Longterm Aftercare of Landfills

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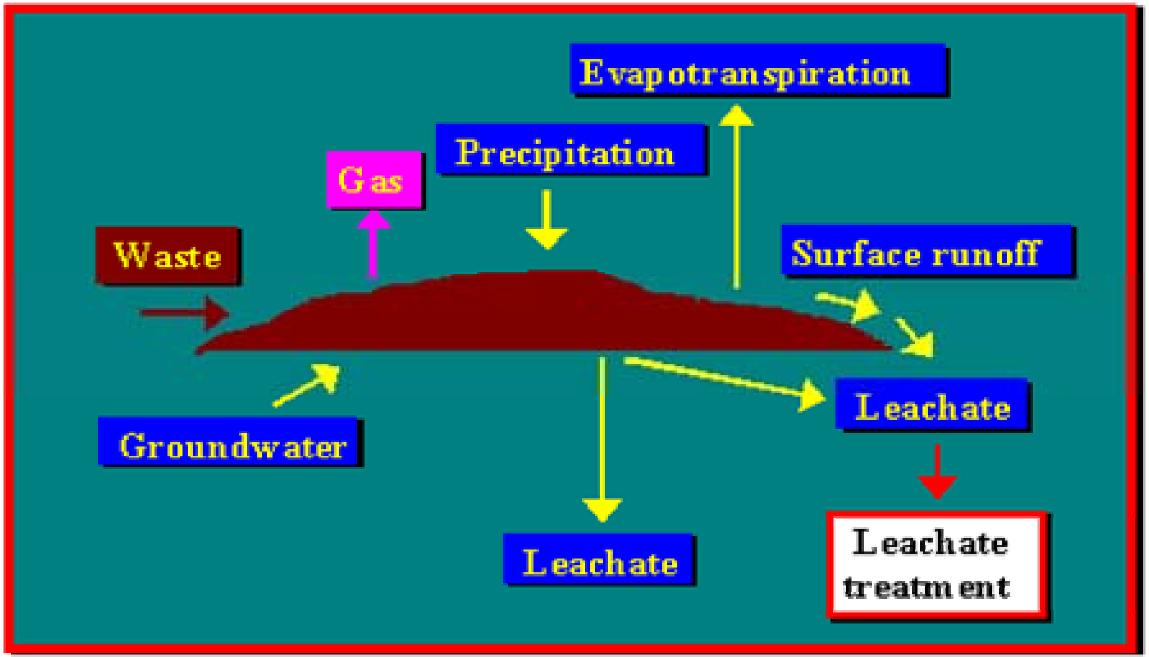
Lecture Padova 2004

Landfill Technology

Processes in Landfill Bodies

Prozesse im Deponiekörper/
Processes in the Landfill Body

The landfill as a flow system



Prozesse im Deponiekörper/ Processes in the Landfill Body

Aerobe Abbauprozesse / Aerobic processes

$$C_6H_{12}O_6 + O_2 \rightarrow CO_2 + H_2O + \text{Biomass} + \text{Heat}$$

1 kg	0,64 kg	0,88 kg	0,34 kg	0,40 kg	9300 kj

(Angaben als Trockengewicht / Dry matter)

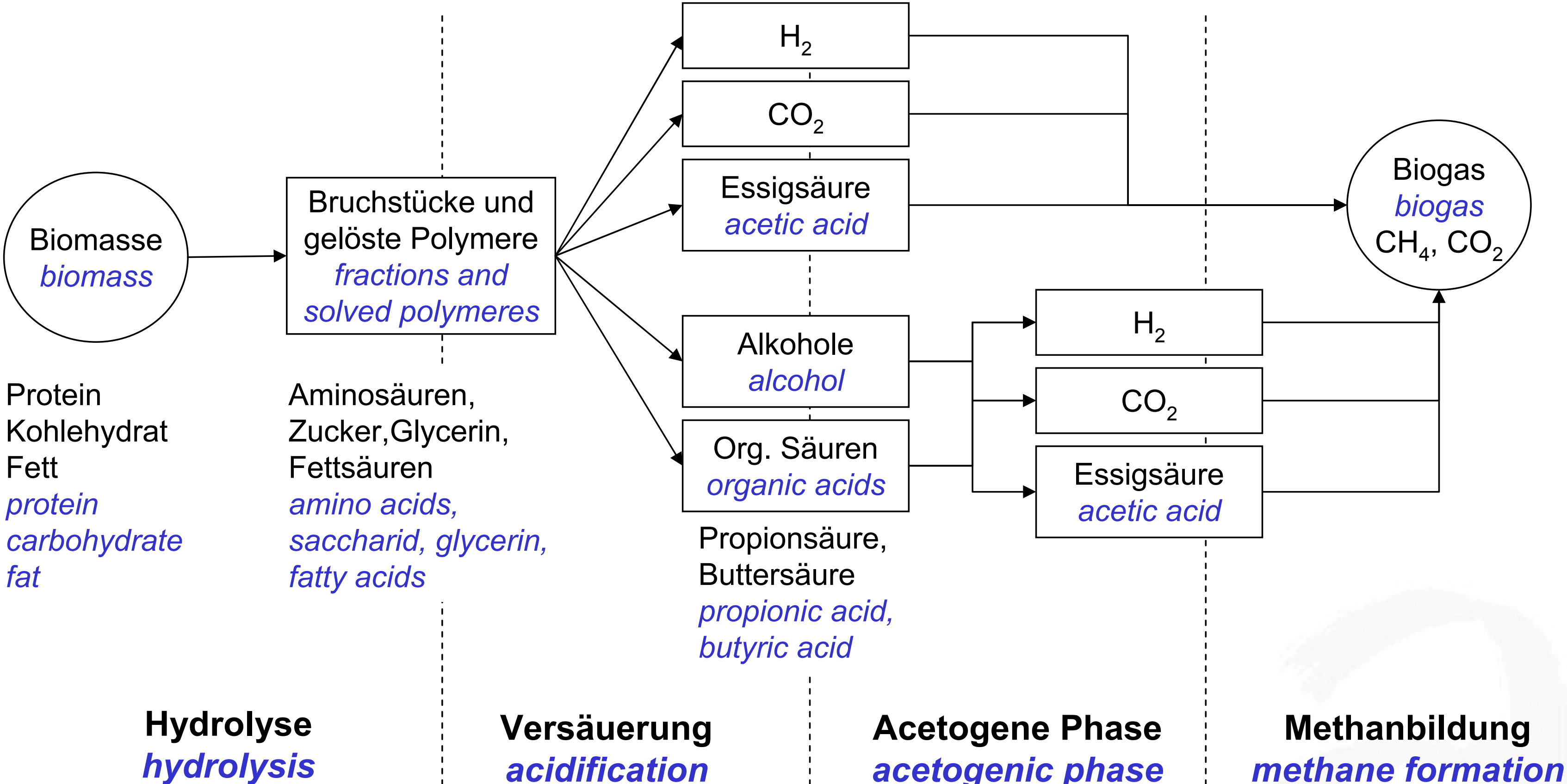
Anaerobe Abbauprozesse / Anaerobic processes

$$C_6H_{12}O_6 \rightarrow CH_4 + CO_2 + \text{Biomass} + \text{Heat}$$

1 kg	0,25 kg	0,69 kg	0,056 kg	632 kj

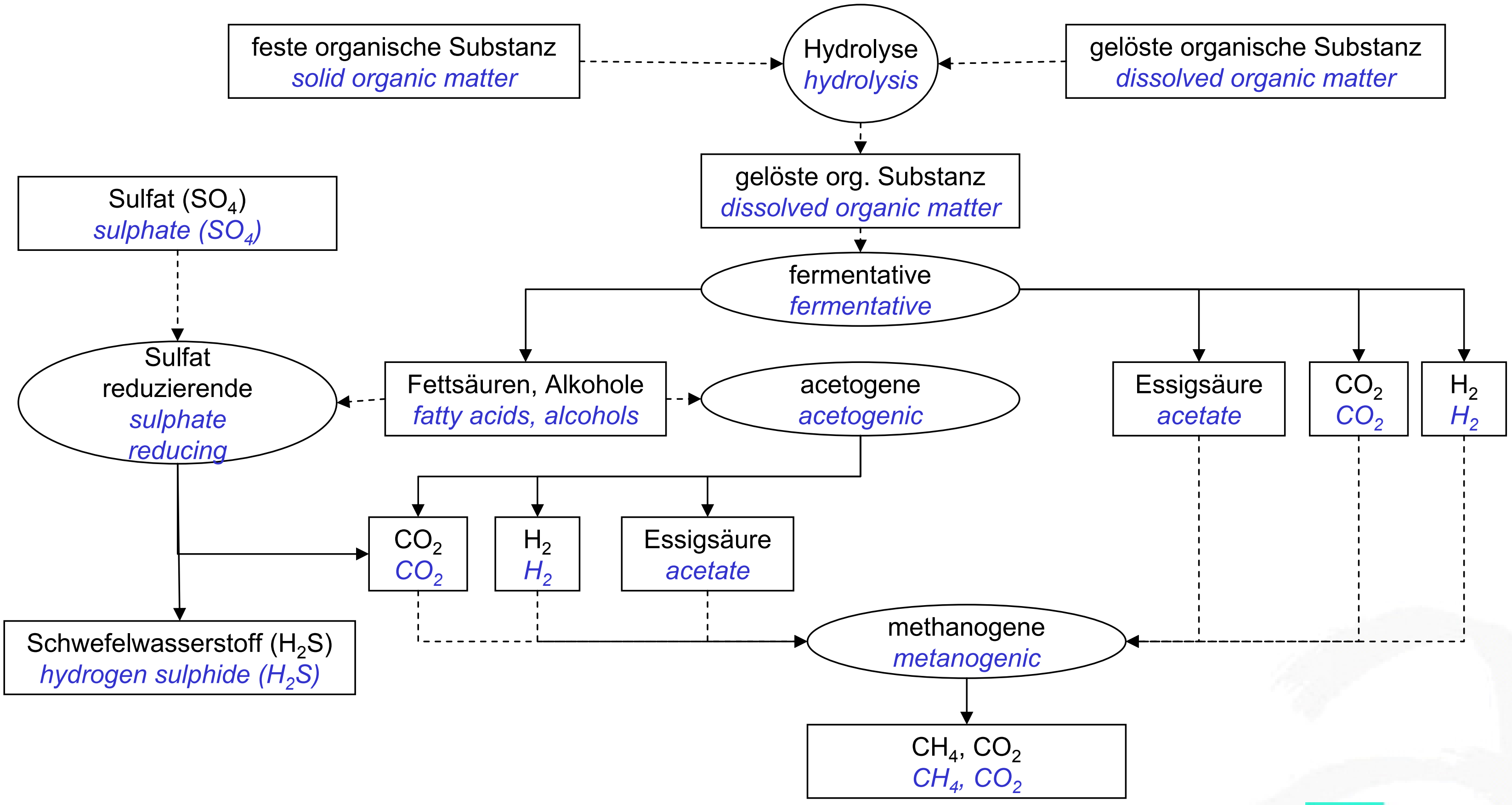
(Angaben als Trockengewicht / Dry matter)

Anaerober Abbau I /
Anaerobic Degradation Process I



BMBF Statusbericht „Deponiekörper“, 1995

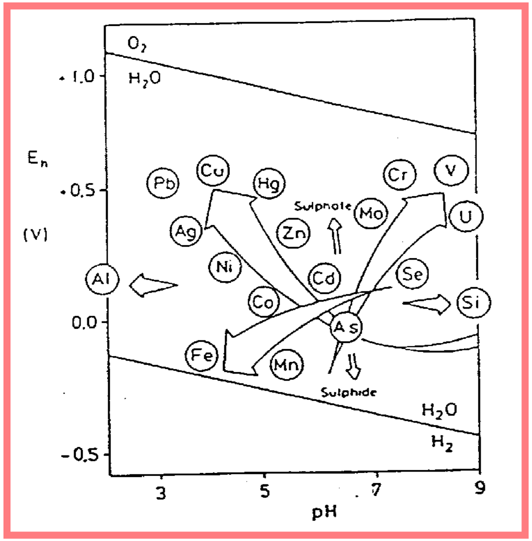
Anaerober Abbau II
Anaerobic Degradation Process II



Schwermetalle /
Heavy Metals

Mobilität von Schwermetallen im Sickerwasser

- Löslichkeit (Erhöhung durch organische Komplexbildner)
- Acidität (Erhöhung hauptsächlich in der acetogenen Phase)
- Adsorption und Desorption
- Immobilisierung durch Fällungsreaktionen (z.B. Eisenfällung)
- Oxidative Prozesse (z.B. Sulfat-Atmung)

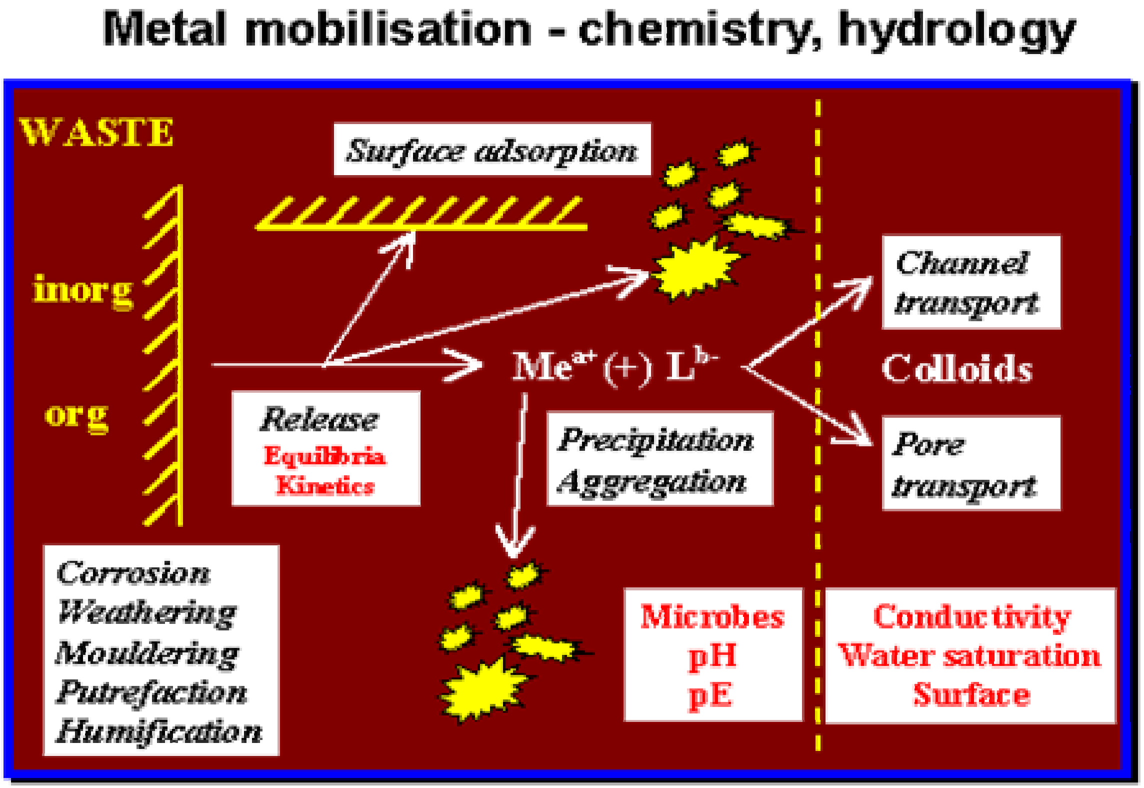


Förstner, 1989

Mobility of Heavy Metals in Leachate

- *Solubility (Increases with organic complex builders)*
- *Acidity (increase mainly within acetogenic phase)*
- *Adsorption and Desorption*
- *Immobilisation by precipitation (e.g. Precipitation of Iron)*
- *Oxidative processes (e.g. Sulphate respiration)*

Metal mobilisation



Emissionsbestandteile / Emission-Components

Sickerwasser / Leachate

- organische Bestandteile (CSB, BSB, TOC) /organic components (COD, BOD, TOC)
- Salze / Salts
- Stickstoff / Nitrogen
- Schwermetalle / Heavy Metals
- Halogenierte organische Verbindungen (AOX) / adsorbable organic halogen compounds (AOX)

Deponiegas / Landfillgas

- Hauptkomponenten / Main Components (CH_4, CO_2, H_2, O_2, N_2)
- Spurenstoffe / Trace components (BTEX, CFC, Hydrogen Sulfide ...)

Leachate Composition II

Average concentrations of biochemical influenced leachate components

		average values acetogenic phase		average values methanogenic phase	
		Ehrig, 1989	Kruse, 1994	Ehrig, 1989	Kruse, 1994
pH	[-]	6,1	7,4	8,0	7,6
BSB_5	[mg / l]	13000	6300	180	230
CSB	[mg / l]	22000	9500	3000	2500
BSB_5 / CSB	[-]	0,58		0,06	
Sulfat	[mg / l]	500	200	80	240
Ca	[mg / l]	1200	650	60	200
Mg	[mg / l]	470	285	180	150
Fe	[mg / l]	780	135	15	25
Mn	[mg / l]	25	11	0,7	2
Zn	[mg / l]	5	2,2	0,6	0,6
Sr	[mg / l]	7		1	
AOX	[µg / l]	1674	2400	1040	1725

Chang: „Auslegung von einstufigen Belebungsanlagen zur Stickstoffelimination bei Sickerwässern aus Siedlungsabfalldeponien", 1998

Leachate Composition III

average concentrations of non biochemical influenced leachate components

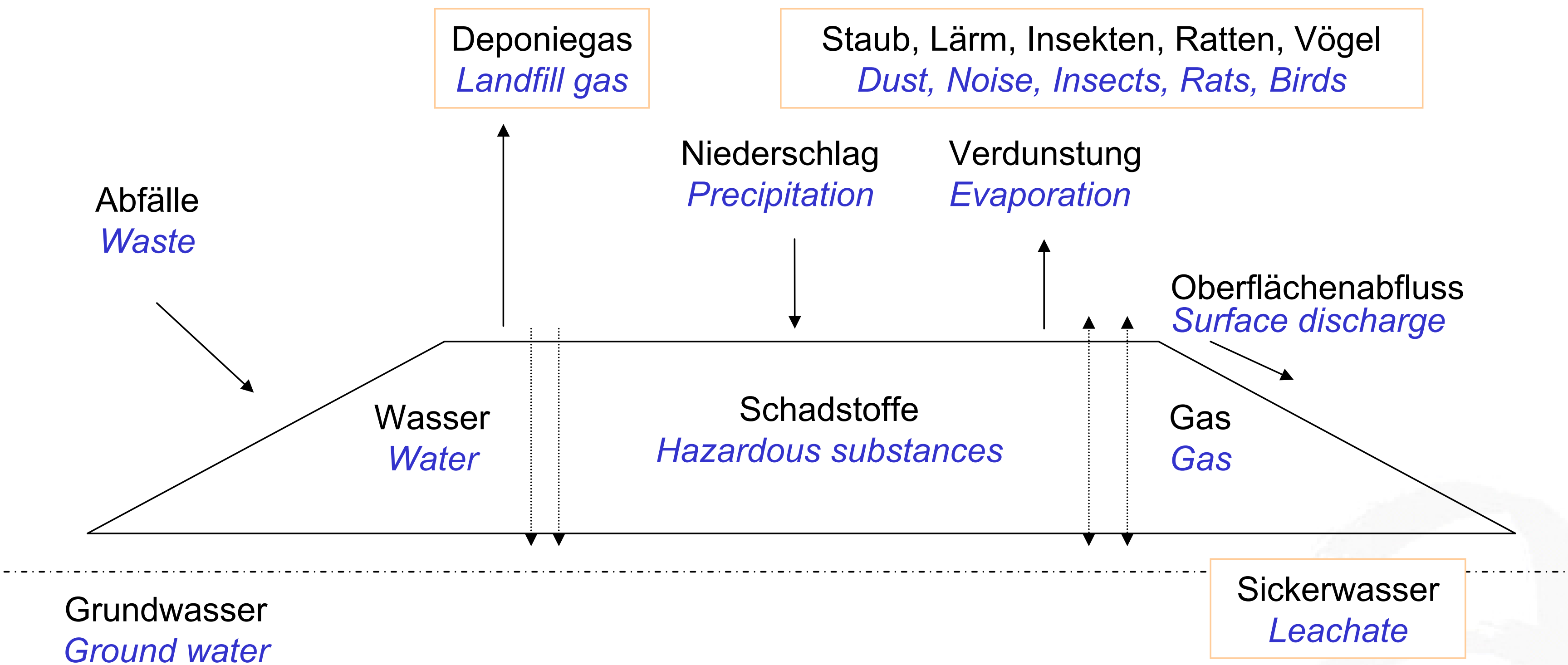
		Ehrig, 1989	Kruse, 1994
TKN	[mg / l]	1250	920
NH4-N	[mg / l]	740	740
ges. P / *total P*	[mg / l]	6	6,8
Chlorid	[mg / l]	2100	2150
Na	[mg / l]	1350	1150
K	[mg / l]	1100	880
As	[µg / l]	160	25,5
Pb	[µg / l]	90	160
Cd	[µg / l]	6	37,5
Cr	[µg / l]	300	155
Co	[µg / l]	55	
Cu	[µg / l]	80	90
Ni	[µg / l]	200	190
Hg	[µg / l]		1,5

TKN = total Kjeldal nitrogen

Chang: „Auslegung von einstufigen Belebungsanlagen zur Stickstoffelimination bei Sickerwässern aus Siedlungsabfalldeponien“, 1998

Emissionen aus Deponien / Landfill Emissions

Stofflüsse / Mass Transfer Within The Landfill



Long-term behaviour of landfills

*The long-term behaviour of a landfill site is essentially determined by **biological**, **chemical**, and **physical** processes in the landfill body and the **toxicity** of the deposited materials. The gas - / and leachate emissions can lead to a long-term impairment of the environment.*

Estimation of periods T_E for reaching the target values C_e

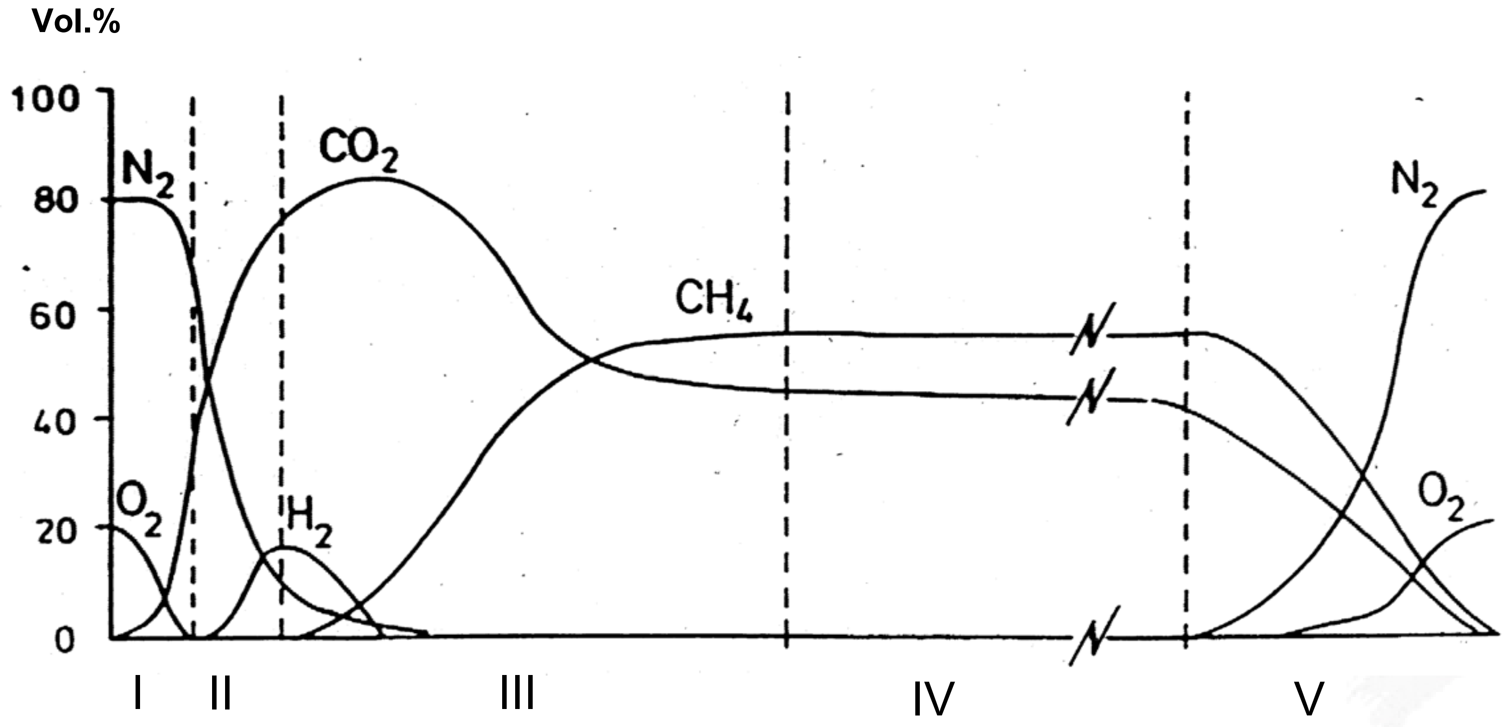
Parameter	C_E Limiting concentrations [mg/l]	C_0 Concentrations at the test beginning [mg/l]	T★ Half-life [a]	T_E Periods [a]
COD	**$C_{E2-51.Anhang}$ = 200 mg/l**	2.000 - 43.000	25 - 96	**120 - 220**
	$C_{E1-Switzerland}$ = 60 mg/l	2.000 - 43.000	25 - 96	200 - 300
TKN	**$C_{E2-51.Anhang}$ = 70 mg/l***	800 - 3.900	40 - 150	**120 - 300**
	$C_{E1-Switzerland}$ = 5 mg/l	800 - 3.900	40 - 150	280 - 580
Cl	**$C_{E-Switzerland}$ = 100 mg/l**	500 - 4.200	40 - 90	**120 - 220**

* total amount of nitrogen, sum of ammonia, nitrite and nitrate

TUHH
Technische Universität Hamburg-Harburg

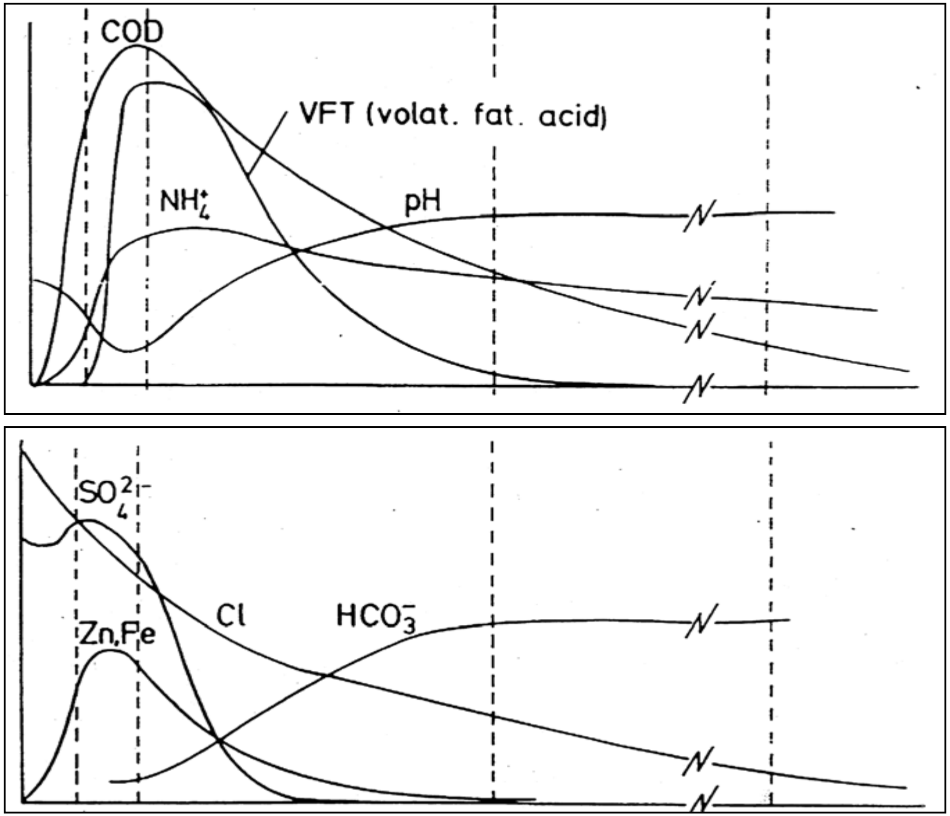
abfallwirtschaft

Gaszusammensetzung
Landfill Gas Composition



BMBF Statusbericht „Deponiekörper“, 1995

Sickerwasserzusammensetzung / Leachate Composition



Phase I II III IV V

BMBF Statusbericht „Deponiekörper“, 1995

Aim: Sustainable Landfill

Own Definition:

„Landfill requiring little aftercare and creating low short and long-term risk“

Aim

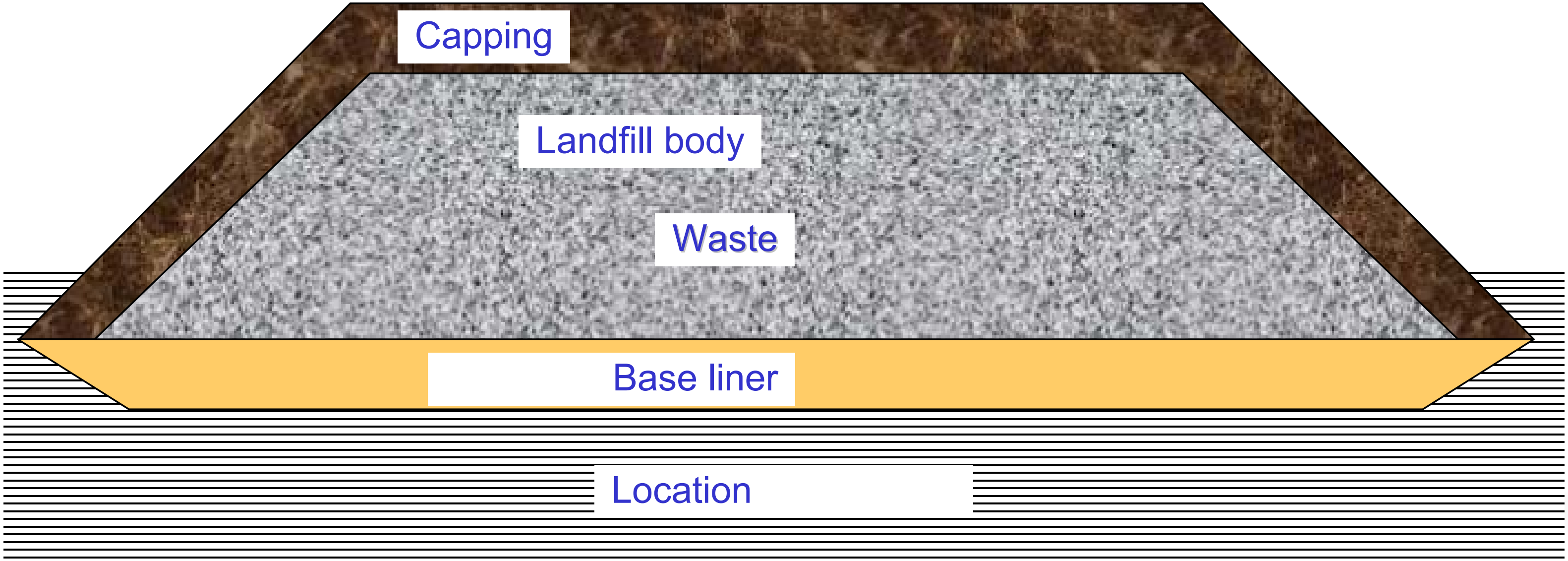
- Closed landfills without supervision after 30 years (one generation) → no transfer of waste problems from today to future generations

⇨ German “Solution“

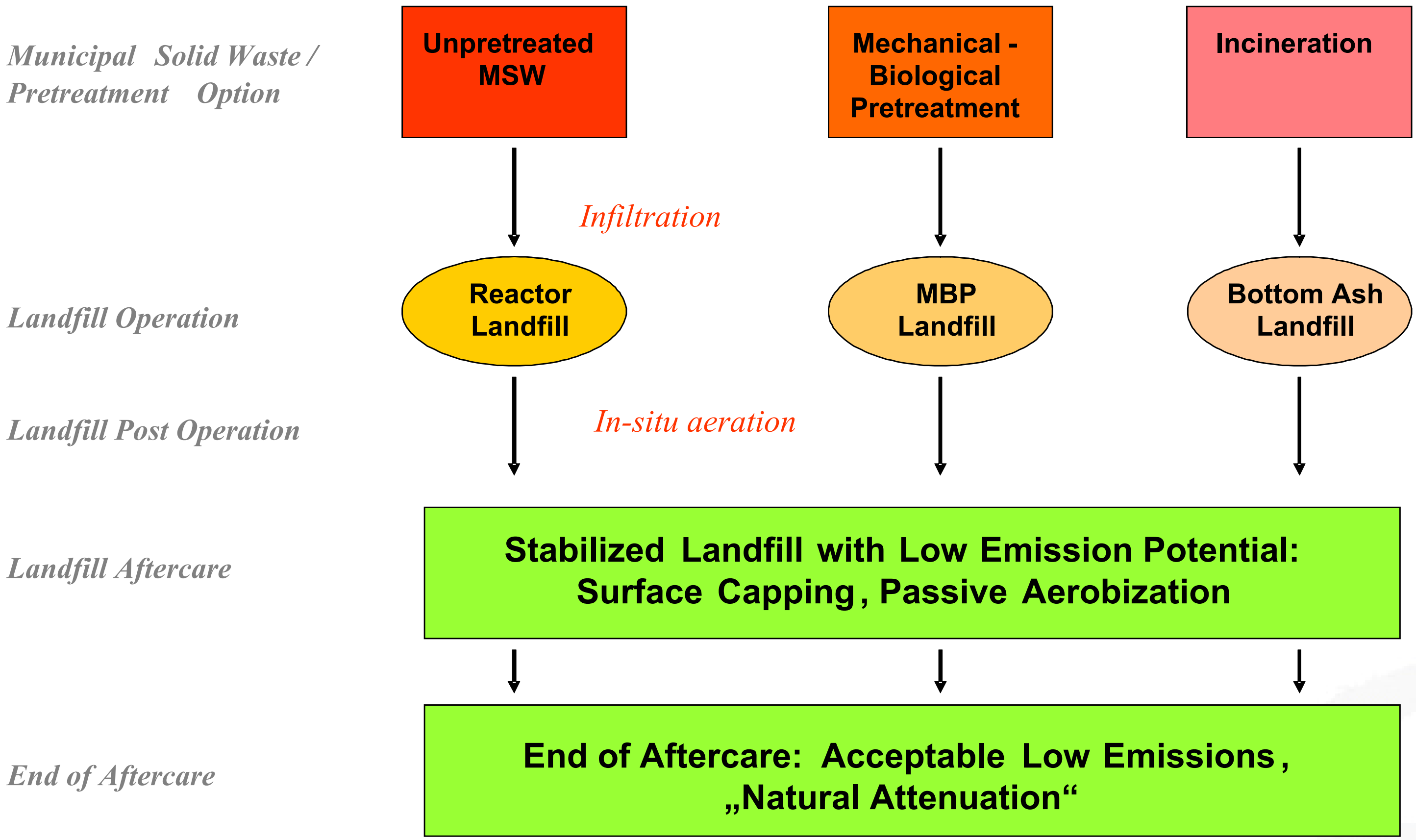
- Multibarrier system

[Literaturhinweis: asasas]

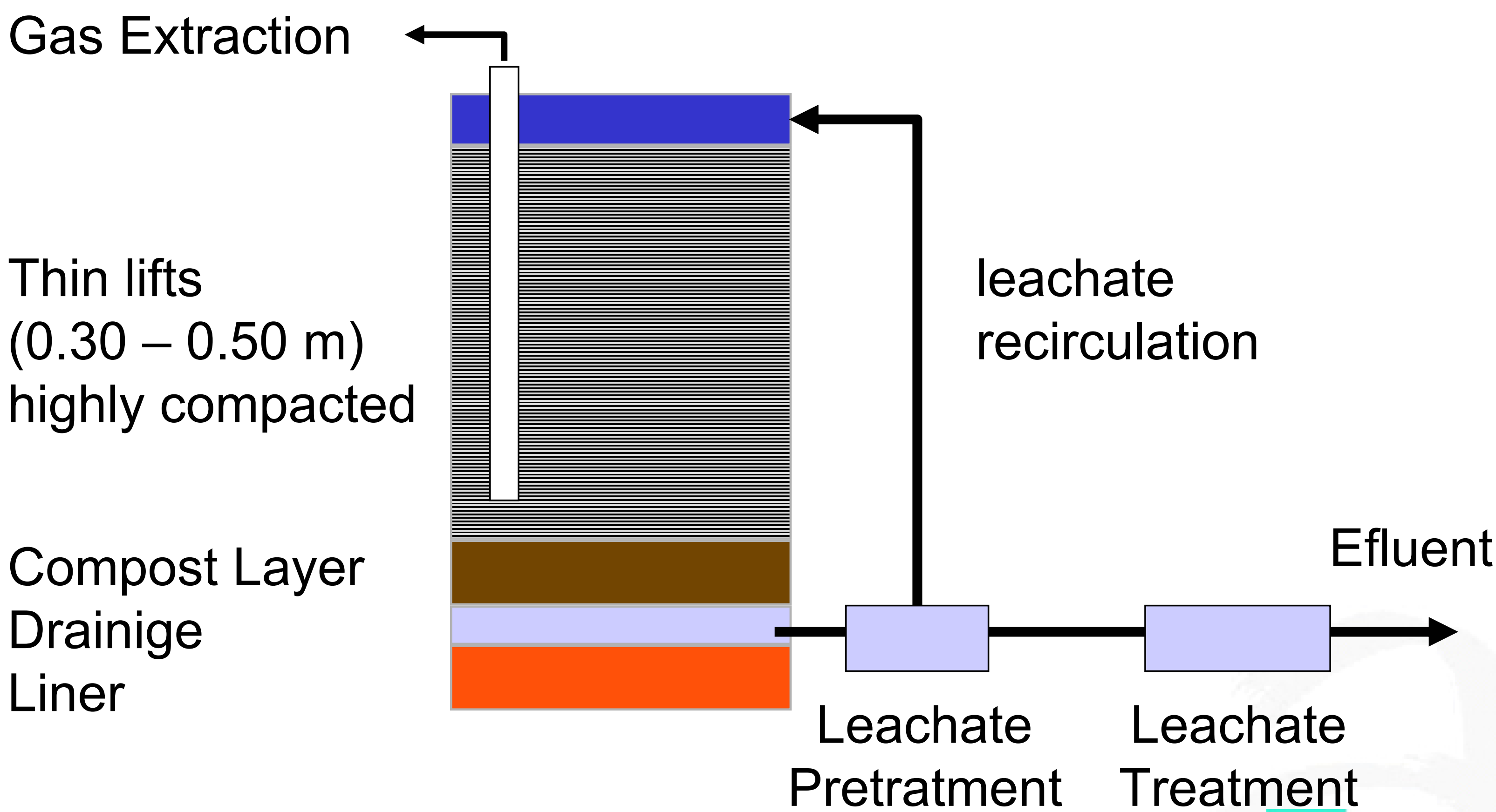
Multibarrierenkonzept II



Pretreatment and operation measures for a sustainable landfill



Reactor Landfill



Operation scheme for closed Landfills

Approx. 10 – 15 years after closure

Leachate treatment
gas collection utilization
If need be irrigation

↓ At low gas production

Approx. 2 years

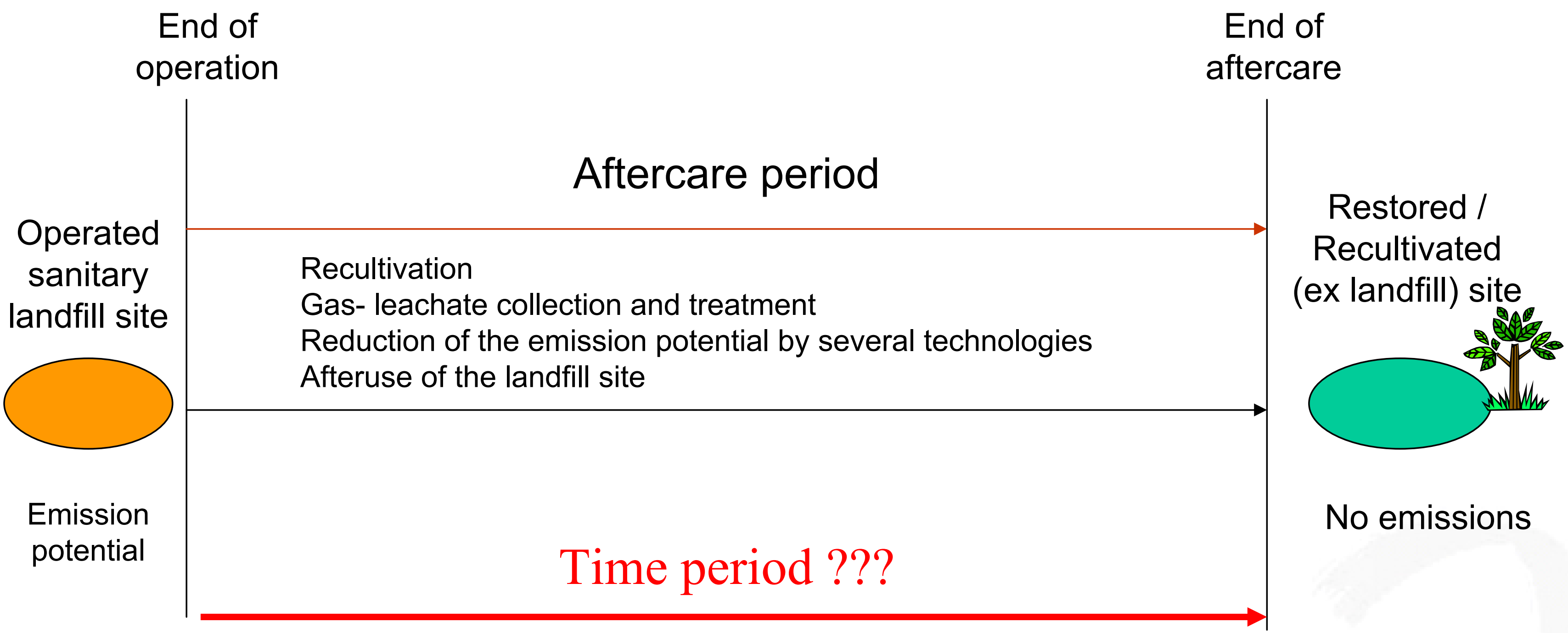
In situ- aeration
leachte re-circulation
leachate treatment

↓ At low biological activity

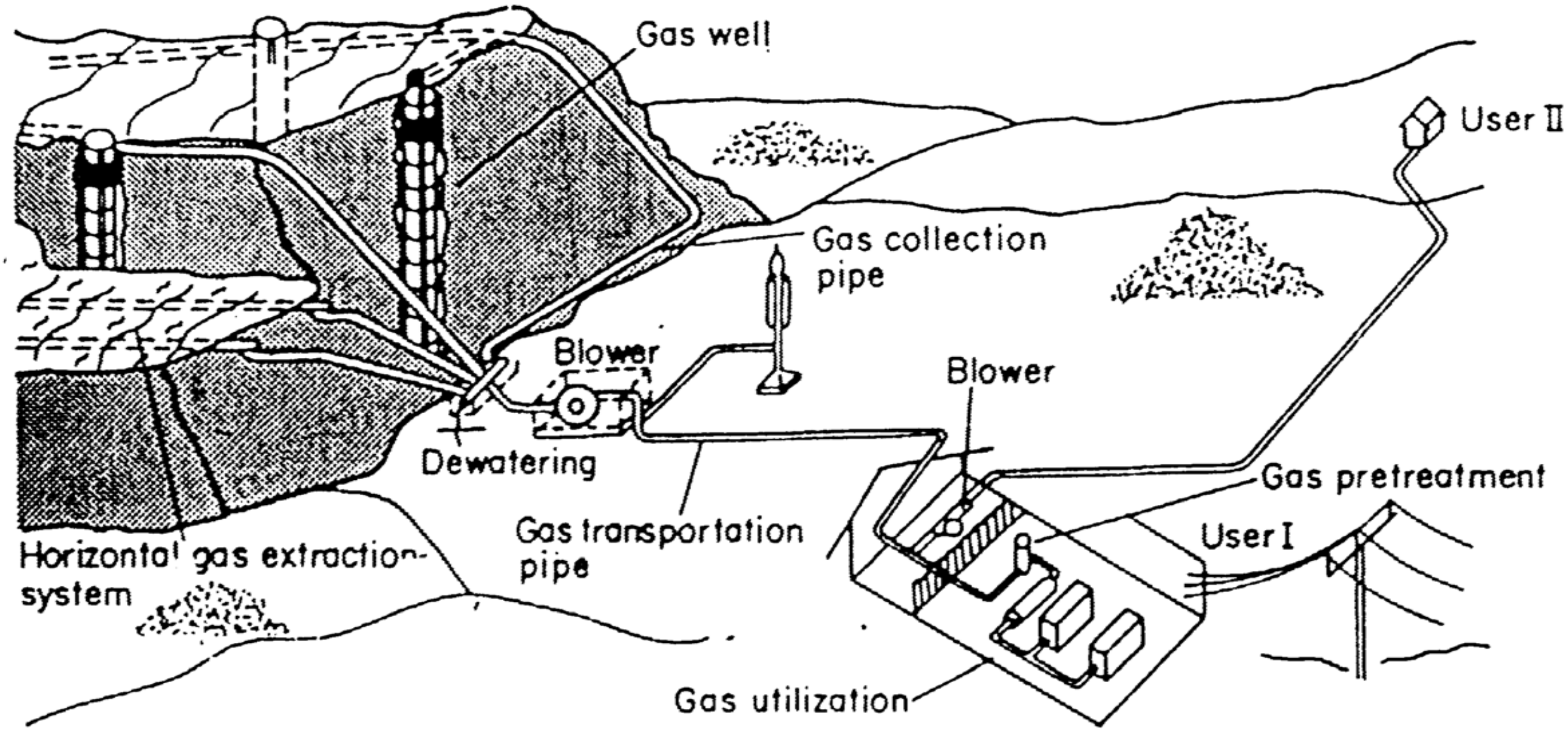
Long term

surface capping
passive aeration
co- treatment with sewage or „ natural“ treatment
supervision / monitoring

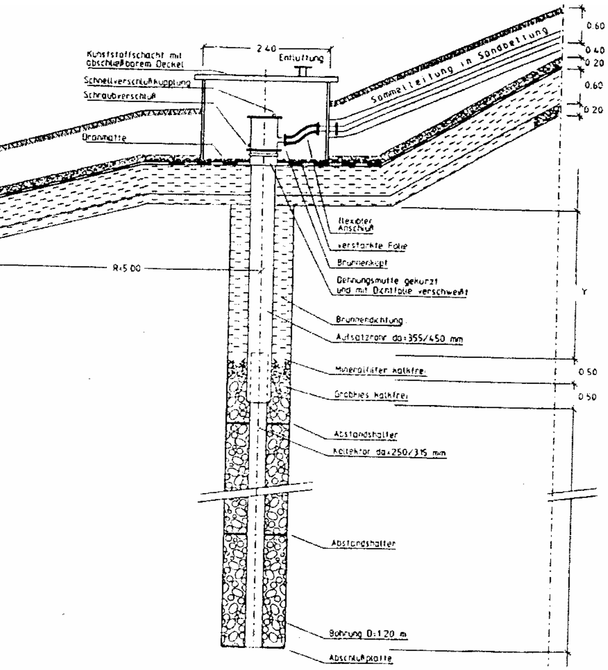
Nachsorge
Aftercare

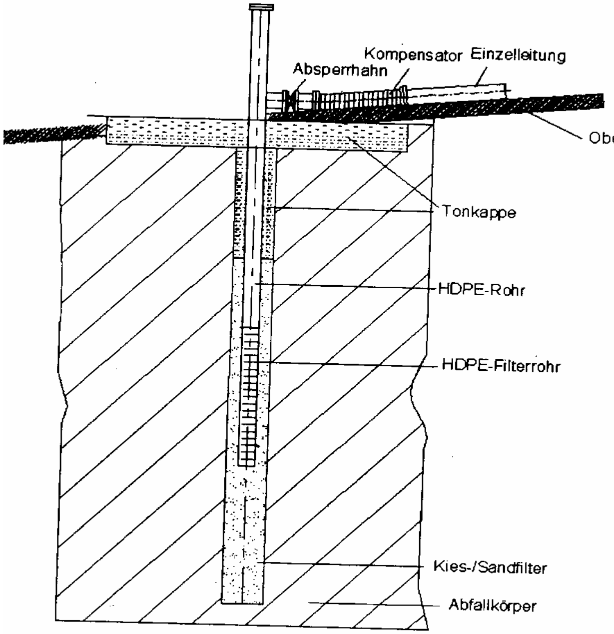


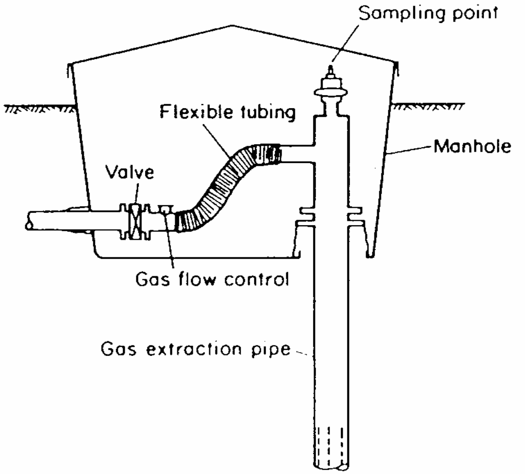
Landfill gas extraction system



Gas wells


Kunststoffschacht mit abschließbarem Deckel
2.40
Entlüftung
Schnellverschlußkupplung
Schraubverschluß
Dränmatte
Sammelleitung in Sandbettung
0.60
0.40
0.20
0.60
0.20
flexibler Anschluß
verstärkte Folie
Brunnenkopf
R=5.00
Dehnungsmuffe gekürzt und mit Dichtfolie verschweißt
Brunnendichtung
Aufsatzrohr da=355/450 mm
Mineralfilter kalkfrei
0.50
Grobkies kalkfrei
0.50
Abstandshalter
Kollektor da=250/315 mm
Abstandshalter
Bohrung D=1.20 m
Abschlußplatte


Kompensator
Einzelleitung
Absperrhahn
Oberflächenabdeckung
Tonkappe
HDPE-Rohr
HDPE-Filterrohr
Kies-/Sandfilter
Abfallkörper


Sampling point
Flexible tubing
Manhole
Valve
Gas flow control
Gas extraction pipe

Aerobic Biological Methods
Activation Plants

Activation Lagoon; Waldeck / Germany

Activation Lagoon; Lingen / Germany

Recultivation Example

After covering the waste with a HDPE-liner, the recultivation layer has to be constructed

First step: compacted subsoil layer

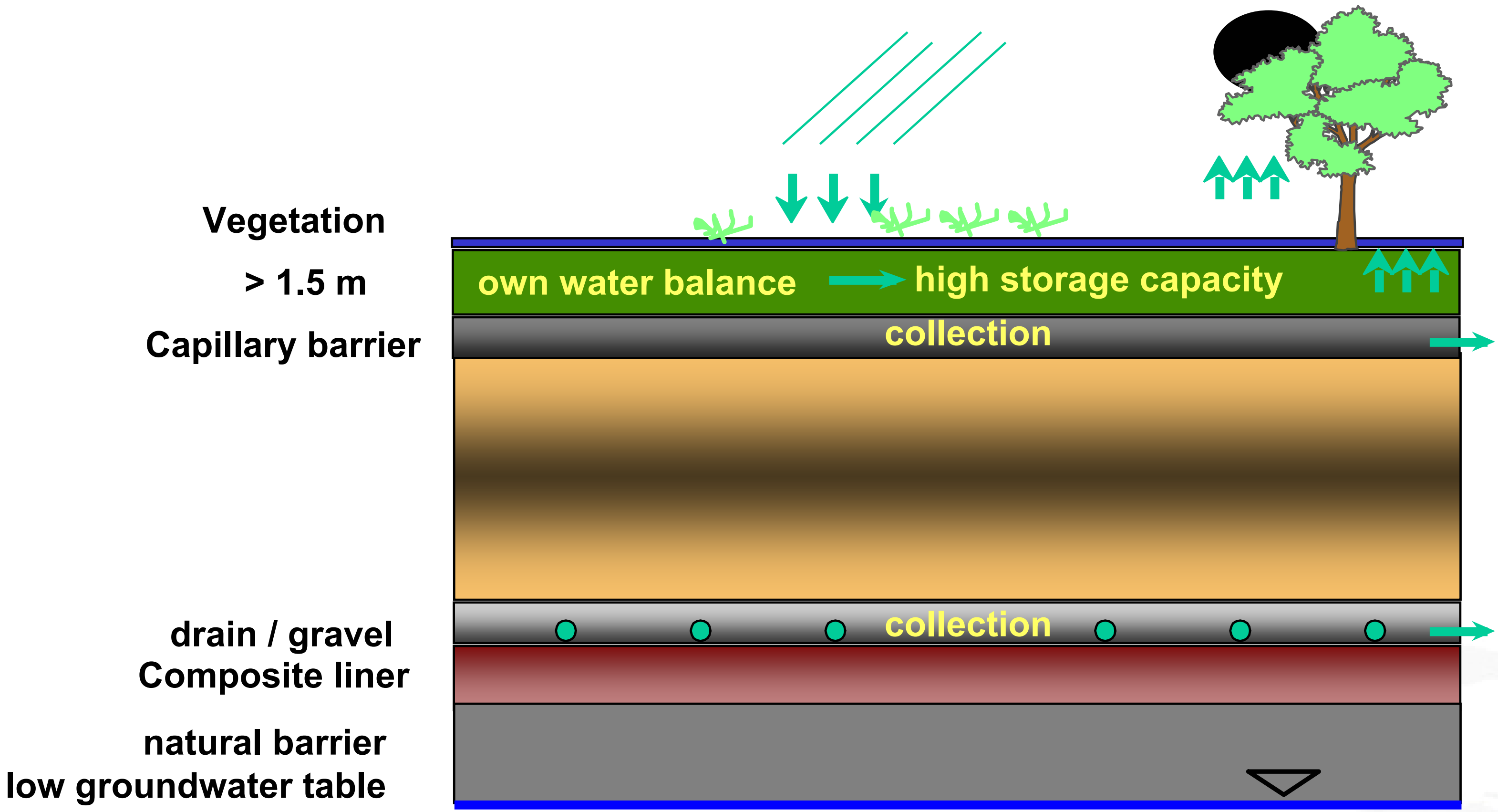
Second step: topsoil layer

Quelle: Trinekens

Concept for Closed Landfills

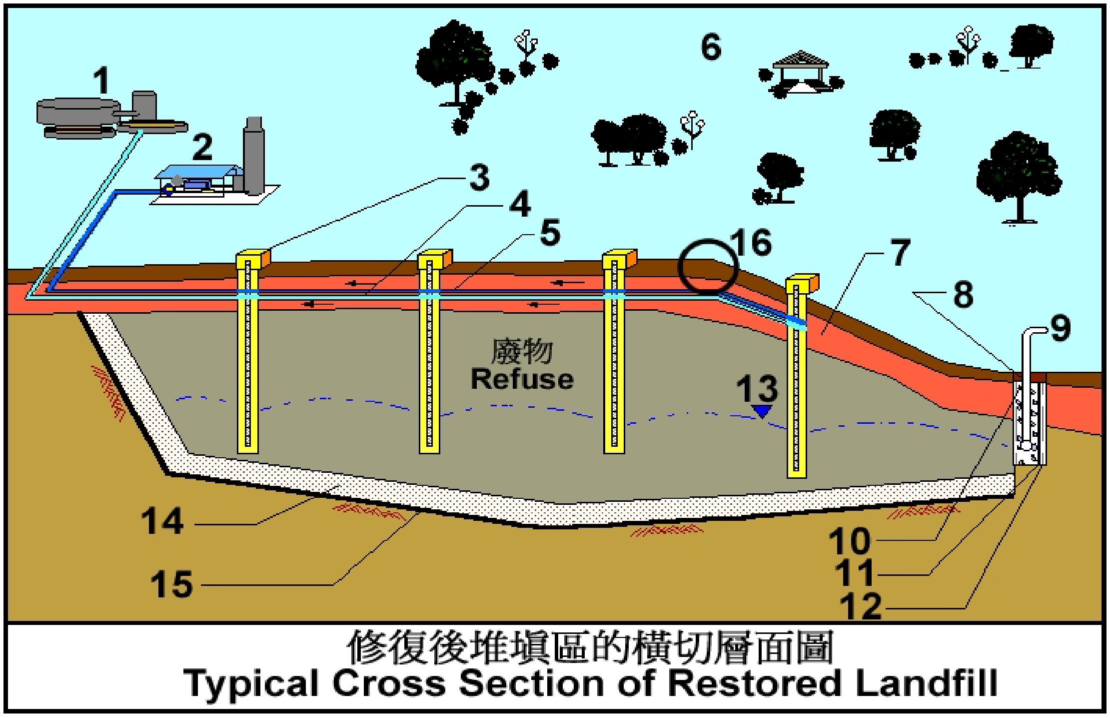
- **Reduction of emission potential**
  - water addition/ re-circulation (only for lined landfills)
  - in-situ aeration
- **Reduction of emissions**
  - surface capping for minimizing leachate production
  - passive aeration for avoiding methane emissions
- **Low long term maintenance**
  - alternative surface cap
  - leachate treatment using “natural“ systems (f.e. lagoons, wetlands) or co-treatment with sewage

Modified Landfill concept for MBP Waste



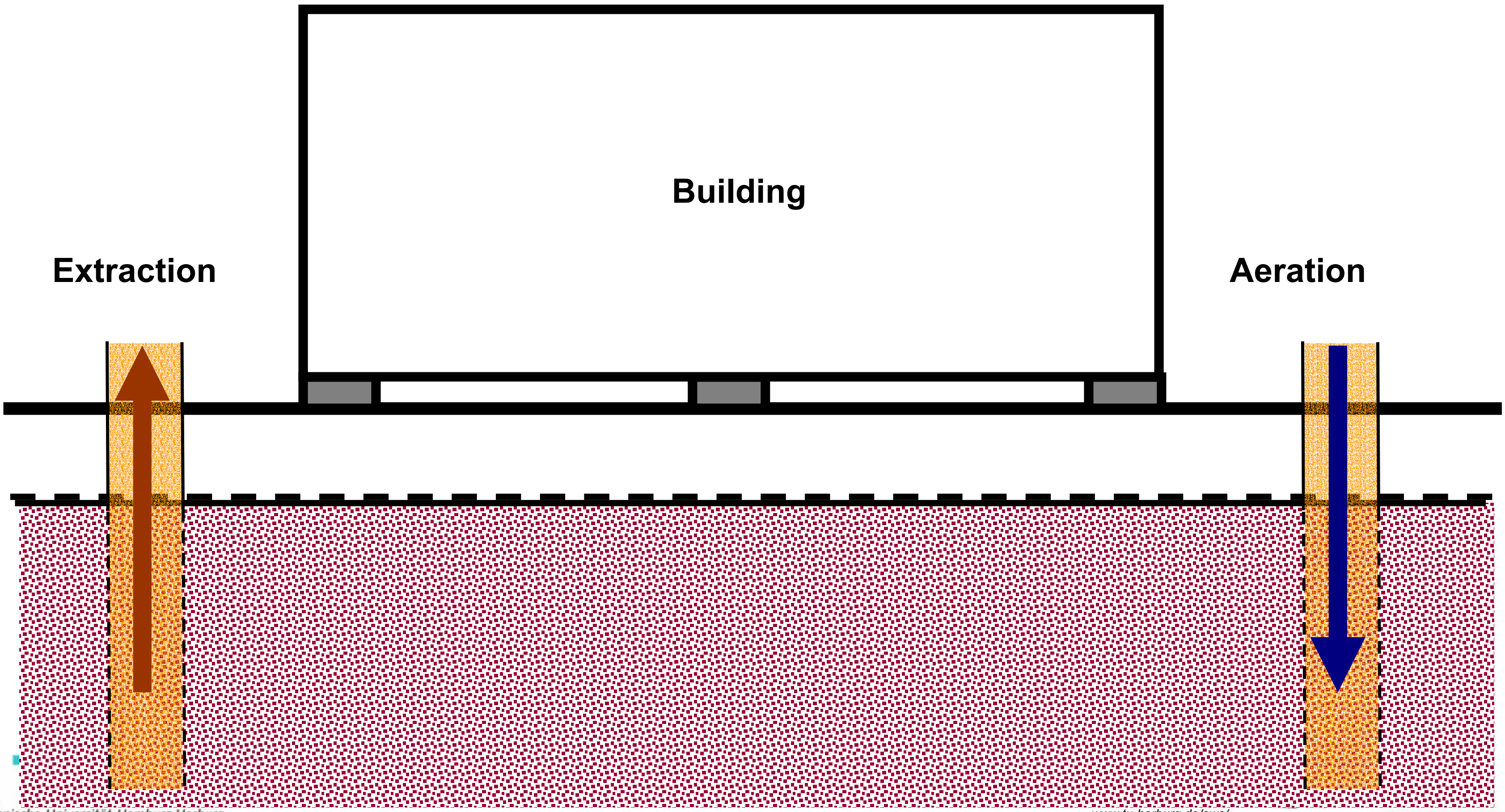
Leachate treatment in wetlands/ lagoons

Typical recultivation details

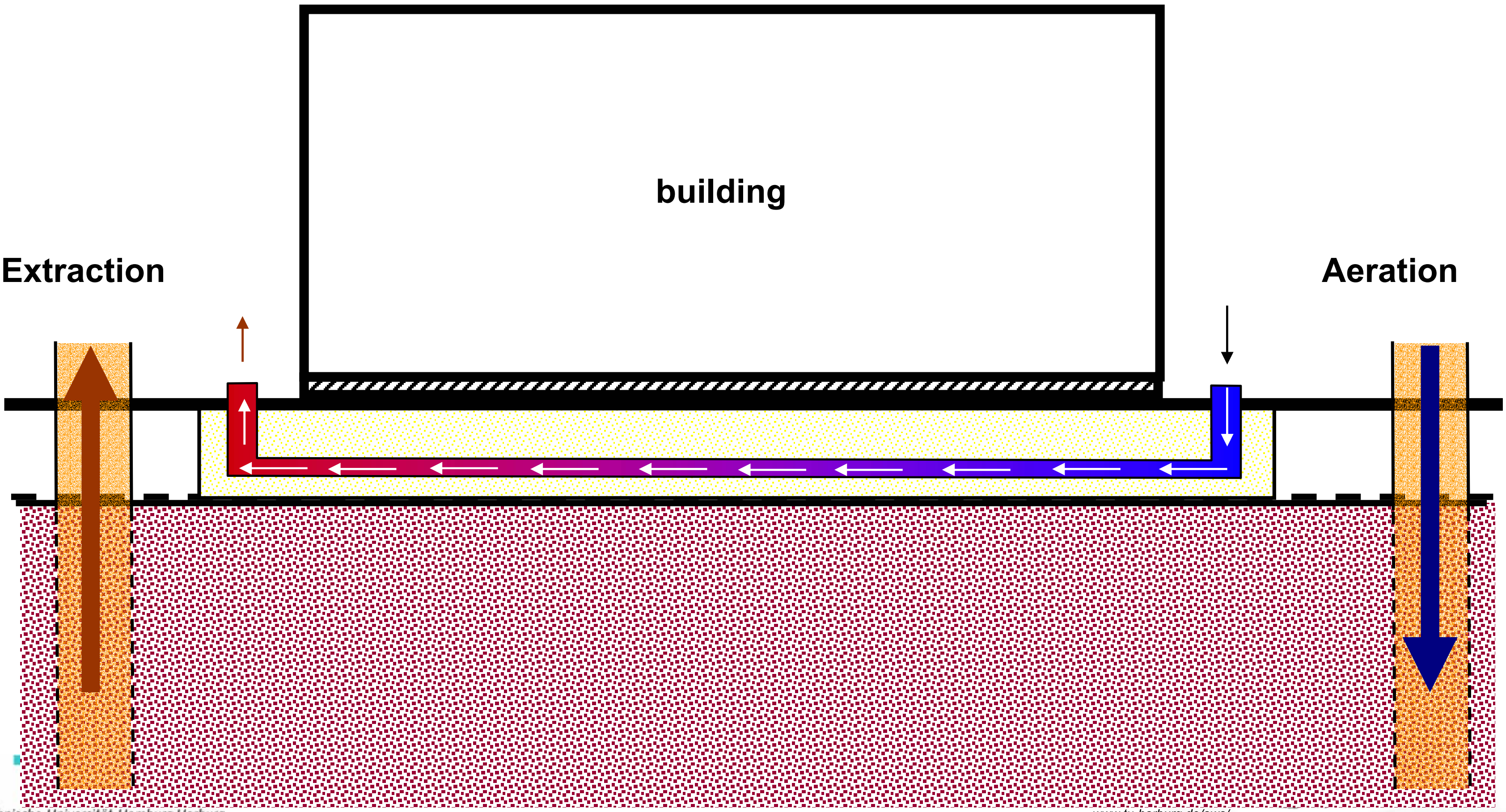


1. Leachate Treatment Plant
2. Gas Treatment Plant
3. Leachate / Gas Extraction Well
4. Leachate Header/collector and pipe system
5. Gas Header/ Collector and pipe system
6. Recreational or Other Beneficial Use (Compensation measures)
7. Landfill Cover
8. Gas Venting Trench
9. Vertical Riser
10. Crushed Stone
11. Geomembrane
12. Geotextile
13. Leachate Level
14. Drainage Layer
15. Geomembrane (Where Applicable)
16. Capping System

Protection of a building on a landfill from gas infiltration



Protection of a building on a landfill from gas infiltration



Open Question:

„*What kind of criteria have to be met, that a landfill can be released from aftercare?*“

TASI: „The control and action measures described in No. 10.6.6 as well as appendix G of the TASI have to be practised as long as the responsible administration releases the landfill out of the aftercare.“

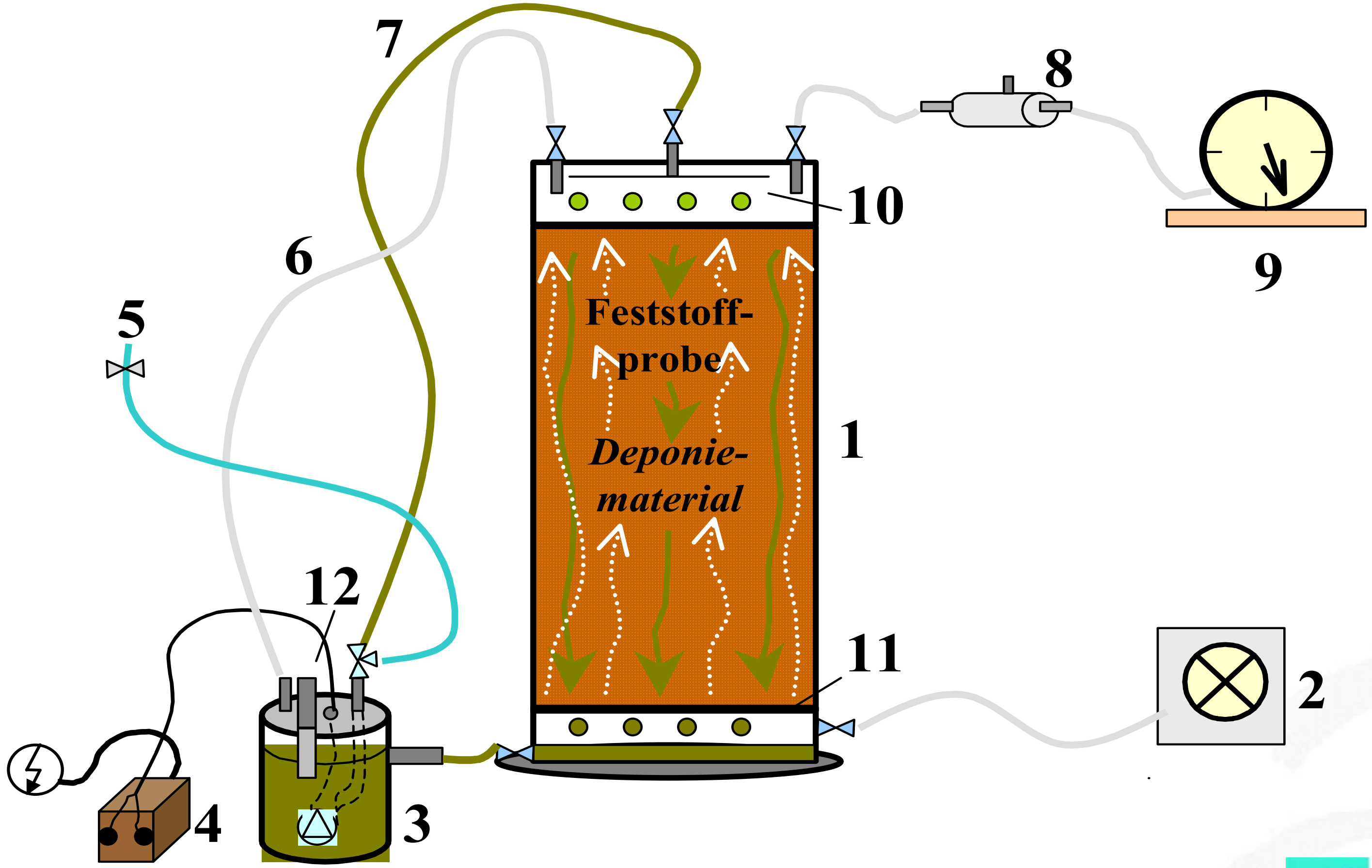
Criteria may be developed on the basis of the following investigations:

- *Landfill Body:*
  - Monitoring water budget including leachate qualitiy
  - Monitoring LFG (volume and quality)
  - Monitoring settling

Criteria may be developed on the basis of the following investigations:

- *Waste samples*
  - water-, carbon-, nitrogen content
  - elution tests (pH, COD, BOD, SO_4, Cl, etc.)
  - biotests (respiration rate, AT_4, gas production potential, GB_{21})
  - toxicity tests
  - lysimeter tests (gas-, leachate quality prognosis)

Landfill Simulation Reactor (LSR)



Evaluation of the results

Question:

- How should the results from the tests be validated?
- Which kind and level of emissions are acceptable for the environment (in general and/or specific)?

Evaluation of the results (2)

Options:

- Emissions should meet target values independent of the specific situation (as f.e. air emission standards)
- Emissions should be validated dependent on the specific situation (geology, hydrogeology, future utilisation etc.)
- Combination of both models

  - *minimum standards and site specific factors*

Discussion of Target Values for LFG (1)

Question:

Which level of LFG emissions is acceptable?

- CH_4 oxidation potential in the top cover
  - range for discussion: 0.34 –5,6 lCH_4/m² • h
- Proposal: 1 l CH_4 / m² • h ⇒20 m³ LFG /ha • h
  shallow landfill allow higher gas production/m³ than higher landfills
  Height 10m: 0,2 l/m³ • h;
  Height 20m: 0,1 l/m³ • h;
  1ha : 20m³/h; 10 ha = 200m³/h

Discussion of Target Values for LFG (2)

Proposal:

- Total LFG production ≤ 50 – 70 m³/h
- LFG emissions via surface ≤ 0,5 – 1,0 $lCH_4/m^2 \cdot h$

  ⇒ at small landfills (1-2 ha) ***surface emissions*** *and at larger landfills* ***absolute gas production rates*** *are valid*

(Reflections based on LFG composition 50% Ch_u and 50% CD_2

Discussion of Target Values for LFG (3)

Actual gas production rates?

Options:

- Actual gas production can be determined by means of extraction tests (f.e. if a LFG extraction system exists)
- Gas production in LSR
- Using a standardised LFG prediction model

note: LFG extraction rate $\neq$ LFG production rates

Target Values for Leachate (1)

- Leachate migrating into the ground – or surface water should not cause negative effects on the water quality

Question:

- Should the following processes be respected:

  - size of groundwater volume (dilution, natural attenuation)

  - height and kind of the unsaturated zone (natural attenuation)

Target Values for Leachate (2)

- *Proposal:*

  - Calculation of the leachate production rate using a water budget model (f.e. HELP)
  - Respecting the solid-liquid ratio
  - Leachate target values (51. Appendix)
  - Leachate concentrations estimated using f.e. standardised methods for landfill waste samples

Target Values for Leachate (3)

Limiting concentrations for the discharge of treated leachate according to German standards (51. Appendix)

Parameter	Limiting concentration [mg/l]
COD	200
BOD_5	20
Nitrogen (NH_4 + NO_2 + NO_3)	70
Phosphorus, total	3
Hydrocarbons	10
Nitrite-Nitrogen	2
AOX	0.5
Hg	0.05
Cd	0.1
Cr VI	0.1
Ni	1
Pb	0.5
Cu	0.5
Zn	2
Cyanide, easy liberatable	0.2
Sulfide	1

Target Values for Leachate (4)

- Ehrig proposes leachate quality and loads at the bottom of a landfill.

  Concentrations:

  max.COD ≤ 100 mg/l

  max.N ≤ 50 mg/l

  Loading:

  CDD ≤ 100 kg/ha • a

  N ≤ 50 kg / ha • a

  Values based on climatic leachate production of 250 mm/a

  ⇒ calculated concentration: 40 mg COD/l and 20 mg N/l

  (Distance between landfill bottom and groundwater > 3m)

Target Values for Leachate (5)

Standardised methods:

Representative samples from landfill (mixed samples gained from single samples f.e. grit 50-100m)

- Elution tests (target values can be extracted from German soil protection act /MBP
- LSR for predicting the emission potential

Target Values for Landfill Stability

Options:

- Respiration rate similar to soil (2-4mg 0_2/gTS 96 h)?
- Gas production potential (GB 21) (<5l/kg TS)?
- Residual carbon content?

(see also target values for mechanical-biological pre-treatment (TASI) as guidance)

Costs

- Aftercare should be paid by waste collection and treatment fees
  - ⇨ this is in Germany only possible for the landfills operated today

Questions:

- what are the actual costs?
- how to finance already closed landfills?

Conclusions (3)

- *Release of landfills from aftercare when emissions do not harm the environment*

  ⇒ Target values may be based on:

  - eluate concencations (soil protection act, MBA)
  - max. leachate concentrations and loads for COD,
  - N emitting from the landfill (Ehrig, et al., 2002)
  - emission standards for leachate (51. Anhang)
  - respecting natural attenuation ?
  - waste quality

→ *Intensive discussion is necessary*

Conclusions (1)

Landfill should be operated in a way that the emission potential is minimized:

- Bioreactor landfill
- Controlled treated leachate infiltration
- In-situ aeration

Conclusions (2)

- *Release of landfills from aftercare when emissions do not harm the environment*

⇒ LFG is subject to oxidation in the surface

⇒ Leachate quality meets discharge target values (if needed polishing in constructed wet lands)

⇒ Emission potential can be described analysing waste samples using leaching test, LSR, respiration tests

Conclusions (4)

Release of the landfill from aftercare in most cases still needs minimum maintenance as f.e.

- cleaning of drain system
- monitoring of groundwater and leachate quality
- monitoring of gas emission
- supervision of liner performance
- operation of pumps for leachate transportation

⇒ *Landfills as mounds have less maintenance than lanfills in pits*