation
- Landfill gas capture + heat and energy generation
- Avoidance of landfill gas generation on site

→ Landfill aeration
Anaerobic landfill:
LFG extraction and disposal or utilization

CH$_4$ and CO$_2$
(60/40 Vol.-%)
Approaches by IPCC - Evaluation -

- Climate projects (JI/CDM) for direct avoidance of LFG emissions are ecologically sound, potentially create economical benefits but might prevent other (further) emission reduction measures.

**Example:**

- Many CDM projects are based on LFG capture and flaring (‘simple technique, cost effective’)
  - Registered CDM projects (06/2011): 3131
  - Waste handling & disposal sector: 544
  - LFG projects: 137
  - LFG capture and flaring: 76 (approx. 56%)

- Potential for energy generation: approx. 0.63 m tons CH$_4$ /a
  (→ approx. 8,500 GWh/a; i.e. ≈ 1 nuclear power plant)

### Approaches by IPCC
- **Evaluation** -

- The emission behaviour is mainly temporarily improved (avoidance of uncontrolled CH$_4$ emissions); after the project landfills might still exhibit a significant emission potential:
  - Continuous methane generation
  - Leachate pollution on a high level
  - Settlements not completed

### Alternative or additional approach:
- Aerobic in situ stabilisation (**Landfill Aeration**):
  - Short and long term avoidance of methane generation
  - Reduced leachate pollution
  - Settlements (widely) completed
Concepts for landfill aeration

- **Semi-aerobic landfill concept (NM0333)**
  Aeration driven by the temperature difference between the waste and the ambience ("passive" aeration concept)

- **Air venting (AM0083)**
  Aeration as a result of induced negative pressure inside the landfill ("overdrawing concept")

- **Low pressure aeration (AM0083)**
  Aeration by compressed air; parallel extraction (and treatment) of the off-gases ("active" aeration concept)

- **High pressure aeration (no methodology so far)**
  Pulsed aeration by high pressures; air enriched with oxygen; parallel extraction (and treatment) of the off-gases
Landfill aeration in the framework of CDM projects

- CDM-Methodology NM0333
  „Avoidance of landfill gas emissions by passive aeration of landfills“
- Not yet approved by the CDM Executive Board; Meth Panel 49 (May 2011): “external expertise on appropriate N₂O emission factor is needed”
- Aims and characteristic:
  - Avoidance of anaerobic conditions inside the landfill
  - Conversion of anaerobic landfill to semi-aerobic conditions
  - Reduction of methane emissions; faster bio-stabilisation
  - Does not require mechanically induced air injection, thus very limited in operation costs and indirect CO₂,e emissions
Semi-aerobic landfill concept (type 1)

Two options (types):
1) Gas wells connected to the leachate collection pipes (for new LF constructions)
2) Gas wells without direct connection to the leachate pipes (for LF remediation)
Semi-aerobic landfill (Example type 1)

Vertical gravel layers

Vertical gas venting wells
Semi-aerobic landfill (Example type 2)

1. semi-aerobic conditions
2. anaerobic conditions
3. semi-aerobic conditions

CH$_4$ and CO$_2$

(30/25 Vol.-%)

Air in

Leachate out
# Semi-aerobic landfill (Example type 2)

<table>
<thead>
<tr>
<th>Introduction</th>
<th>Landfills &amp; GHG</th>
<th>Aeration concepts</th>
<th>Emission reductions</th>
<th>Costs &amp; benefits</th>
</tr>
</thead>
</table>

**Introduction**

- Landfills & GHG
- Aeration concepts
- Emission reductions
- Costs & benefits
Landfill aeration in the framework of CDM projects

- **CDM-Methodology AM0083**
  
  „Avoidance of landfill gas emissions by in-situ aeration of landfills“

- Approval by the CDM Executive Board in July 2009

- **Aims:**
  - Reduction of methane emissions
  - Creation of environmentally compliant landfills
  - Shortening of landfill aftercare

- **Concepts:**
  Air venting and low pressure aeration
Air venting

Source: J. Heerenklage, TUHH
Low pressure aeration

CH$_4$ and CO$_2$

(1/15 Vol.-%)

- Ground water
- Leachate
- Surface run-off
- RTO
- CO$_2$
- Leachate treatment
- LFG
- Air
- Base sealing
- Unsatuated soil zone

Introduction
Landfills & GHG
Aeration concepts
Emission reductions
Costs & benefits
Aerated landfills (examples, D)
Examples world wide

- Aerated Landfills in Germany
  - Kuhstedt, Amberg-Neumühle, Milmersdorf, Dörentrup, Schwalbach-Griesborn, Süpplingen (all by means of low pressure aeration)
  - Kiel Drachensee, Schenefeld (air venting)

- Aerated Landfills in Austria
  - Mannersdorf, Pill, Heferlbach (LPA)

- Aerated Landfills in Italy
  - Sassari, Legnago (LPA)

- Aerated Landfills in the USA
  - NY, NJ, TN, MI, FL, KY, CA, AZ

- Aerated landfills in Switzerland and The Netherlands
  - Sass Grand (SUI); Almere, Landgraaf (NL) (AV (SUI); LPA (NL))

- Semi-Aerobic Landfills in Japan and Malaysia
CDM methodology AM0083
- Calculation of emission reductions -

- Comparison between the status without CDM project activity ("Baseline") and the actual project emissions (incl. secondary emissions from energy production and fossil fuel consumption)

- Baseline emissions:
  Only CH₄-emissions; N₂O-emissions are supposed to be irrelevant under anaerobic conditions
  → 3 stage calculation (!)

- Project emissions:
  CH₄ and N₂O emissions, CO₂ from energy production and fossil fuel consumption
Practitioners Workshop on CDM Standards (8.-10. June 2011, Bonn)

Project emissions calculation

Aeration devices

Off-gas collection & treatment

Source: K.-U. Heyer, IFAS Hamburg

Introduction
Landfills & GHG
Aeration concepts
Emission reductions
Costs & benefits
Landfill aeration – Calculation approaches

MSW landfills in „non annex I countries“ (CDM-projects)

- No or limited legal or contractual obligations for LFG recovery

- Amount of biodegradable organic carbon: 40 – 60 kg per ton waste; up to 70% (90% with RTO) of the resulting CH₄ emissions avoided by LF aeration (secondary emissions: 10%; N₂O according to IPCC default value (0.027 kg/Mg TS))

- Approach:
  - Landfill aeration after LFG projects or as an alternative to LFG capture and flaring
  - Thermal off-gas treatment not mandatory (NM0333, AM0083); but it would significantly increase the project performance
Assessment and balance of GHG emissions from aerated LF

- Methane (major contributor of GHG emissions from landfills) generation and release can be minimized
- GHG emission reductions can be achieved in two areas:

1. Landfill body
2. Thermal off-gas treatment (RTO)
### Emission reductions (anaerobic and aerobic landfills)

<table>
<thead>
<tr>
<th>Landfill / example</th>
<th>Annual ER (per ton TS) [kg CO₂,e / Mg TS* a]</th>
<th>Annual ER (per project) [Mg CO₂,e / a]</th>
<th>Crediting period [a]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anaerobic landfills (CDM LFG-projects*, according to PDD’s)</td>
<td>10 – 100</td>
<td>180,000</td>
<td>7 (21) or 10</td>
</tr>
<tr>
<td>Aerobic landfill (planned CDM project in Israel, according to PDD)</td>
<td>30</td>
<td>20,000</td>
<td>7</td>
</tr>
<tr>
<td>Aerobic landfill (example from Germany)</td>
<td>30</td>
<td>4,750</td>
<td>6</td>
</tr>
<tr>
<td>Aerobic landfills 1 million tons MSW (non Annex I countries)</td>
<td>40 – 70</td>
<td>42,000 – 68,000</td>
<td>7</td>
</tr>
<tr>
<td>Semi aerobic landfill (planned CDM project in Malaysia, according to PDD)</td>
<td>~ 15</td>
<td>43,000</td>
<td>8</td>
</tr>
</tbody>
</table>

* as per 09/2010; projects based on ACM0001 and AMS-III.G; UNFCCC/CDM
LF Aeration and Climate Protection - Reduction of GHG emissions -

GHG-Emissions [tons CO₂,eq. / a]

anaerobic landfill

creditable reduction of emissions

Landfill aeration

aerated landfill

total emissions reduction

remaining emission potential

CH₄

CO₂

Flare

CPE

Residual emissions

Project duration (crediting periods) [a]

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21

Introduction  Landfills & GHG  Aeration concepts  Emission reductions  Costs & benefits
Landfill aeration
- Critical remarks -

General:
- Uncertainty regarding the actual amount of \( \text{N}_2\text{O} \) emissions
- Risks related to increased temperatures during aeration
- Emission reductions potentially limited without RTO integration
- Creditable reduction of emissions is limited

Air venting:
- Aeration is secondary effect; at first increase in the amount of captured biogas (i.e. increase in \( \text{CH}_4 \) emissions)

Semi-aerobic concept:
- Emission reductions probably limited (\( \text{CH}_4 \) flux, not concentration !)
- Discontinuous measurement of PE might be critical
### Costs vs. Benefits

#### Costs:
- Very rarely in literature
- For low pressure aeration:
  - D:
    - approx. 1 to 3€ per m³ of landfilled waste*
  - A:
    - approx. 2 to 5€ per m³ of landfilled waste*

#### Benefits:
- Reducing CH₄ emissions from landfills
- Reducing the duration of LF-aftercare – reducing the costs for LF-aftercare
- Improving the quality of leachate – reducing the costs for leachate treatment
- Enhanced environmental conditions

* depending on various factors such as existing infrastructure and landfill volume
Thank you very much for your attention!