


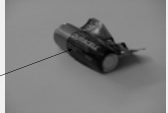
LIFE CYCLE INVENTORY ANALYSIS OF SPENT ALKALINE BATTERIES TREATMENT

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BATTERIES CHARACTERIZATION



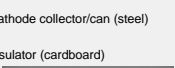
AA alkaline batteries




Outer plastic sleeve (PVC)



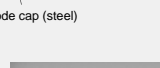
Anode collector (tin-plated brass)




Cathode collector/can (steel)




Insulator (cardboard)



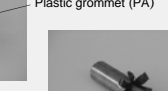
Anode cap (steel)



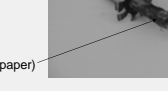
Cathode (MnO₂, C, KOH)



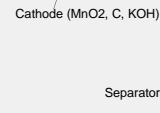
Anode (Zn, ZnO, KOH)




Plastic grommet (PA)




Separators (paper)



Cathode (MnO₂, C, KOH)



Separators (paper)



- Average weight: 23.5 g
- Moisture: 2 g
- Lower heating value: 121 kJ
- Steel: 4.7 g
- Tin-plated brass: 0.44 g
- PVC: 0.23 g
- PA: 0.22 g
- Cardboard: 0.060 g
- Paper: 0.11 g
- Cellophane: 0.045 g
- Mn (cathode): 5.4 g
- C (cathode): 0.71 g
- Zn (anode): 3.2 g
- KOH: 0.92 g
- Others: 7.5 g

Trace elements (mg/battery)

- As: 0.021
- Cd: 0.060
- Co: 0.84
- Cr: 9.5
- Cu: 281
- Hg: 0.0038
- Mn (except cathode): 10.7
- Ni: 65
- Pb: 1.2
- Sb: 0.44
- Si: 0.84
- Tl: 1.4
- Zn (except anode): 265

BATTERIES LANDFILLING

Landfill

MSW landfill

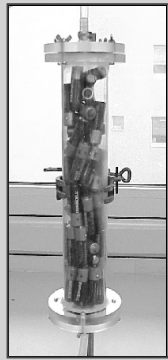
- spread of waste, compaction
- soil covering (daily and final)
- gas extraction system
 - collection efficiency assumed as 50%
 - collected gas is flared on the site
- leachate collection system
- methane oxidation on the soil cover (15%)

Surveyable time period (STP)

- time period until the landfill reaches some kind of pseudo-steady-state
- period until the later part of the methanogenic phase
- magnitude of one century

Infinite time period (ITP)

- when all landfilled material has been released to the environment.



Landfilling process modelling

Diesel for compactor

- 1 L/ton
- Allocation by weight

Daily and final soil cover

- 0.08m³/ton
- 0.125m³/ton

Degradation yield during the STP:

- 3% for PVC and PA
- 70% for paper, cardboard and cellophane

CH₄, CO₂ and NH₃

$$C_{H_2O,N,S} + (a + \frac{b}{4} - \frac{c}{2} - \frac{d}{2} - \frac{e}{2} - \frac{f}{2} - \frac{g}{2} - \frac{h}{2} - \frac{i}{2} - \frac{j}{2} - \frac{k}{2} - \frac{l}{2} - \frac{m}{2} - \frac{n}{2} - \frac{o}{2} - \frac{p}{2} - \frac{q}{2} - \frac{r}{2} - \frac{s}{2} - \frac{t}{2} - \frac{u}{2} - \frac{v}{2} - \frac{w}{2} - \frac{x}{2} - \frac{y}{2} - \frac{z}{2}) CH_4 + (\frac{a}{2} - \frac{b}{4} + \frac{c}{2} - \frac{d}{2} + \frac{e}{2} - \frac{f}{2} + \frac{g}{2} - \frac{h}{2} + \frac{i}{2} - \frac{j}{2} + \frac{k}{2} - \frac{l}{2} + \frac{m}{2} - \frac{n}{2} + \frac{o}{2} - \frac{p}{2} + \frac{q}{2} - \frac{r}{2} + \frac{s}{2} - \frac{t}{2} + \frac{u}{2} - \frac{v}{2} + \frac{w}{2} - \frac{x}{2} + \frac{y}{2} - \frac{z}{2}) CO_2 + aNH_3 + bH_2S$$

degraded carbon outflow:

- 1% weight via leachate (mainly as fatty acids)
- 99% via the landfill gas (as CH₄ and CO₂)

1g of total organic carbon (TOC) corresponds to 3g of chemical oxygen demand (COD)

- BOD/COD=0.25 during the STP
- On the ITP a complete degradation of the materials occurs and the major degradation product is assumed to be CO₂

Results 1 battery

	Outputs Air emissions (mg)	STP	ITP
CO ₂		195.7	1078
CH ₄		19.9	19.9
HCl		3.9	3.9
NH ₃		0.96	0.96
Cd		3.00E-06	6.00E-03
Hg		1.90E-07	1.90E-03
Water emissions (mg)			
TOC		0.69	0.69
COD		2.1	2.1
BOD		0.52	0.52
As		4.20E-05	2.10E-02
Cr		2.70E-05	5.40E-02
Co		6.65E-03	9.50E+00
Cu		1.97E-02	2.81E+02
Fe		4.66E-01	4.66E+03
Hg		1.90E-07	1.90E-03
Ni		3.25E-01	6.50E+01
Pb		7.20E-05	1.20E+00
Zn		7.14E-01	3.57E+03

Inputs

- Energy (diesel): 2.35E-05 L
- Soil cover: 4.82E-06 m³

BATTERIES INCINERATION

Incineration operation conditions

Mass-burn incinerator

- 379 918 t/y
- 7 700 kJ/kg

Semi-dry flue gas cleaning system

- Ammonia solution (NO_x): 1 620 t/y
- Ca(OH)₂ (acid gases): 7 446 t/y
- Activated carbon (dioxins, Hg): 38 t/y
- Fabric filter (particles)

Fly ash stabilization

- Additives: 26 060 t/y

Water: 106 507 m³/y

Electricity: 2.5 MWh

Solid residues

- Bottom ash: 70 285 t/y
- Recovered ferrous: 13 860 t/y
- Fly ash: 23 175 t/y

Air emissions

- Flue gas: 1 857 240 000 Nm³
- CO₂, SO₂, HCl, HF, Dust
- Cd, Ti, Hg, Sb, As, Pb, Cr, Co, Cu, Mn, Ni, V
- CO, COV, Dioxins/furans, NO_x

Electricity: 24.7 MWh



Incineration process modelling

- Bottom ash
 - All inert components
- Fly ash
 - Ash content organic components
 - Zinc metal oxidation
 - 99.5% filter efficiency
 - + calcium hydroxide, activated carbon
- Stabilized fly ashes
 - Fly ash amount
 - Stabilization additives
- Electricity production
 - Heating value batteries
 - Total heating value of MSW
 - Plant production
- Ammonia, calcium hydroxide, activated coke
 - NO_x, acid gases, dioxins from batteries
 - Total NO_x, acid gases, dioxins from waste
 - Plant consumption
- Stabilization additives
 - Fly ash from batteries
 - Fly ash from waste
 - Plant consumption
- Energy, water consumption
 - Mass batteries
 - Total mass waste
 - Plant consumption

Incineration process modelling - air emissions

- CO₂
 - C content batteries
 - 97% oxidation
- SO₂, HCl
 - S and Cl content batteries
 - 80% transferred to gas
 - 95% cleaning efficiency
- Dust
 - Ash content organic components
 - Zinc metal oxidation
 - 100% transferred to gas
 - 99.5% filter efficiency
- Heavy metals
 - Laboratory incineration tests
 - 90% removal efficiency Hg
 - 99% for other metals
- CO, COV, Dioxins/furans
 - C content batteries
 - Total C waste (0.3 kgC/kg waste)
 - Plant total emission
- NO_x
 - Fuel: 95%
 - N content batteries
 - Total N content waste (0.007 kgN/kg waste)
 - Prompt: 5%
 - Organic carbon (plastic/paper)
 - Total C waste
 - Plant total emission

Results - 1 battery

Inputs	Air emissions
Ammonia solution: 0.016 g	CO ₂ : 3.6 g
Calcium hydroxide: 0.24 g	SO ₂ : 0.032 mg
Activated carbon: 0.34 mg	HCl: 5.2 mg
Fly ash stabilization additives: 3.6 g	Dust: 15.1 mg
Water: 6.6 ml	As: 1.0E-06 mg
Electricity: 1.5E-07 kW	Cr: 2.5E-02 mg
	Cu: 9.0E-04 mg
	Mn: 1.9E-02 mg
	Pb: 3.6E-03 mg
	Tl: 2.0E-04 mg
	CO: 0.83 mg
	COV: 0.17 mg
	Dioxins/furans: 0.0017 mg
	NO _x : 4.5 mg

