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Solid waste landfilling

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Solid Waste Valorization Module

Solid waste landfilling



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Laurent MAZEAS

**Master Environmental Engineering and
Sustainability Management**



Municipal solid waste landfill

- Context
- Municipal solid waste landfill conception
- Anaerobic degradation in landfill: influence on leachate composition
- Landfill leachate recirculation optimisation
- Micropollutant in waste and landfill leachates
- Landfill mining

Municipal solid waste landfill

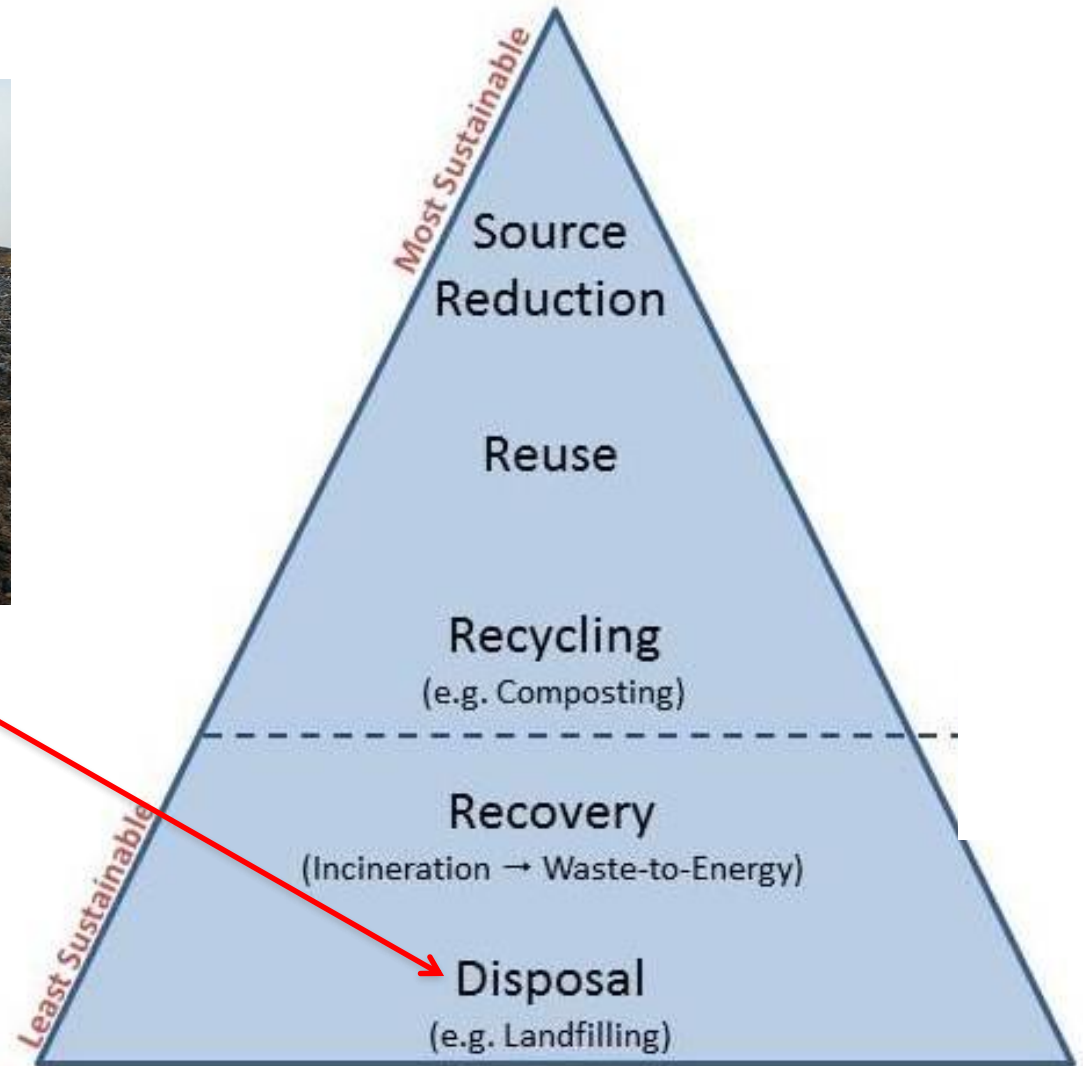
- **Context**
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Sustainability of Landfills ?



Source: SUSANA on Flickr 2009

Landfilling is the least preferred method in the hierarchy of integrated solid waste management.

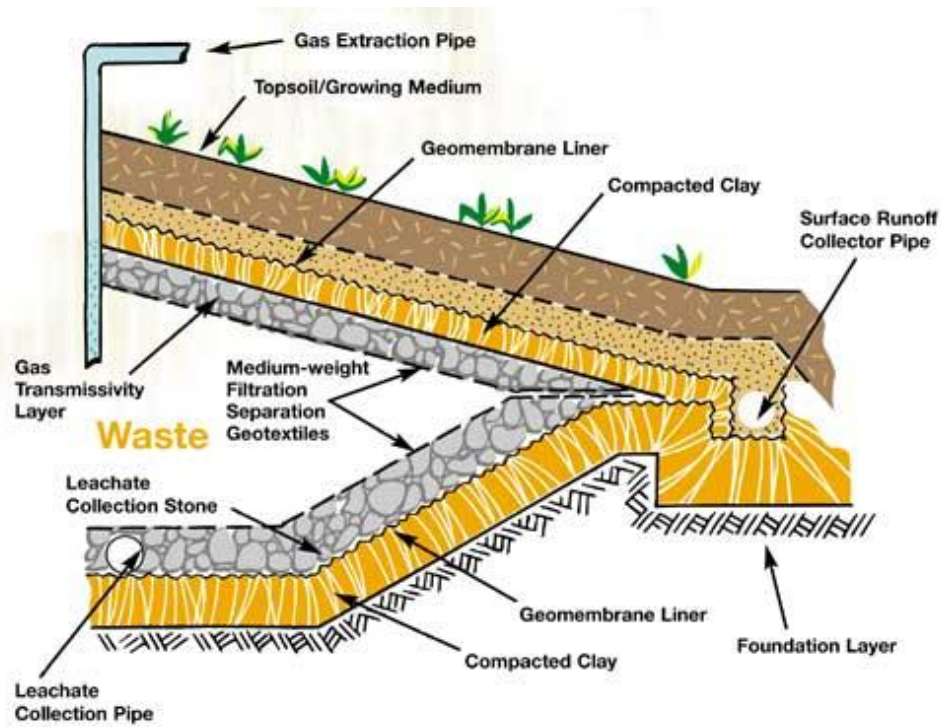


Is a Landfill an Open Dump?



Source: SUSANA on Flickr 2009

It is not an open dump, it is an engineered facility in order to protect the environment and human health!



A cross-section of a best practice landfill cell

Source: LATROBE CITY COUNCIL (2005)

Types of Landfills

- **Open Dump:**
 - Waste is discharge open without any management
- **Basic Landfill:**
 - Waste is discharged in a pit and covered every day
- **Engineered Landfill:**
 - Liner, cover, leachate treatment and gas extraction (energy production or flared)
- **Bioreactor Landfill:**
 - Acceleration of decomposition and creation of a conditions for microbiological activities -> produced gas is used for energy production.

Engineered Landfill

Engineered Landfills in Contrast to Open Dumps

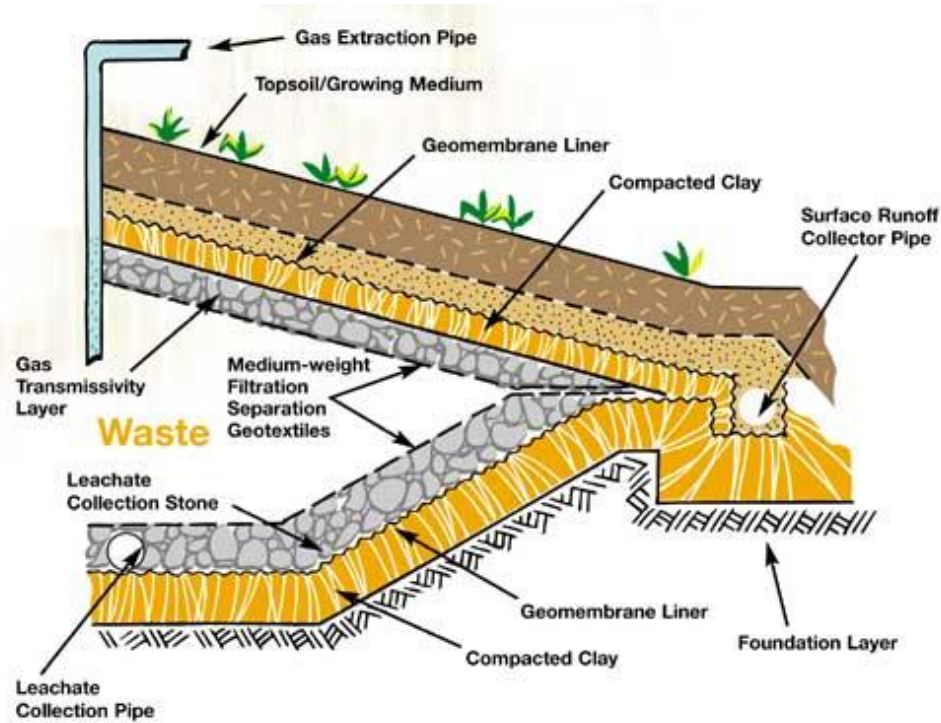
Cover layer → avoids spreading of waste, pathogens, odour

Gas extraction well → control and reuse of biogas (mainly CO₂ and CH₄) for energy production

Liner system → avoids a contamination of ground water

Leachate system → collection and treatment of fluid effluent

Groundwater monitoring → on-going information about the groundwater quality



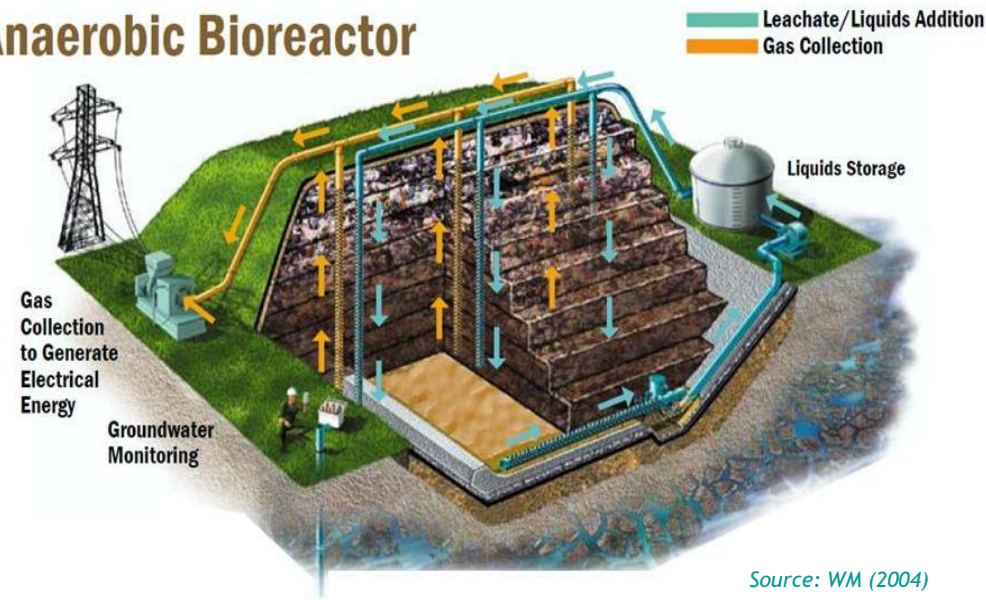
A cross-section of a best practice landfill cell

Source: LATROBE CITY COUNCIL (2005)

Bioreactor Landfill

- Acceleration of biologic decomposition (organic fraction).
- Promoting conditions necessary for the microorganisms (moisture content).
- Liquids must be added (leachate, stormwater, sewage sludge).
- Gas is collected to produce electrical energy.
- Design includes liner, cover, leachate system, groundwater monitoring.

Anaerobic Bioreactor

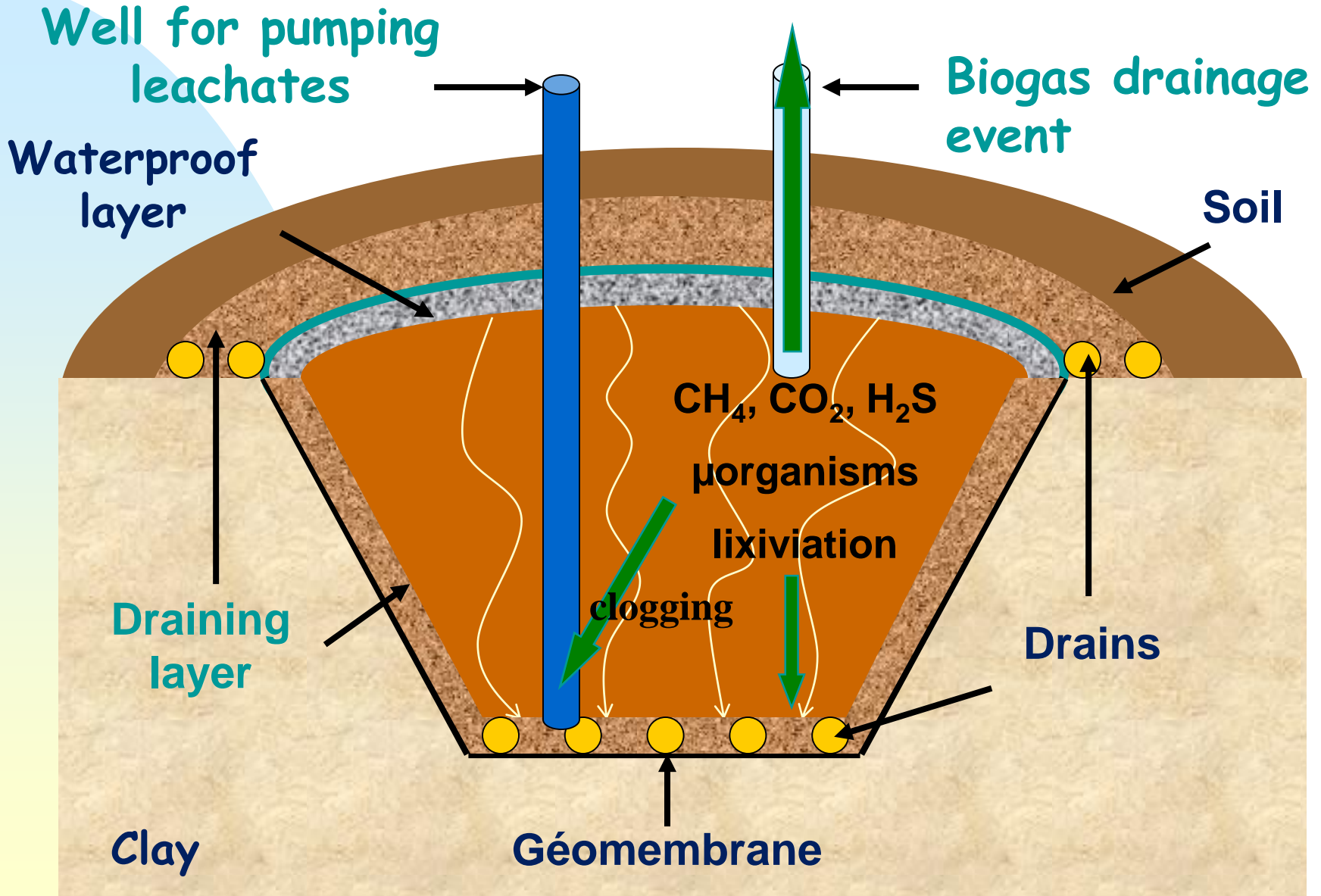


Municipal solid waste landfill

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- MSW Landfill impacts



MSW Landfill conception

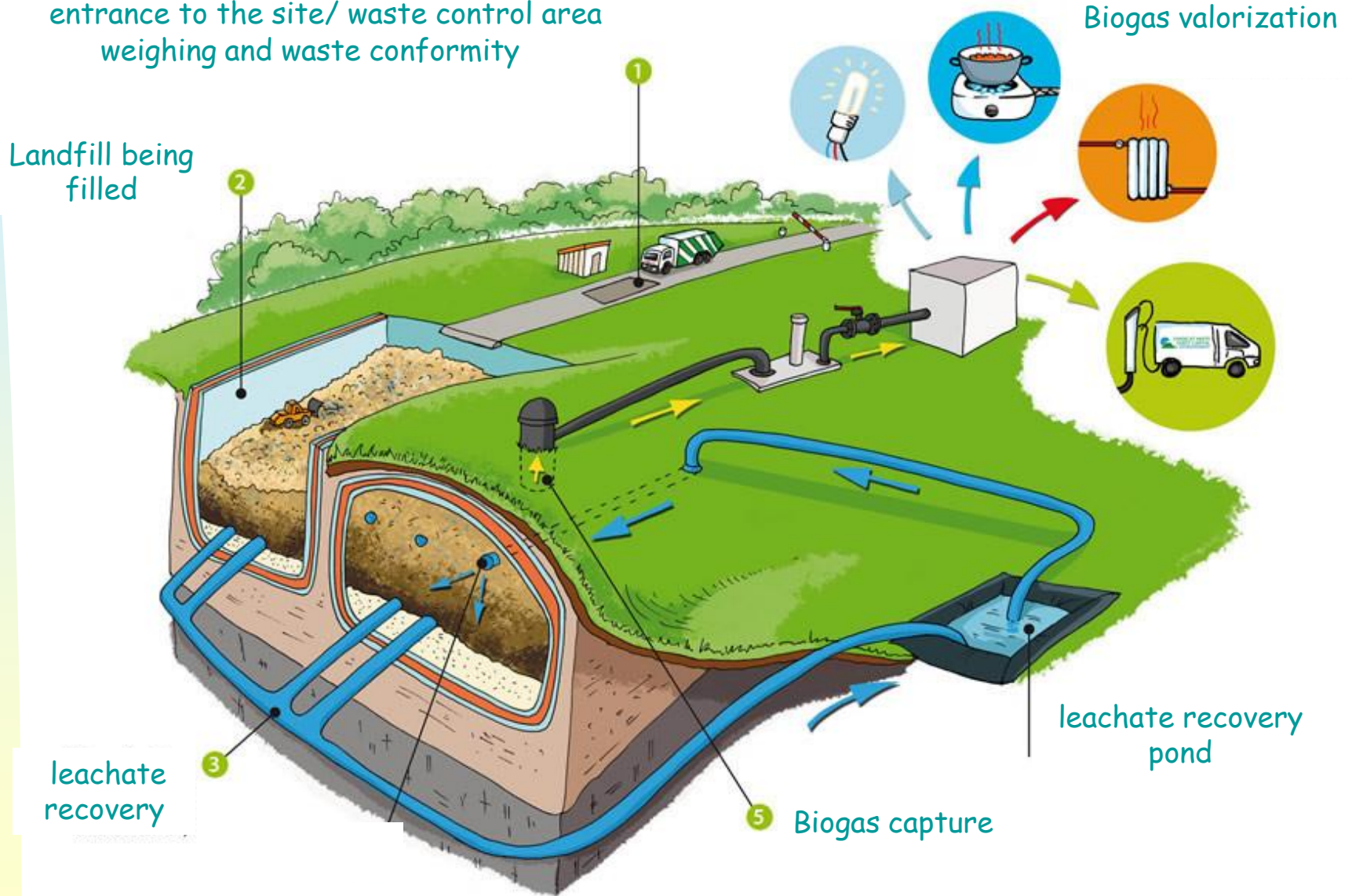


BIOREACTOR LANDFILL CONCEPTION

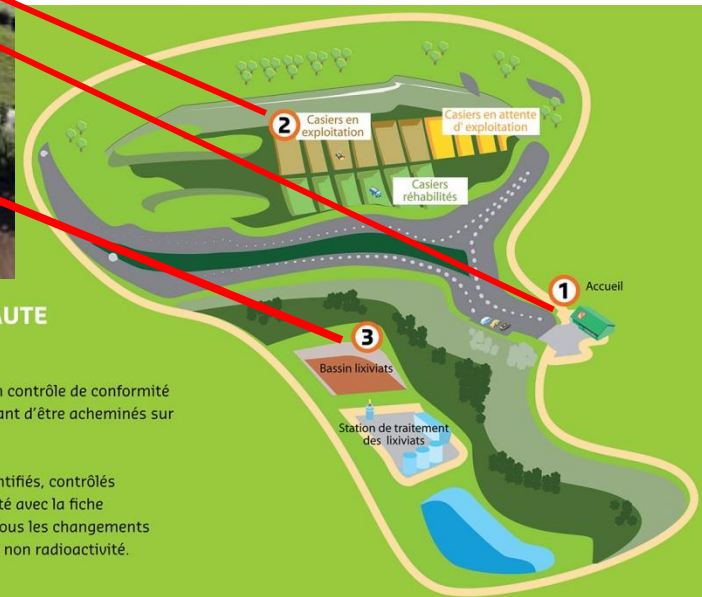
entrance to the site/ waste control area
weighing and waste conformity

Landfill being
filled

Biogas valorization



Picture of a MSW landfill



1 ENTRÉE SOUS HAUTE SURVEILLANCE

> La fiche d'acceptation

Les déchets font l'objet d'un contrôle de conformité sur le site de production avant d'être acheminés sur le site.

> Le contrôle d'accès

Les déchets sont pesés, identifiés, contrôlés visuellement et la conformité avec la fiche d'acceptation est vérifiée. Tous les changements font l'objet d'un contrôle de non radioactivité.

2 ZONES DE STOCKAGE

> Vidage du camion

Un deuxième contrôle est effectué au déchargement par le conducteur du compacteur.

> Compactage des alvéoles

La compression et le confinement des déchets en casiers de petite taille facilite la dégradation

3 MAÎTRISE DES EFFLUENTS

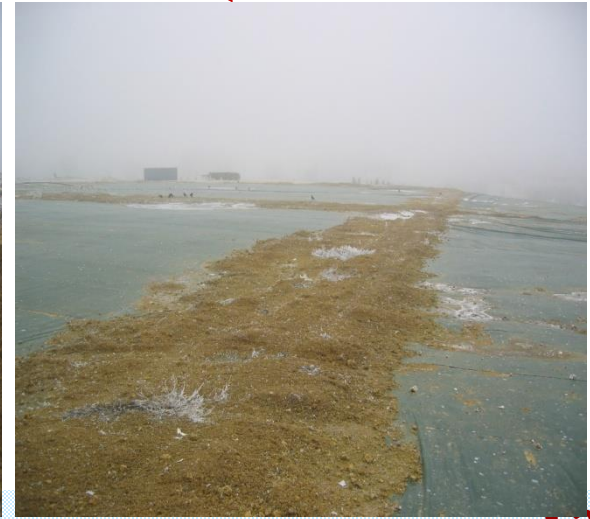
Les effluents gazeux (biogaz) et liquides (lixiviats), produits naturellement par les déchets dans les alvéoles, sont collectés pour être traités. Ces traitements font l'objet d'une surveillance permanente, et les rejets sont régulièrement analysés par des laboratoires indépendants.

weighing and waste conformity



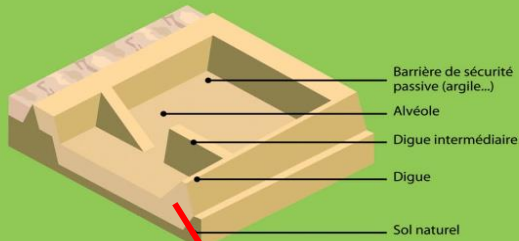
- 1) weighing of waste
- 2) control of the absence of radioactivity
- 3) control of the nature of the waste

Deposition and compaction of waste

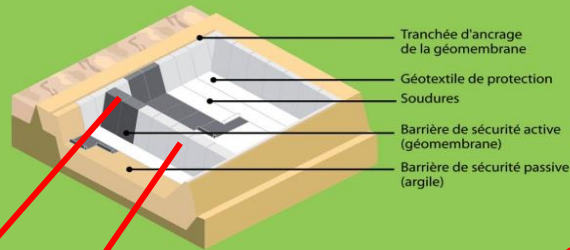


The stages of setting up a landfill

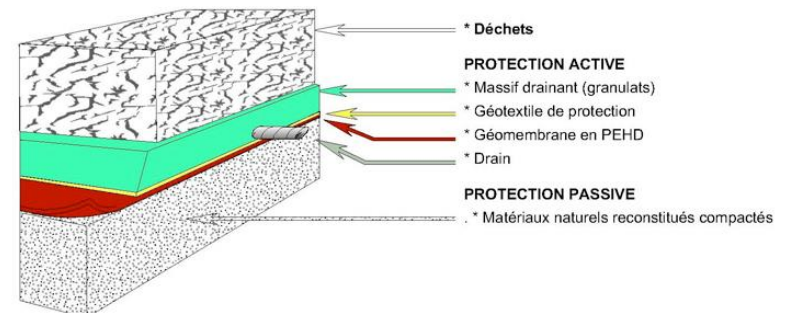
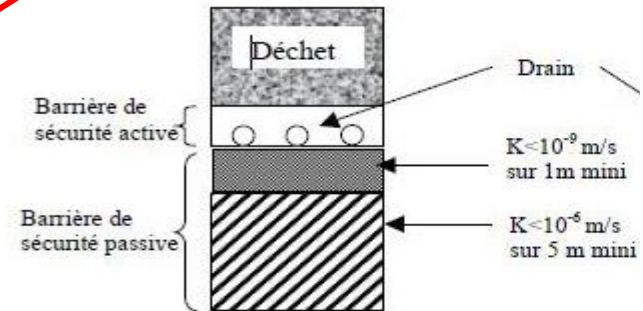
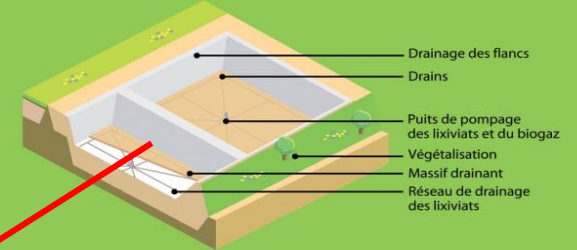
Step 1: earthwork



Step 2: sealing



Step 3: drainage



Leachate treatment



I. Physical processes
a) Sedimentation
b) Evaporation

II. Chemical processes
a) Wet oxidation H_2O_2
b) Oxidation with ozone/UV
c) Oxidation with ozone/catalytic bed

Methods of
leachate treatment

III. Physico-chemical processes
a) Adsorption on activated carbon
b) Adsorption on resin
c) Reverse osmosis
d) Ion exchange
e) Coagulation and precipitation (iron and aluminium salts + $Ca(OH)_2$)

IV. Biochemical processes
a) Treatment under aerobic condition
b) Treatment anoxic condition
c) Treatment under aerobic conditions (elimination BOD_5/COD)
d) Nitrification and denitrification

Regulatory requirements for the release of leachates

(Annexe III de l'arrêté du 9 septembre 1997 modifié)

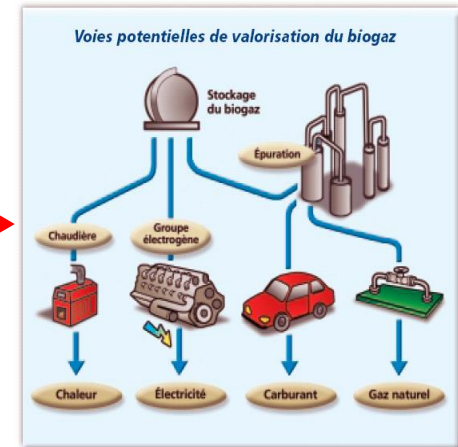
ANNEXE III

Critères minimaux applicables aux rejets d'effluents liquides dans le milieu naturel

Matières en suspension totale (M.E.S.T.)	<100 mg/l si flux journalier max < 15 kg/j < 35 mg/l au-delà
Carbone organique total (C.O.T.)	< 70 mg/l
Demande chimique en oxygène (D.C.O.)	< 300 mg/l si flux journalier max < 100 kg/j < 125 mg/l au-delà
Demande biochimique en oxygène (D.B.O. ₅)	< 100 mg/l si flux journalier max < 30 kg/j < 30 mg/l au-delà
Azote global	concentration moyenne mensuelle < 30 mg/l si flux journalier max > 50 kg/j
Phosphore total	concentration moyenne mensuelle < 10 mg/l si flux journalier max > 15 kg/j
Phénols	< 0,1 mg/l si le rejet dépasse 1 g/j
Métaux totaux,dont :	< 15 mg/l
Cr ⁶⁺	< 0,1 mg/l si le rejet dépasse 1 g/j
Cd	< 0,2 mg/l
Pb	< 0,5 mg/l si le rejet dépasse 5 g/j
Hg	< 0.05 mg/l
As	< 0,1 mg/l
Fluor et composés (en F)	< 15 mg/l si le rejet dépasse 150 g/j
CN libres	< 0,1 mg/l si le rejet dépasse 1 g/j
Hydrocarbures totaux	< 10 mg/l si le rejet dépasse 100 g/j
composés organiques halogénés (en AOX ou EOX)	< 1 mg/l si le rejet dépasse 30 g/j
<i>(La référence à certaines substances toxiques a été supprimée par l'arrêté du 31/12/2001)</i>	

N.B.: Les métaux totaux sont la somme de la concentration en masse par litre des éléments suivants : Pb, Cu, Cr, Ni, Zn, Mn, Sn, Cd, Hg, Fe, Al.

Recovery and valorization of biogas



Examples of valorization of biogas

Thermal valorization:

In Blaringhem (59), the Baudalet company has managed since 1982 a major landfill which receives household waste, industrial waste and automobile shredding residue. Rather than burning the biogas in a flare, Baudalet installed a furnace to melt the aluminum recovered on the site into lingots.

Electric valorization :

The biogas energy recovery facilities at the Claye-Souilly storage facility produce a quantity of electricity equivalent to the electricity consumption, excluding heating, of a city of 228,000 inhabitants

Biofuel valorization :

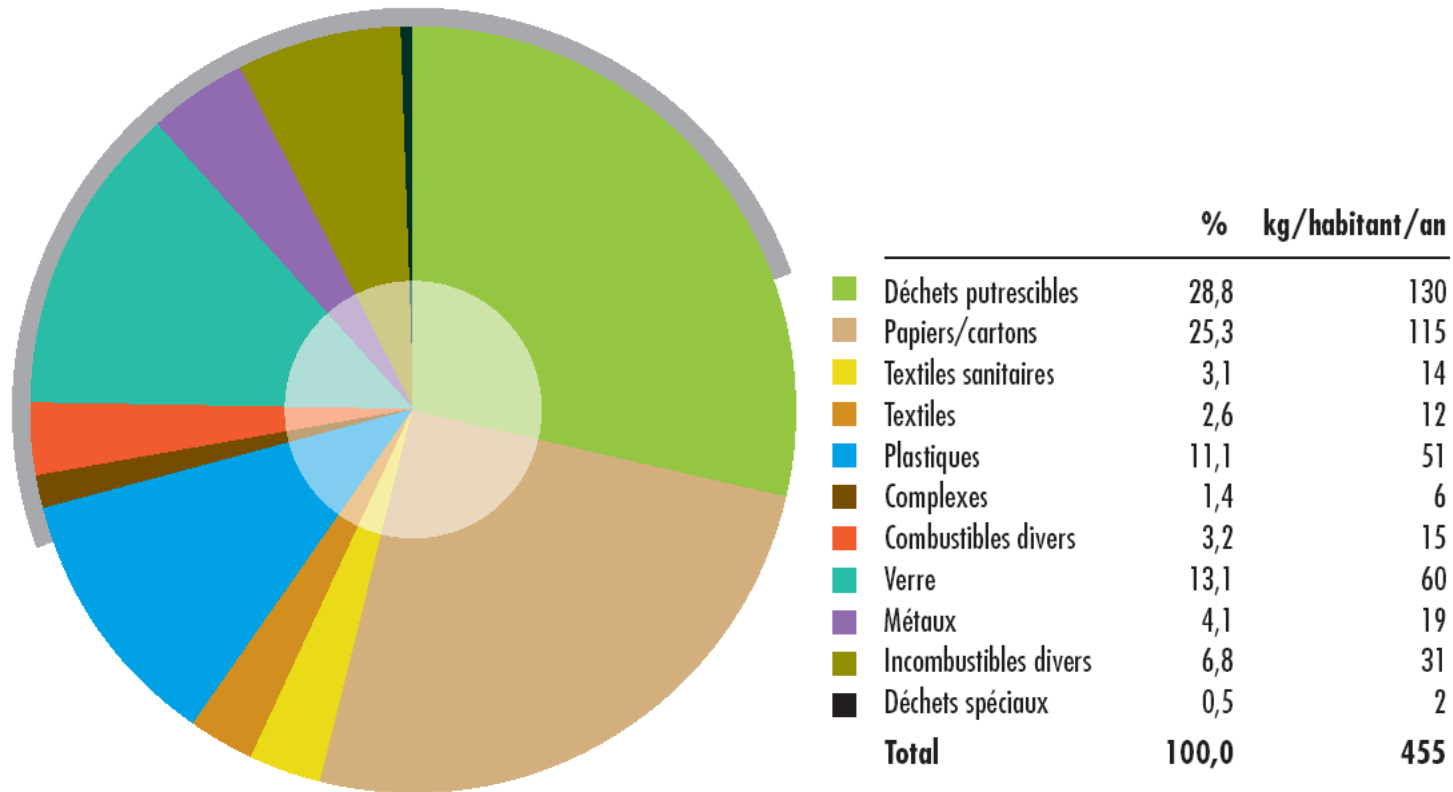
In September 2009, Veolia Environmental Services opened the first biomethane fuel production unit, derived from biogas captured at the non-hazardous waste storage facility at Claye-Souilly (77). The production unit demonstrates a production capacity to cover the annual energy needs of a fleet of 210 light vehicles (1 ton of household waste produces around 200 m³ of biogas or 100 m³ of methane, equivalent to 100 liters of gasoline)



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FRENCH MSW composition

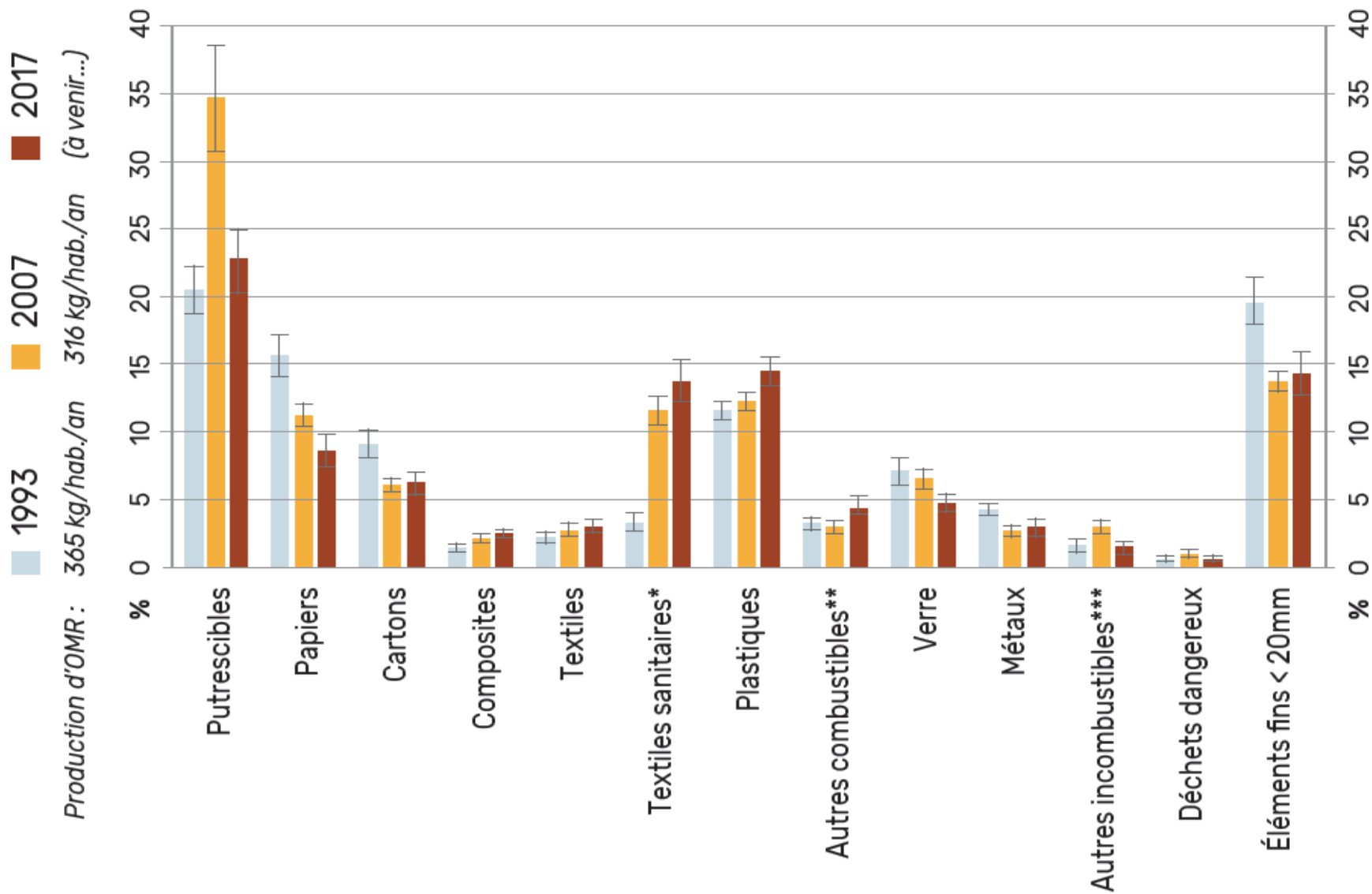


Composition des ordures ménagères - moyenne nationale
(Répartition en poids humide - évaluation pour 1998)

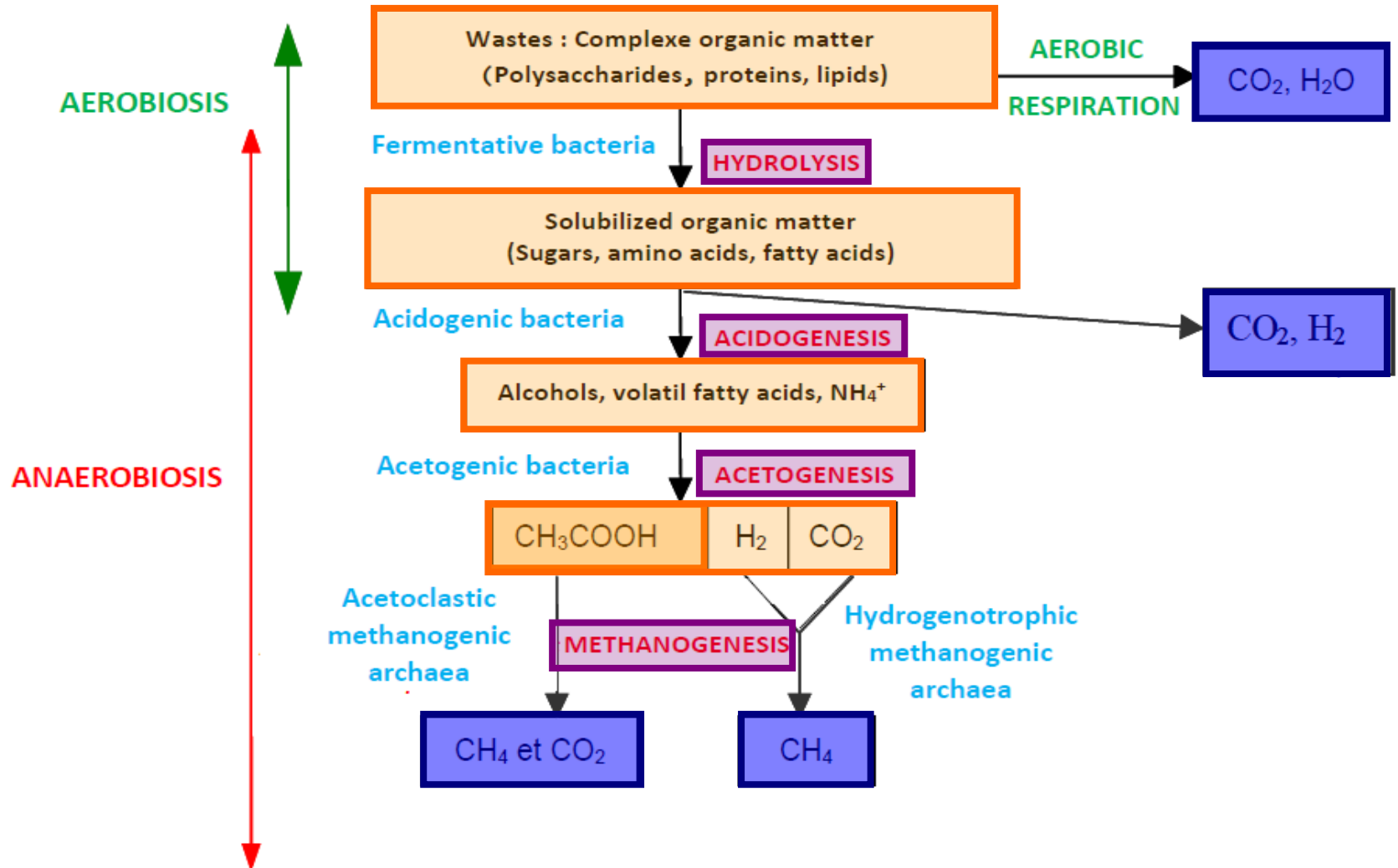
Sources ADEME

1/3 putrescible waste + paper/cardboard = 50 % de biodegradable

French MSW composition evolution



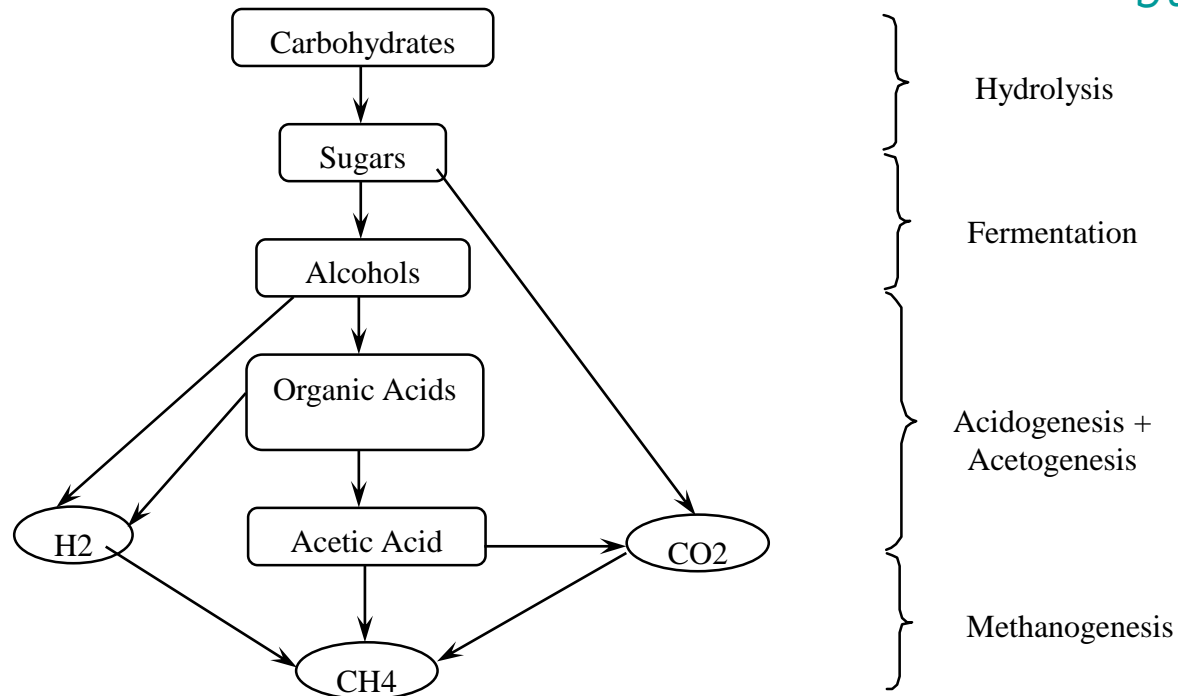
The stages of anaerobic degradation of waste





Anaerobic degradation of carbohydrates

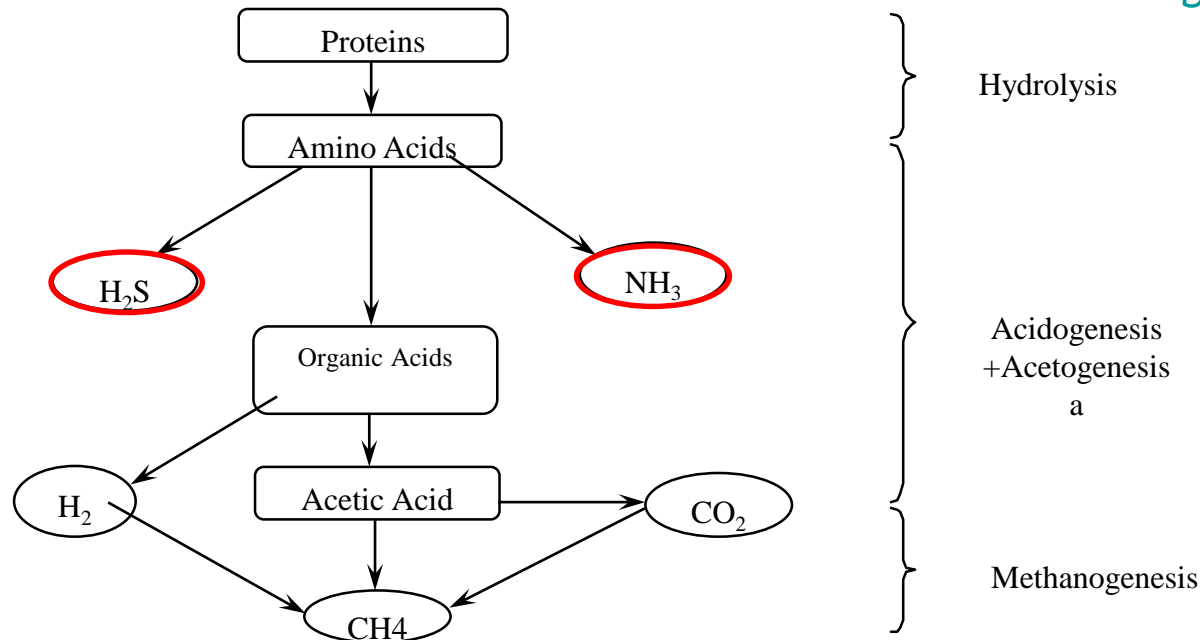
D'après Butler *et al.*, 99



Pour n=2 : $C_6H_{12}O_6 + 2 H_2O \rightarrow 2 CH_3-CH_2-OH + 2 CO_2 + 2 H_2O$ Glucose Ethanol	Hydrolyse des sucres et fermentation en alcools.
Pour n=3 : $C_9H_{18}O_9 + 2 H_2O \rightarrow 2 CH_3-(CH_2)_2-OH + 3 CO_2 + 3 H_2O$ Pour n=4 : $C_{12}H_{24}O_{12} + 2 H_2O \rightarrow 2 CH_3-(CH_2)_3-OH + 4 CO_2 + 4 H_2O$	
Pour n=2 : $CH_3-CH_2-OH + H_2O \rightarrow CH_3-COOH + 2 H_2$ Pour n=3 : $CH_3-(CH_2)_2-OH + H_2O \rightarrow H(CH_3)_2-COOH + 2 H_2$ Pour n=4 : $CH_3-(CH_2)_3-OH + H_2O \rightarrow H(CH_3)_3-COOH + 2 H_2$	Acidogenèse des alcools (conversion en acides gras volatils)
Pour n=3 : $H(CH_3)_2-COOH + 3 H_2O \rightarrow CH_3-COOH + H_2CO_3 + 3 H_2$ Pour n=4 : $H(CH_3)_3-COOH + 2 H_2O \rightarrow 2 CH_3-COOH + 2 H_2$	Oxydation des acides carboxyliques en acétate
Division Acetate : $CH_3-COOH \rightarrow CH_4 + CO_2$ Oxydation hydrogène : $CO_2 + 4 H_2 \rightarrow CH_4 + 2 H_2O$	Méthanogénèse

Anaerobic degradation of proteins

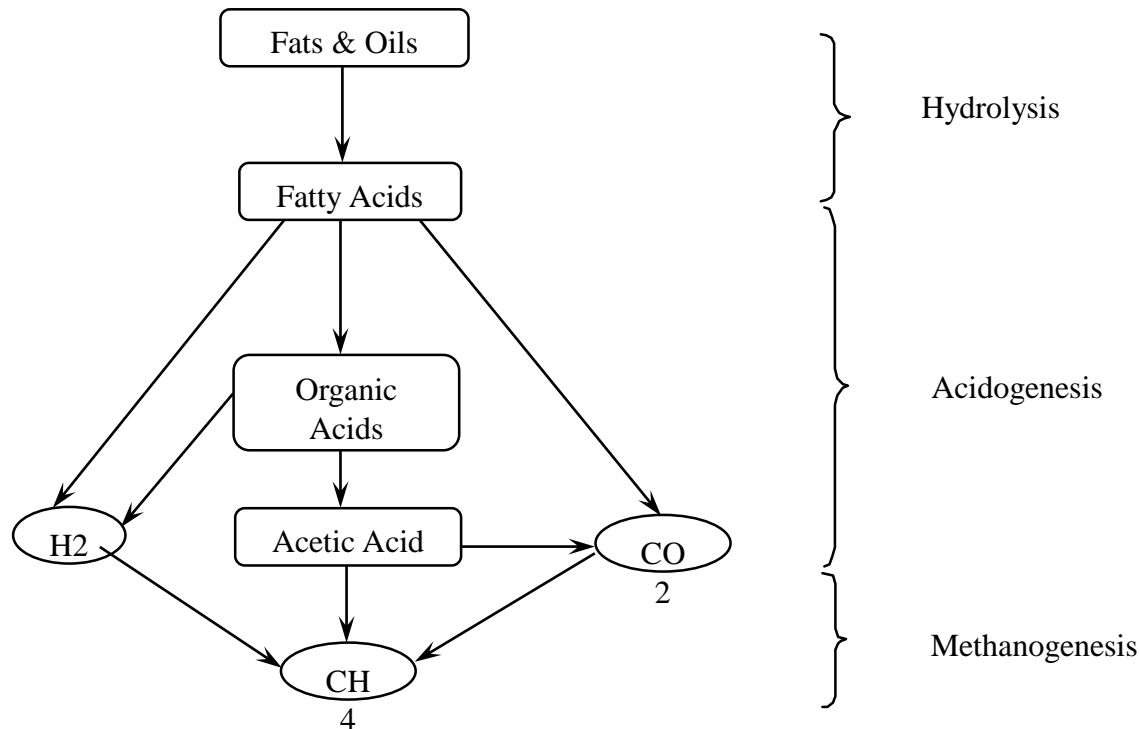
D'après Butler *et al.*, 99



$C_{53}H_{117}O_{22}N_{11}S \rightarrow 10 C_5H_{11}O_2N_1 + C_3H_7O_2NS +$ Protéine modèle (mélange de 10 molécules d'acide é-aminopentanoïque et d'une molécule de cystéine)	Hydrolyse des protéines en amino-acides correspondants
$C_5H_{11}O_2N_1 \rightarrow CH_3-CH_2-CH_2-CH_2-COOH + NH_3$ $C_3H_7O_2NS \rightarrow CH_3-CH_2-COOH + NH_3 + H_2S$	Acidogenèse : conversion des amino-acides en acides carboxyliques
$CH_3-CH_2-CH_2-CH_2-COOH + 5 H_2O$ $\rightarrow 2CH_3-COOH + H_2CO_3 + 5 H_2$ $CH_3-CH_2-COOH + 5 H_2O \rightarrow CH_3-COOH + H_2CO_3 + 3 H_2$	Acetogenèse : oxydation des acides carboxyliques en acétate
Division acétate : $CH_3-COOH \rightarrow CH_4 + CO_2$ Oxydation hydrogène : $CO_2 + 4 H_2 \rightarrow CH_4 + 2 H_2O$	Méthanogenèse

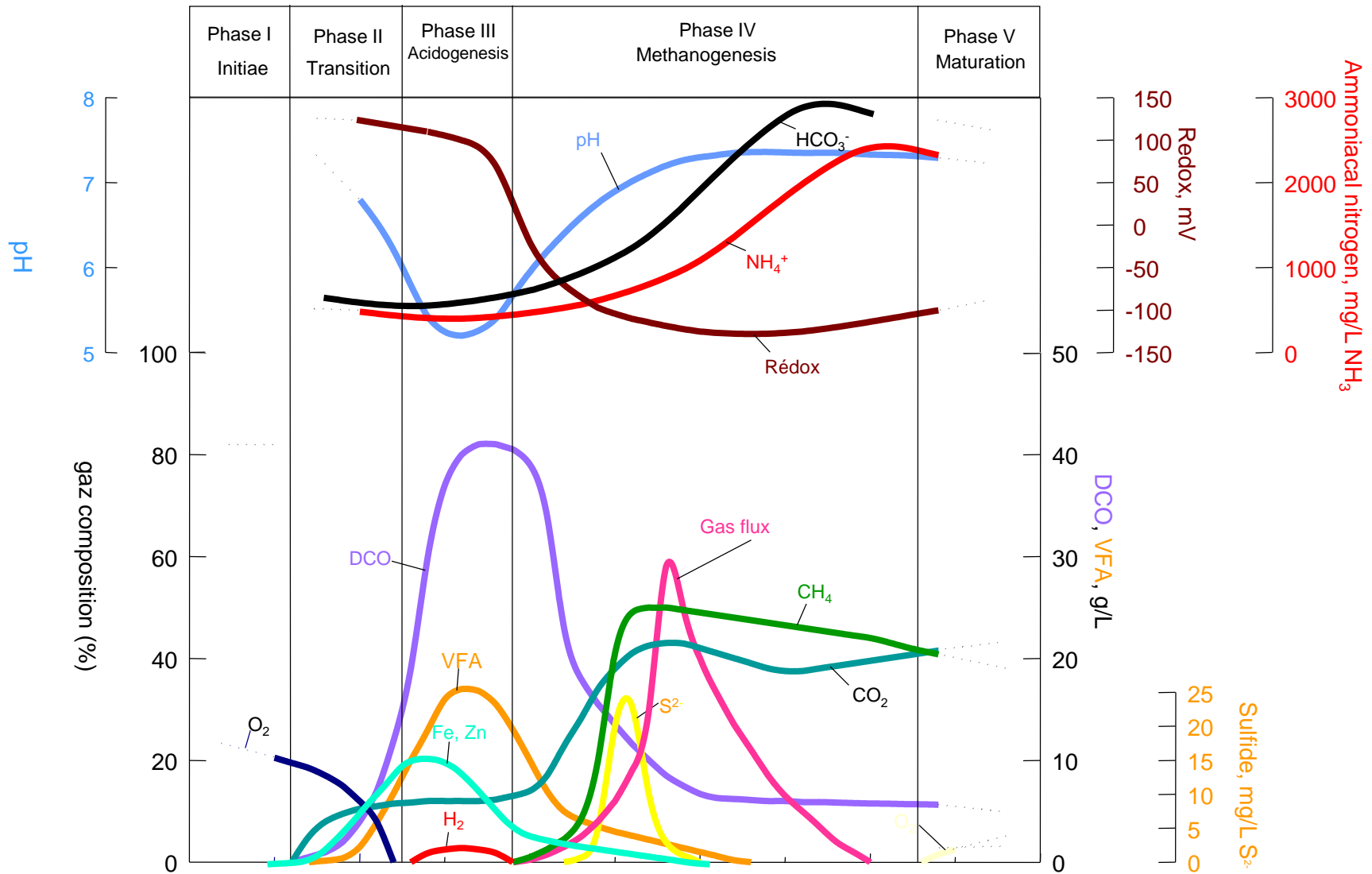
Anaerobic degradation of lipids

D'après Butler *et al.*, 99



$\text{C}_{55}\text{H}_{104}\text{O}_6 + 3 \text{H}_2\text{O} \rightarrow$ $\text{C}_{15}\text{H}_{31}\text{COOH} + \text{C}_{17}\text{H}_{35}\text{COOH} + \text{C}_{18}\text{H}_{33}\text{COOH} + \text{C}_3\text{H}_5(\text{OH})_3$ <p style="text-align: center;">[acides gras] [Glycerol]</p>	Hydrolyse en acides gras de structure plus simple
$\text{C}_{15}\text{H}_{31}\text{COOH} + 28 \text{H}_2\text{O} \rightarrow \text{CH}_3\text{COOH} + 42 \text{H}_2 + 14 \text{CO}_2$ $\text{C}_{17}\text{H}_{35}\text{COOH} + 32 \text{H}_2\text{O} \rightarrow \text{CH}_3\text{COOH} + 48 \text{H}_2 + 16 \text{CO}_2$ $\text{C}_{18}\text{H}_{33}\text{COOH} + 32 \text{H}_2\text{O} \rightarrow \text{CH}_3\text{COOH} + 47 \text{H}_2 + 16 \text{CO}_2$	Oxydation des acides carboxyliques en acétate
$2 \text{C}_3\text{H}_5(\text{OH})_3 \rightarrow 3 \text{CH}_3\text{COOH} + 2 \text{H}_2$	Oxydation du glycerol en acide acétique
Division acétate : $\text{CH}_3\text{-COOH} \rightarrow \text{CH}_4 + \text{CO}_2$ Oxydation hydrogène : $\text{CO}_2 + 4 \text{H}_2 \rightarrow \text{CH}_4 + 2 \text{H}_2\text{O}$	Méthanogénèse

Evolution of the composition of the effluents generated during the degradation of waste in landfill

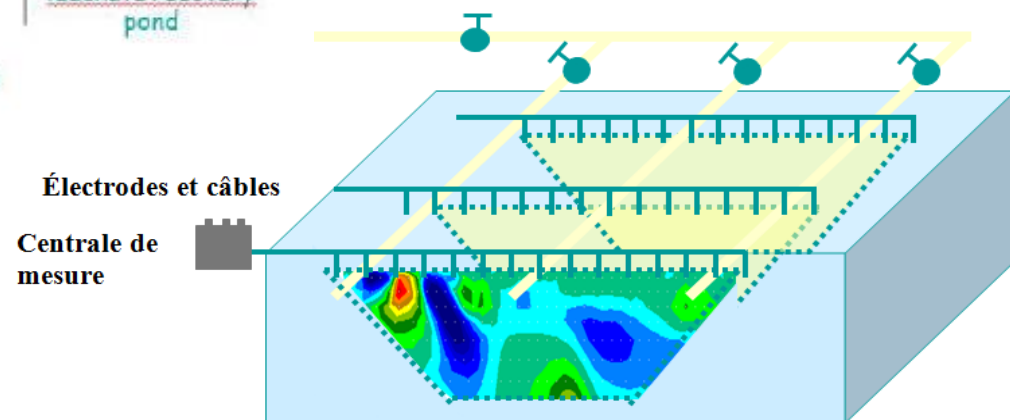
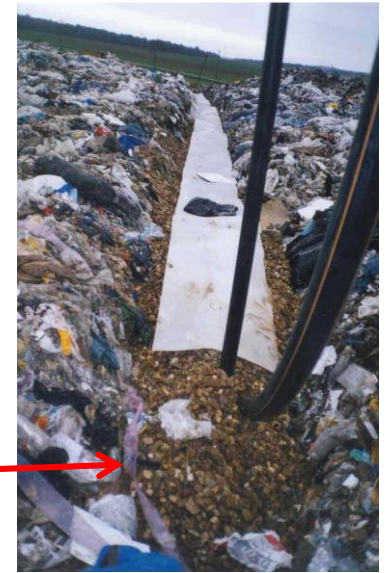
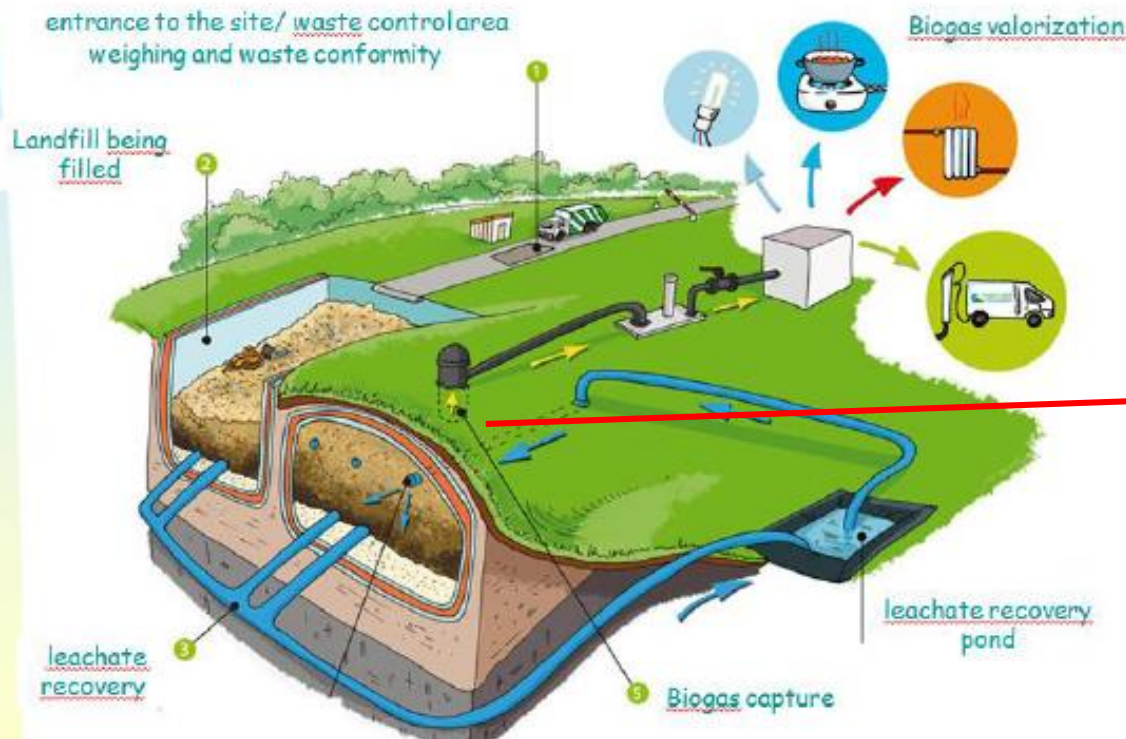


(from Pohland, 2002)

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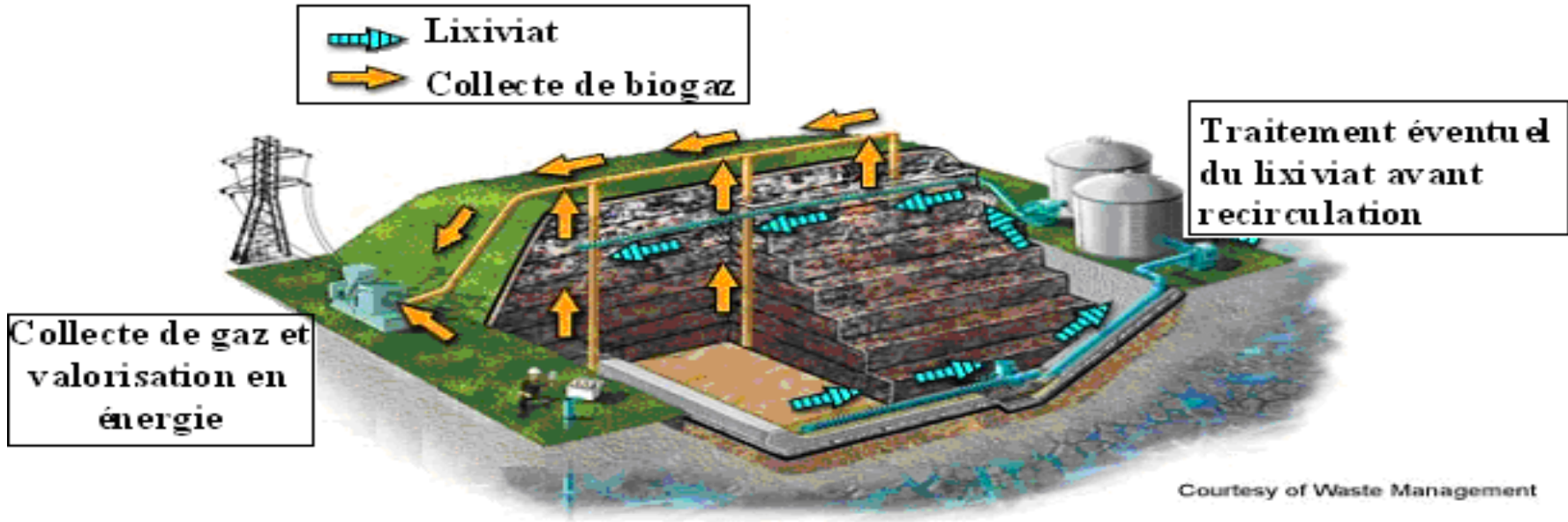
Bioreactor landfill optimisation



Objectives:

- Optimize humidity
- Accelerate waste degradation
- Increase biogas production

Bioreactor landfill optimisation



Leachate recirculation

- Optimize humidity
- Accelerate waste degradation
- Increase biogas production

The amount of leachate produced is often not important enough to get optimal moisture levels within waste mass

RECIRCULATED EFFLUENTS



- MSW LANDFILL LEACHATES

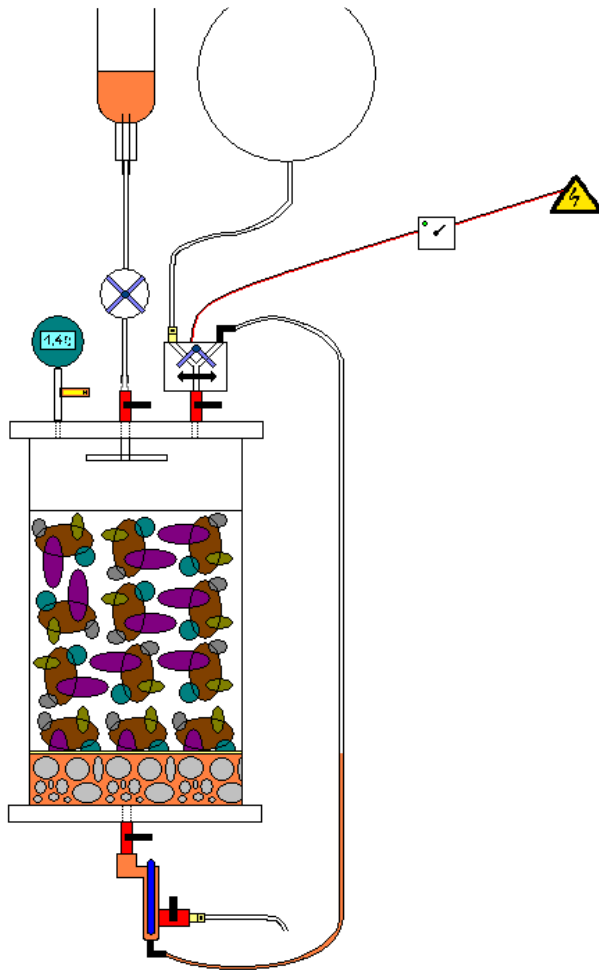


- GREEN WASTE COMPOSTING PLATFORM LEACHATE

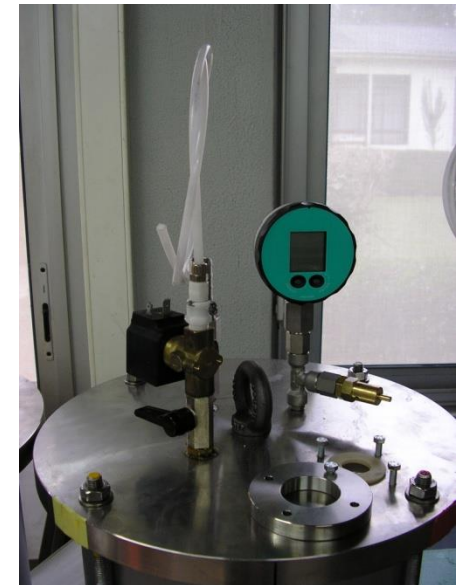


- SEWAGE SLUDGE

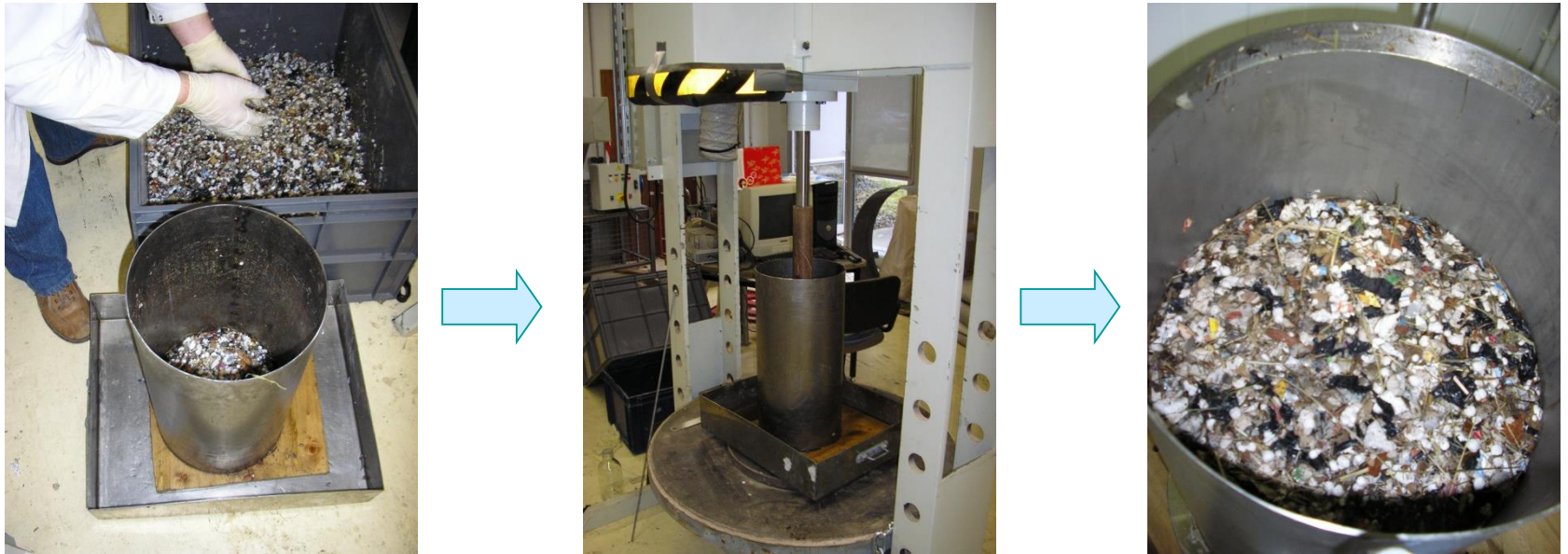
EXPERIMENTAL PILOTS



Legende	
	Sonde (pH, Redoc et T)
	Robinet
	Raccord rapide
	Alim électriQ
	Comande de l'électrovanne
	Electrovanne
	Couche drainante
	Geotextile & géogrille
	Effluent
	Pompe peristatique



Pilote filling with 5 Kg of reconstituted wastes

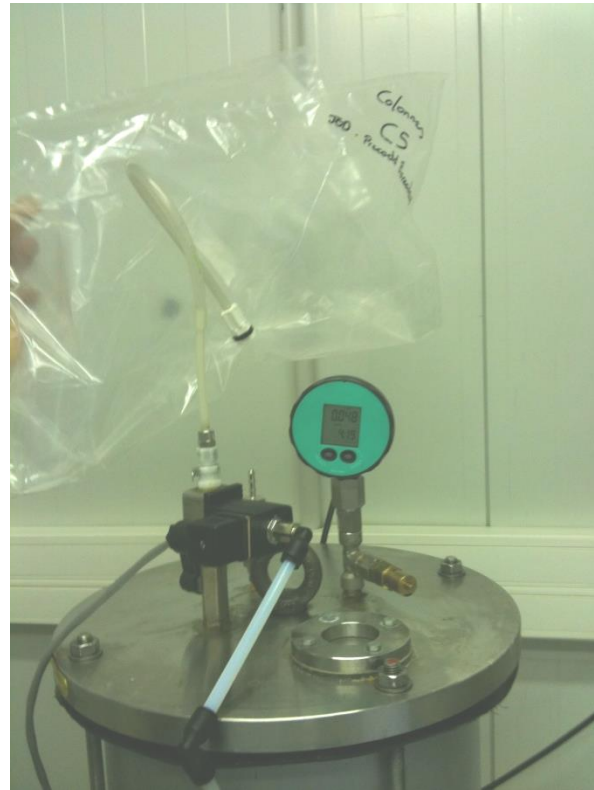


Pilots monitoring

Effluents injection



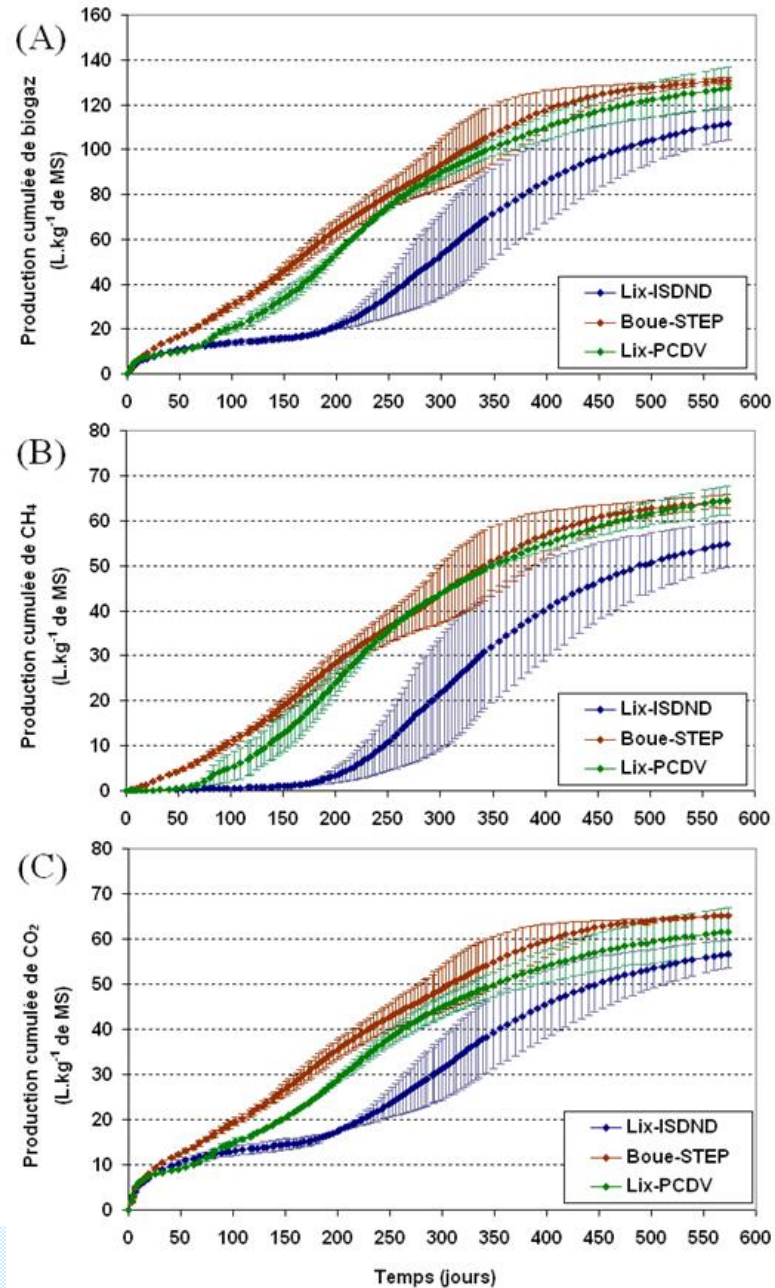
Biogas sampling



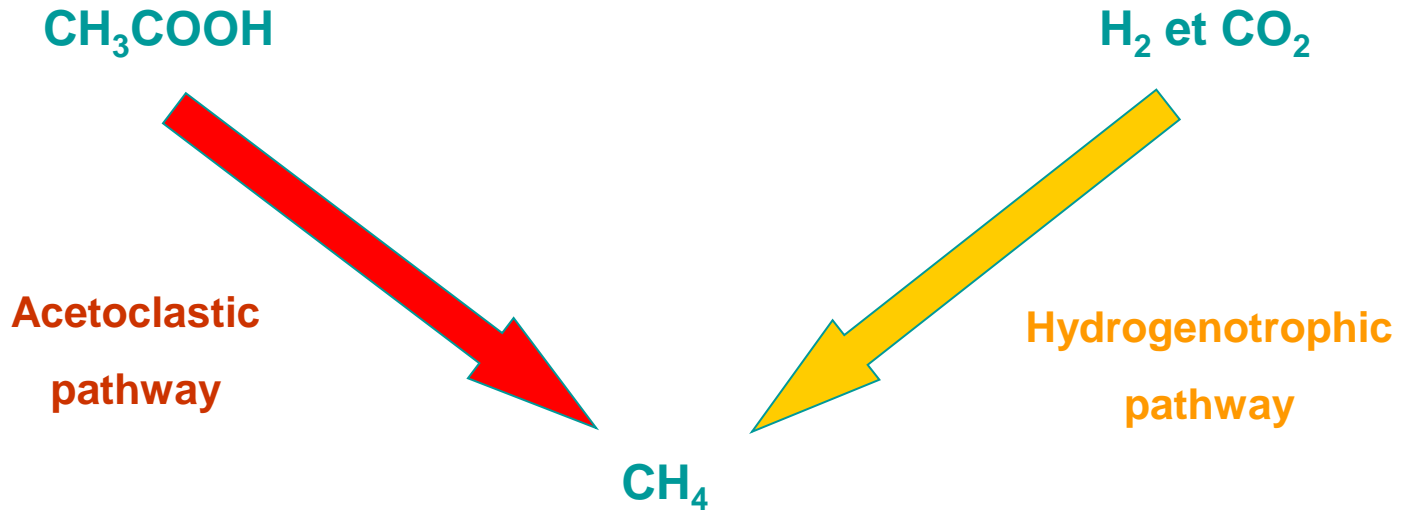
Leachate sampling



Cumulated biogas production



Methanogenesis pathways

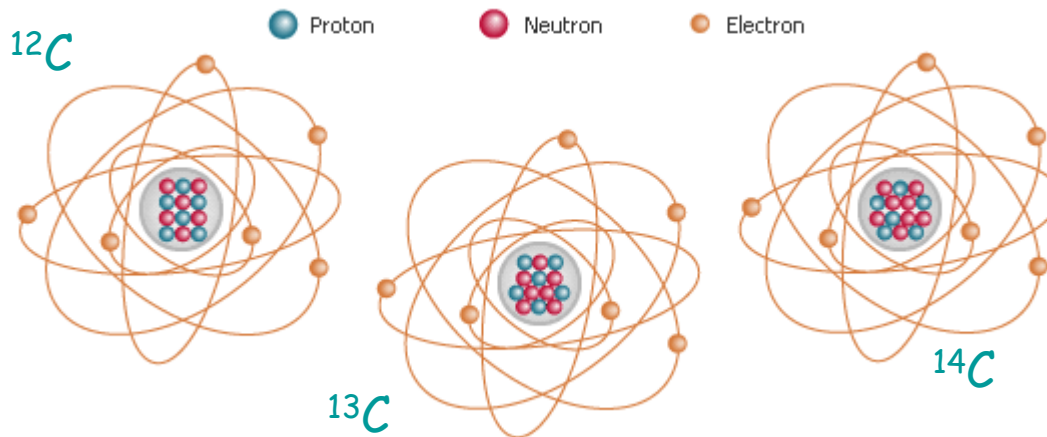


Reactions :



Carbon isotope

- Isotopes are atoms whose nuclei contain the same number of protons but a different number of neutrons



Carbon 12: stable

6 protons / 6 neutrons

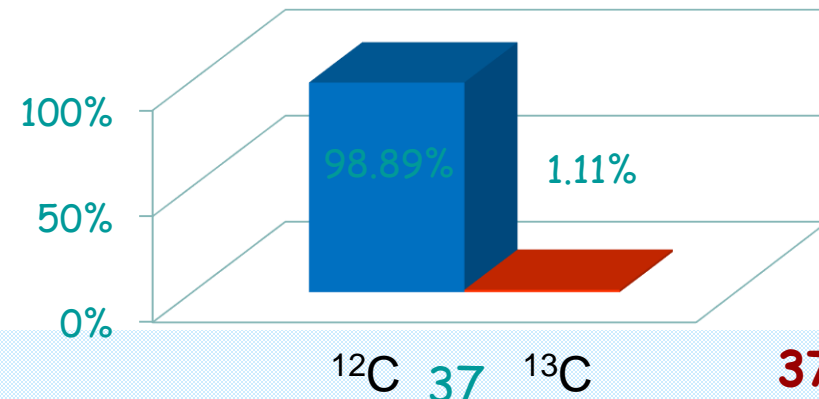
Carbon 13: stable

6 protons / 7 neutrons

Carbon 14: unstable

6 protons / 8 neutrons

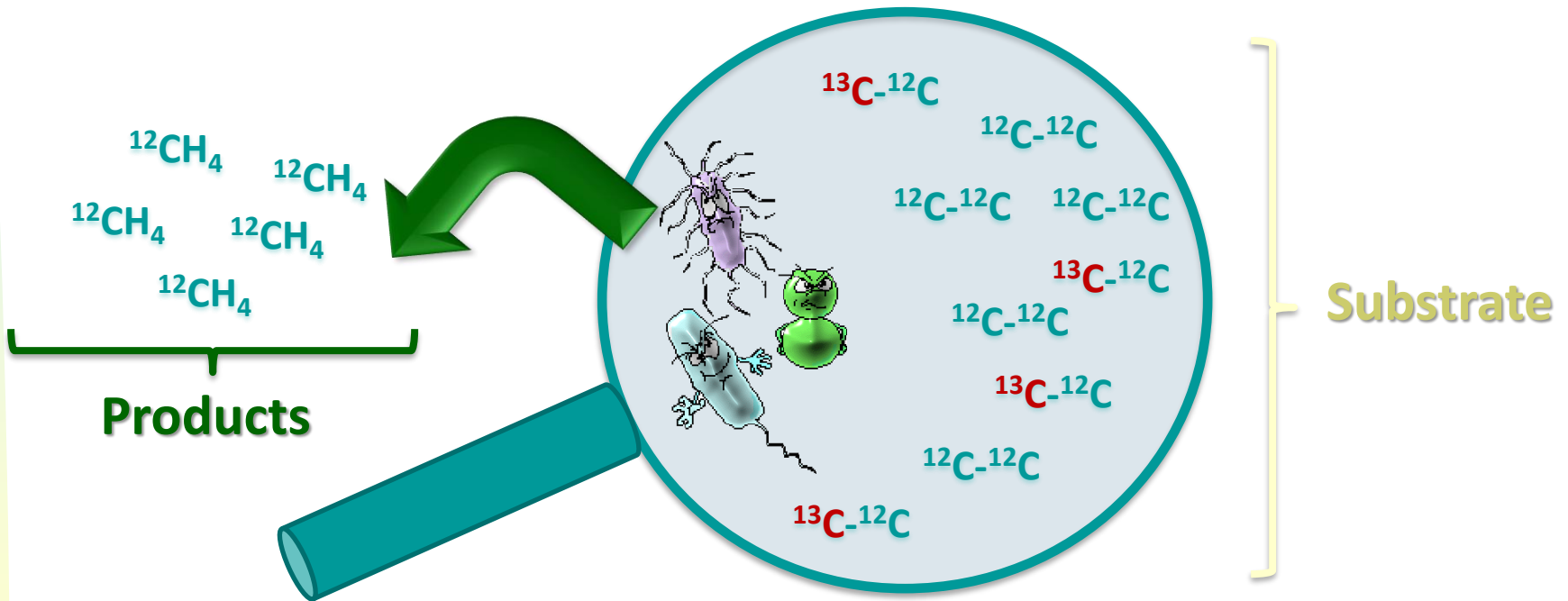
- The natural average abundance of ^{13}C isotope is 1.11 %



^{12}C ^{13}C

Isotopic fractionation

- Molecules containing heavy isotopes undergo the same chemical or biological reactions than light molecules, but simply because chemical bonds involving heavy isotopes are stronger, they have slower reaction rates



- Due to these tiny differences in reaction rates the products of reactions have different isotope ratios than the source materials



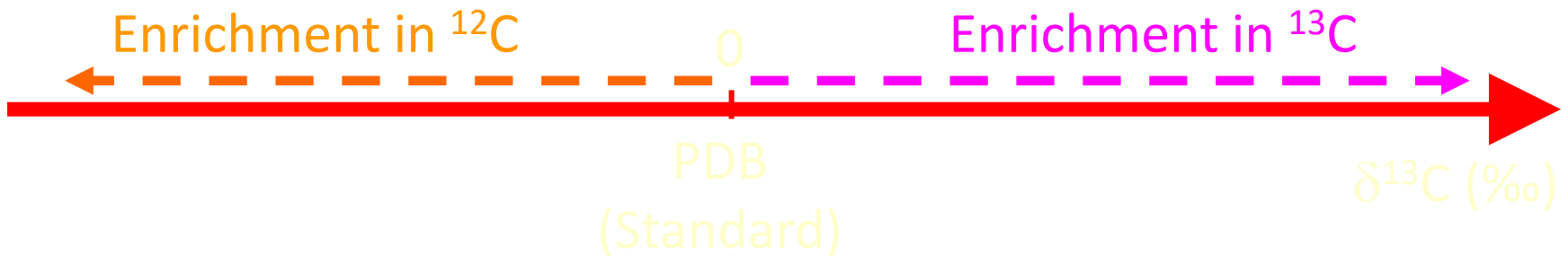
Isotopic composition

Delta notation is a way to express isotopic composition of a sample relative to an international standard (marine carbonate, PDB)

$$\delta^{13}\text{C} = \frac{R_{\text{sample}} - R_{\text{standard}}}{R_{\text{standard}}} \times 1000 \quad [‰] \quad R = {}^{13}\text{C}/{}^{12}\text{C}$$

→ When $\delta^{13}\text{C}$ is positive, the sample is enriched in ${}^{13}\text{C}$ / Standard

→ When $\delta^{13}\text{C}$ is negative, the sample is enriched in ${}^{12}\text{C}$ / Standard



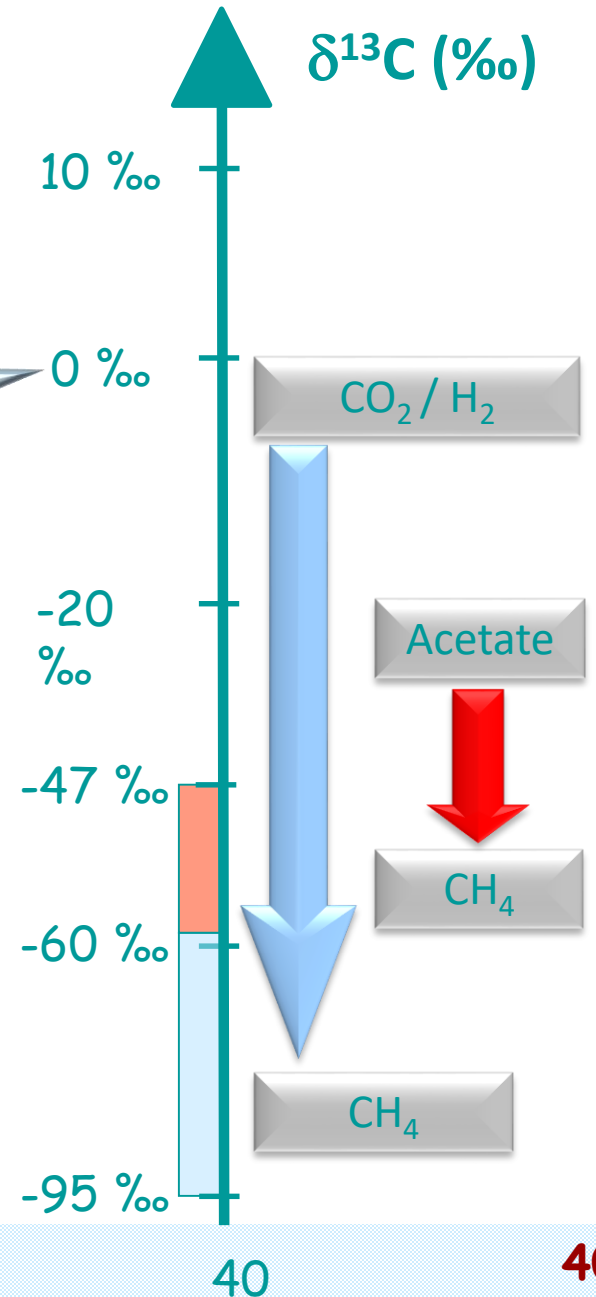
Stable isotopic approach

Isotopic composition is generally different between CO_2 and Acetate

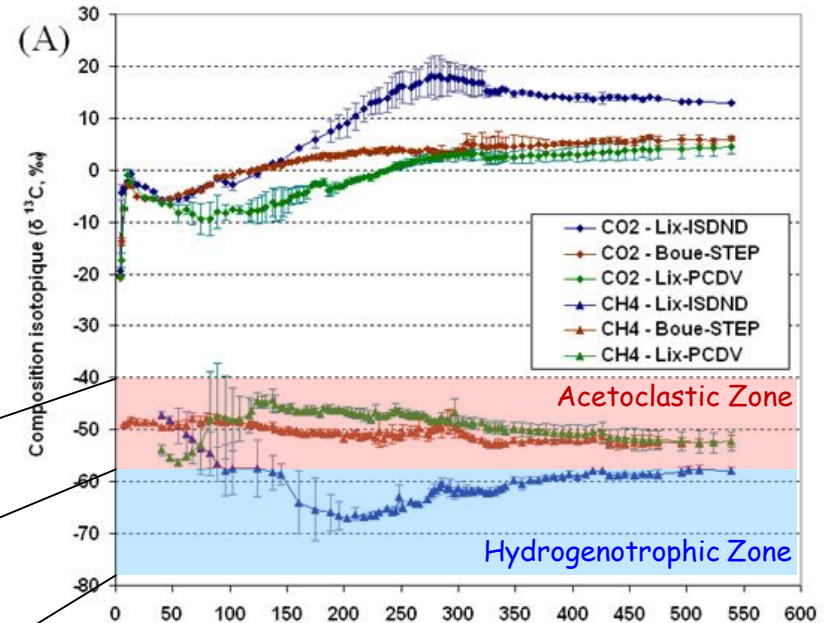
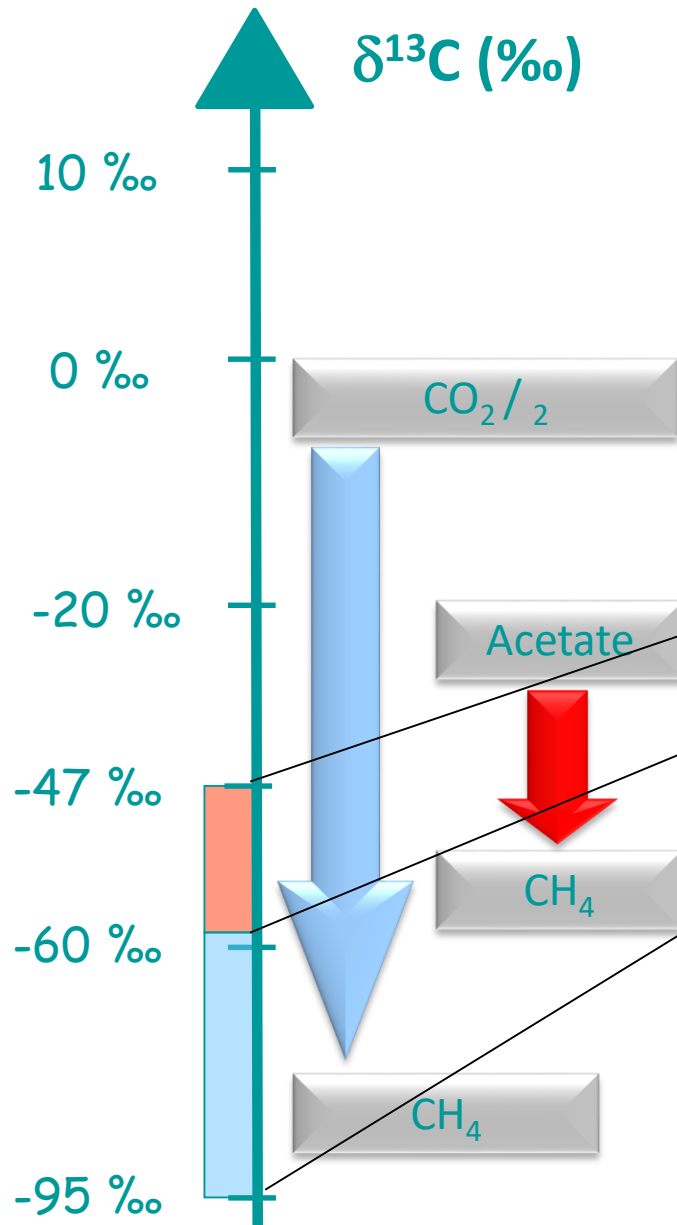
The stable isotopic approach is already used for the study of natural methanogenic environment

Microorganisms are important for the hydrogenotrophic methanogenesis

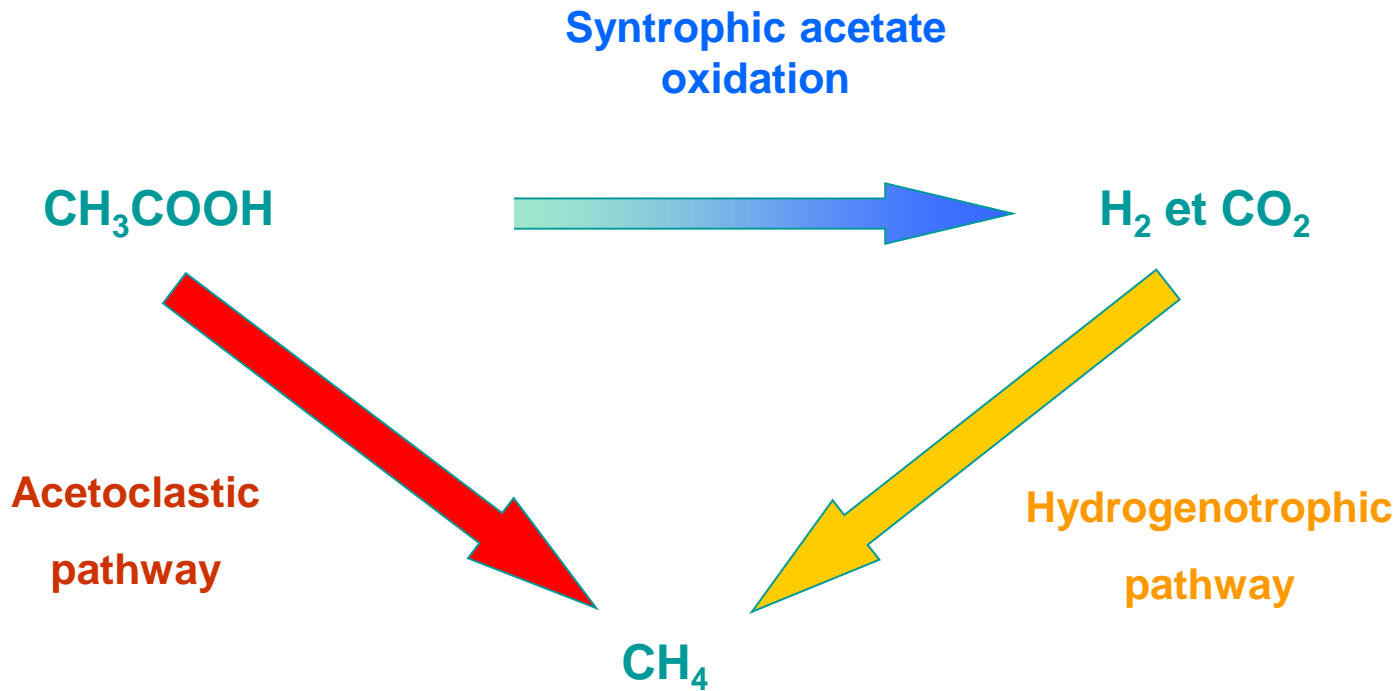
Using bibliographic data, it's possible to determine the methanogenic pathway by using methane stable isotopic composition



Biogas isotopic composition



Methanogenesis pathways

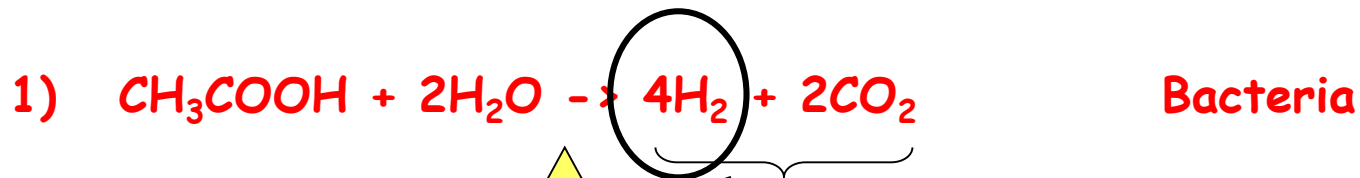


Reactions :



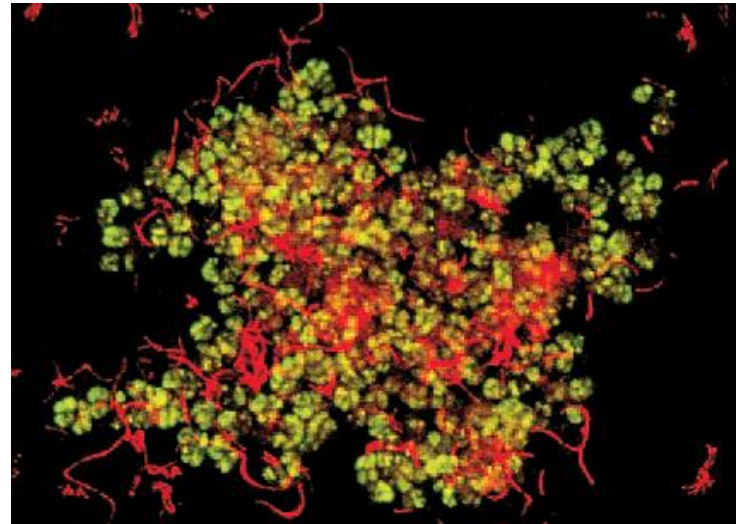
Synthrophic acetate oxidation

Two step reaction:

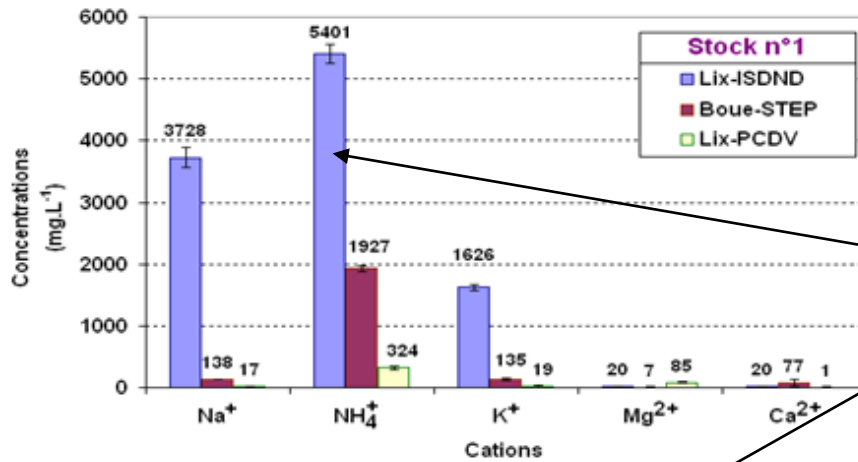


syntrophic relationship between

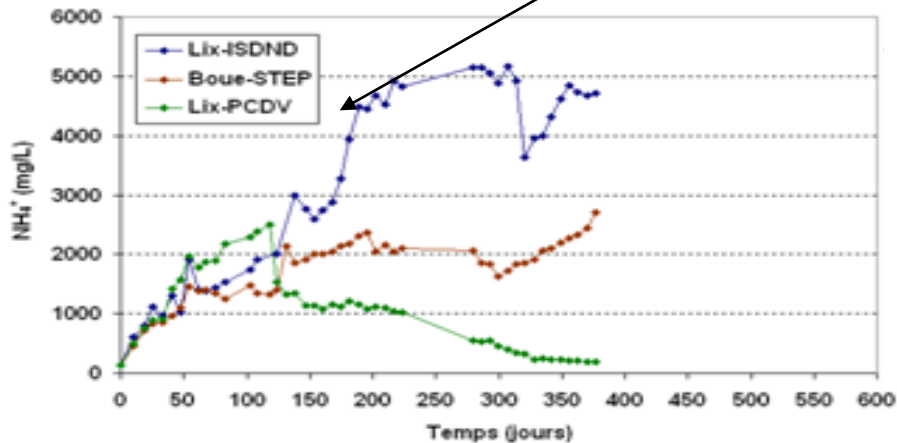
bacteria and archaea 



Why biogas production is slower with landfill leachates?

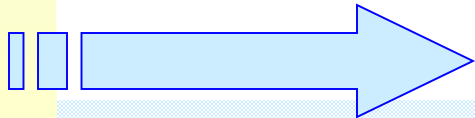
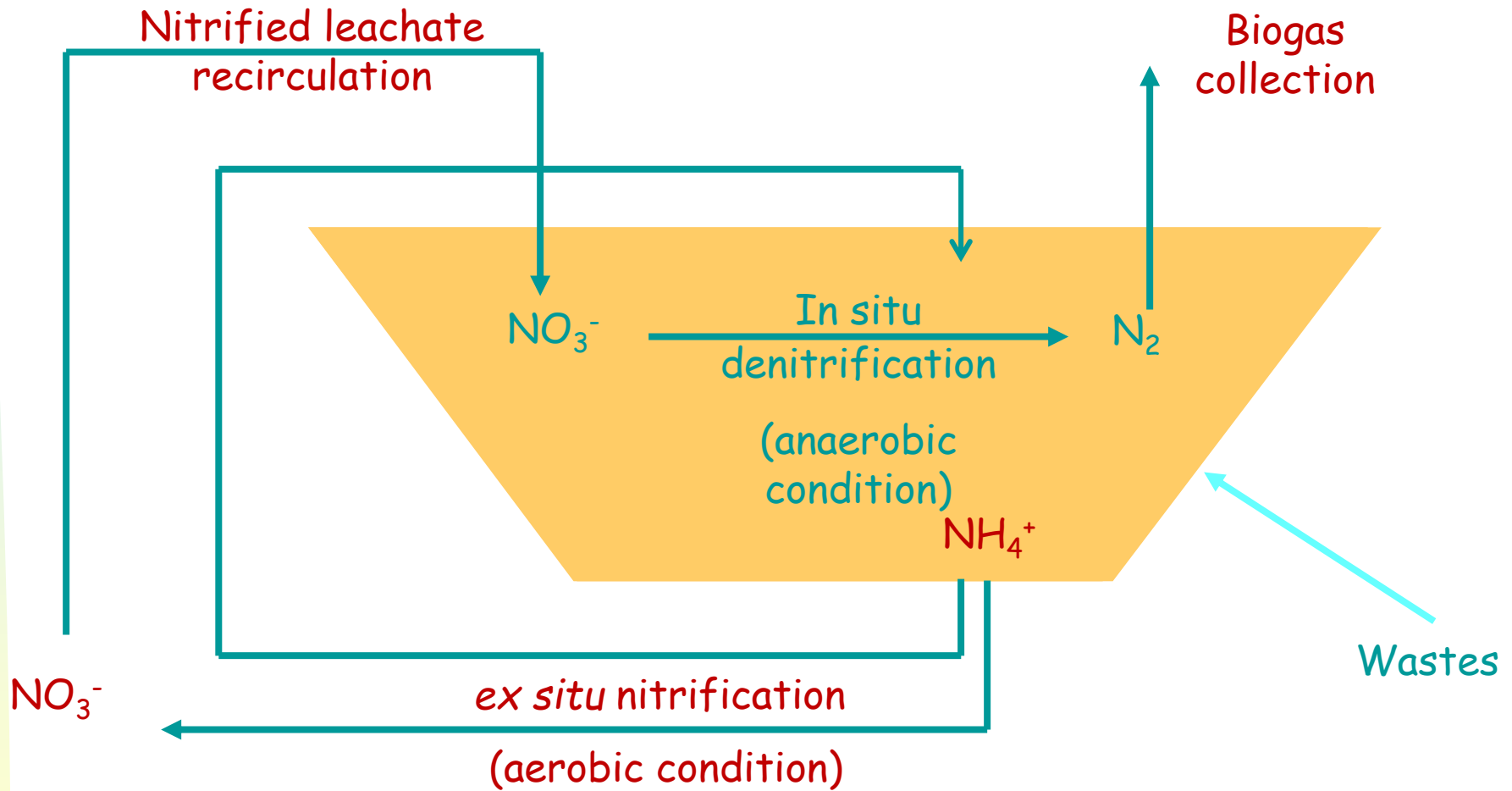


Amonia methanogenesis inhibition





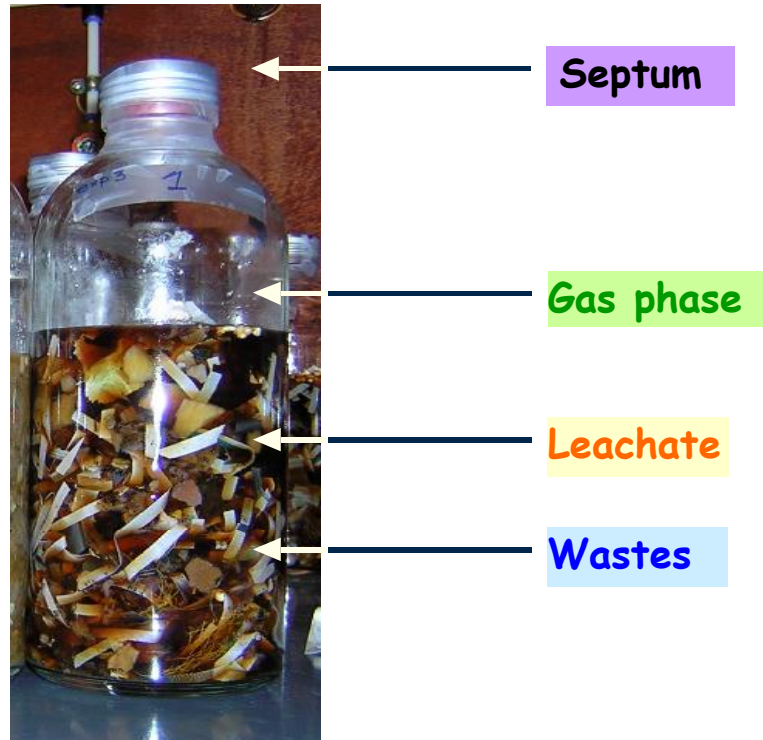
Bioreactor Municipal solid waste landfill



Strategy: leachate pretreatment before recirculation

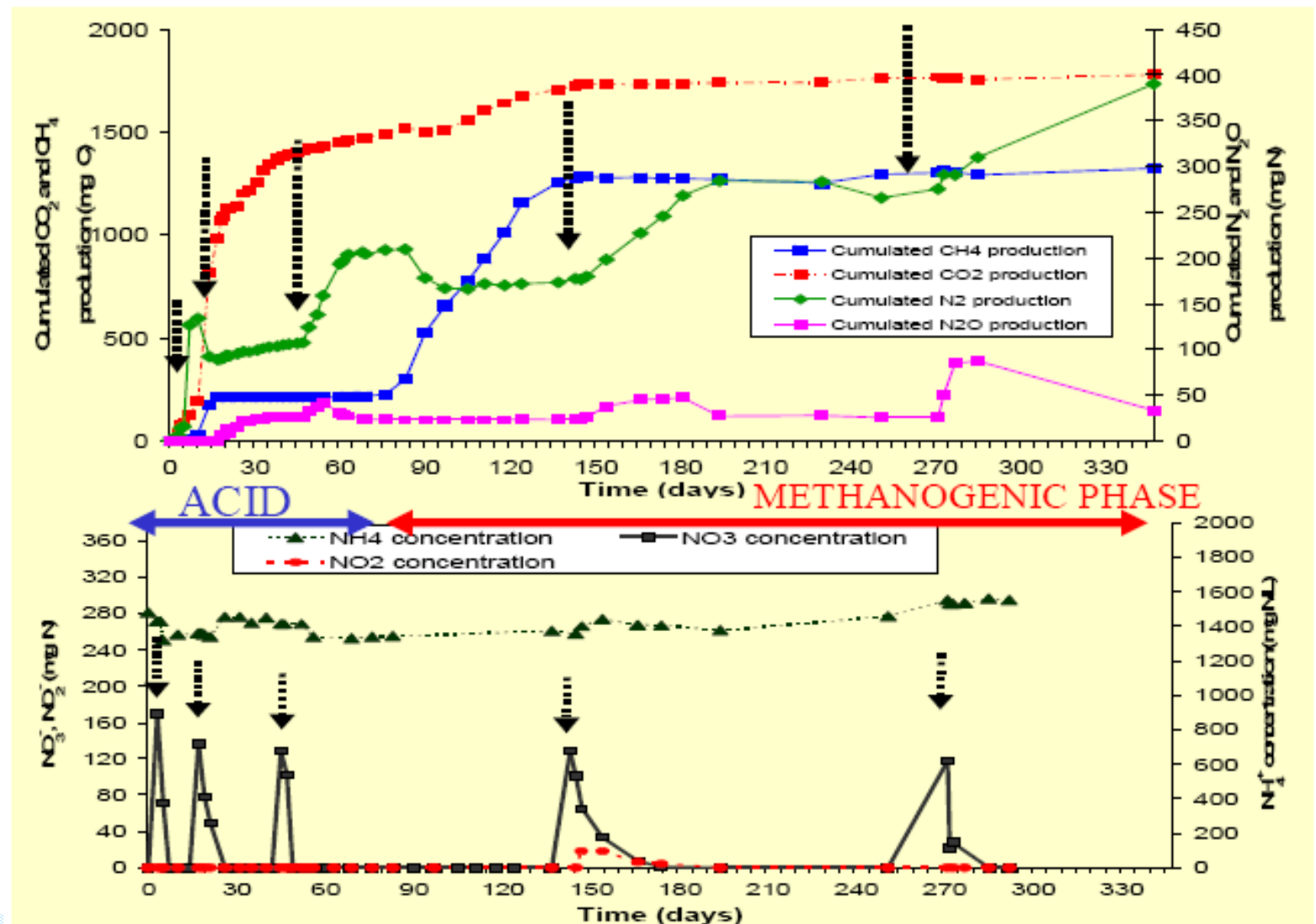


Anaerobic batch experiment





Experimental design



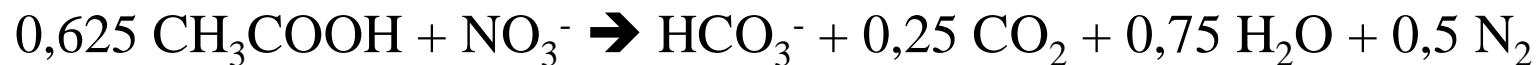


Case 1 Results interpretation

N₂ production = denitrification

Presence of organic matter

→ Heterotrophic denitrification



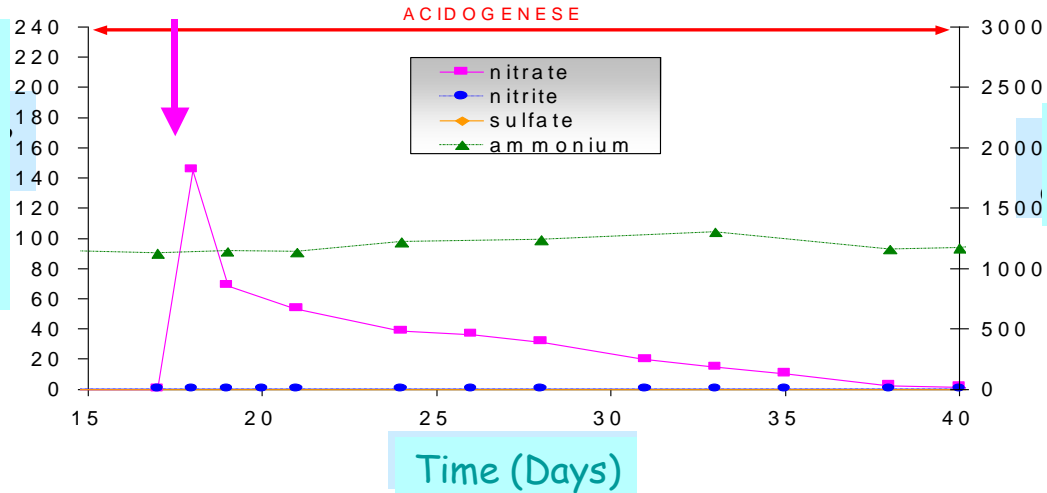
Observed in 13 cases upon 20



Second Case

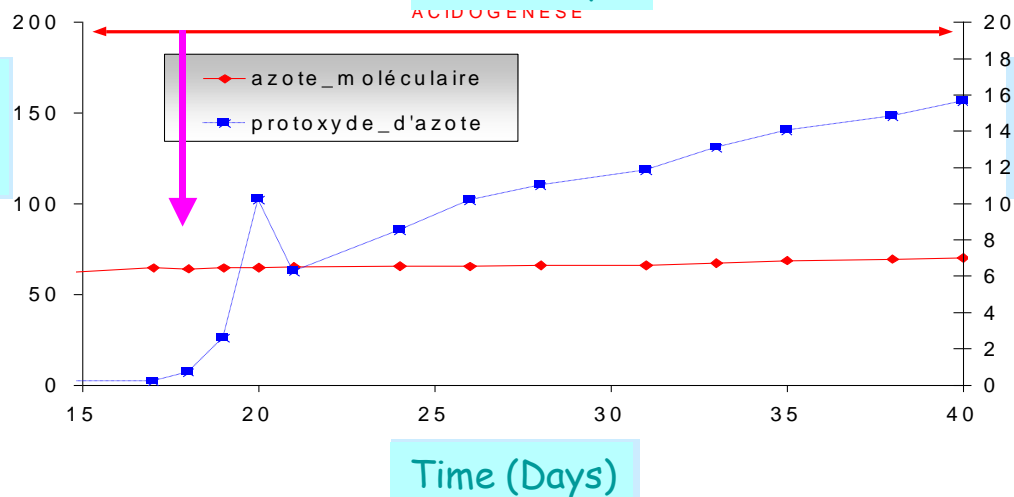
NO_3^- and NO_2^-
content (mg of N)

SO_4^{2-} concentration
(mg.l^{-1})



NH_4^+
concentration (mg.l^{-1})

N_2 cumulated
production (mg of
N)



N_2O cumulated
production (mg of N)



Case 2 Results interpretation

No N₂ production = Nitramonification?



Observed in 4 cases upon 20



Identification of the shifting parameter

Statistical analysis :

$$\text{N}_2 \text{ production} = 0,5245 + 0,1059 [\text{acétate}] - 6,2153 [\text{H}_2\text{S}]$$

R²=0,801

Positive effect on
N₂ production

(Positive coefficient)

Negative effect on
N₂ production

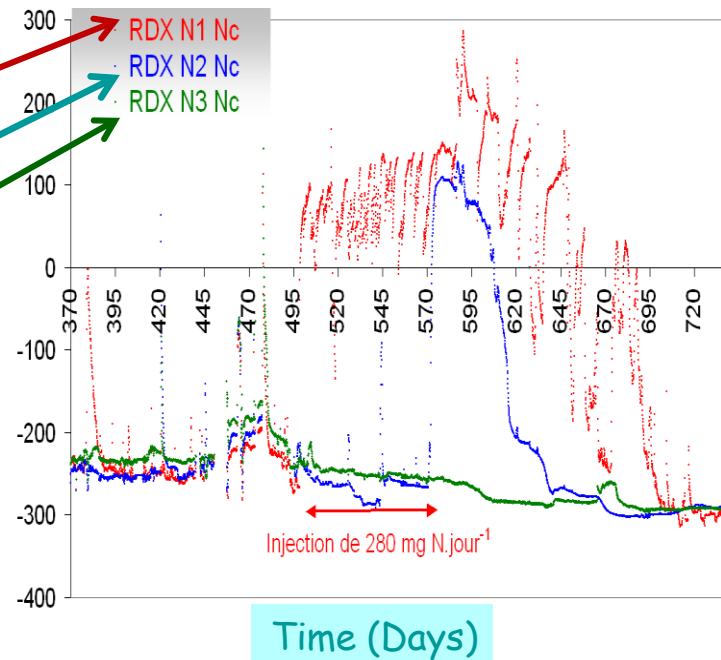
(Negative coefficient)



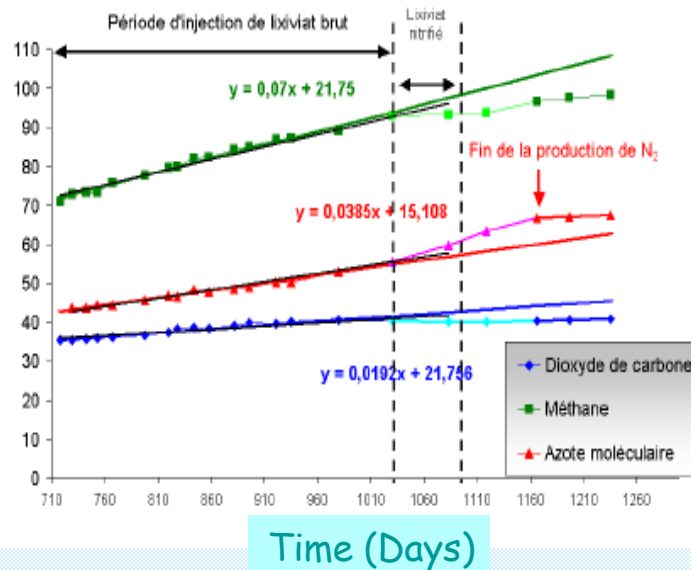
Mesocosm experiment



Oxido-reduction potential against Eh



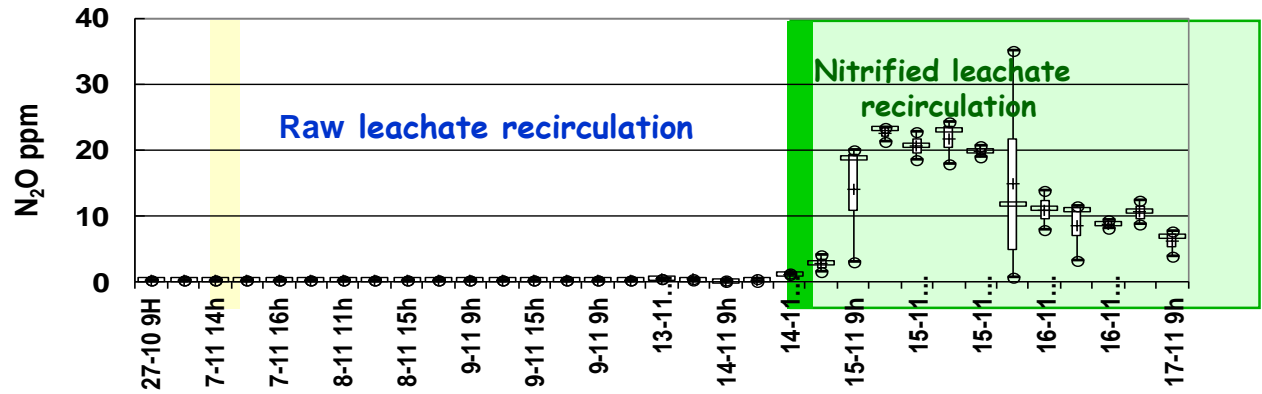
Cumulated production of CO₂, CH₄ and N₂



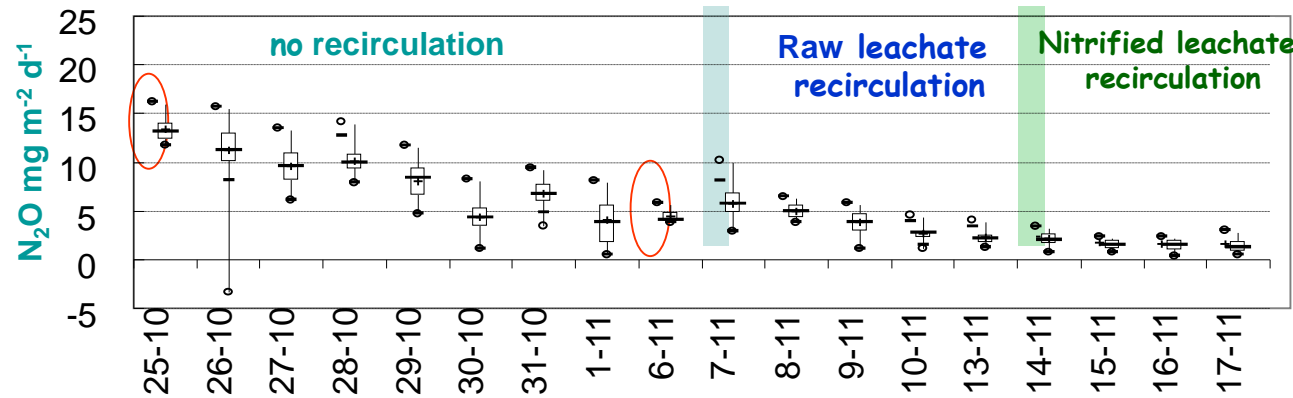


Field experiment

N₂O concentration in biogas collecting system

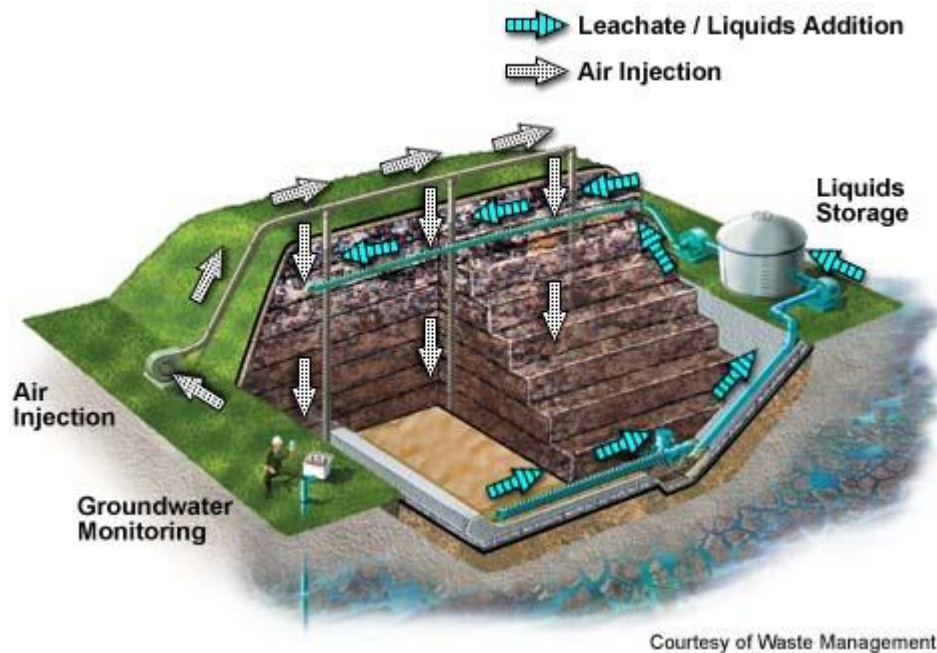


Surface N₂O emission



Aerobic bioreactor landfill

In an aerobic bioreactor landfill, leachate is removed from the bottom layer, piped to liquids storage tanks, and re-circulated into the landfill in a controlled manner. Air is injected into the waste mass using vertical or horizontal wells to promote aerobic activity and accelerate waste stabilization.



Municipal solid waste landfill

- Context
- Municipal solid waste landfill conception
- Anaerobic degradation in landfill: influence on leachate composition
- Landfill leachate recirculation optimisation
- **MSW Landfill impacts**
- Landfill mining

MSW Landfill impacts

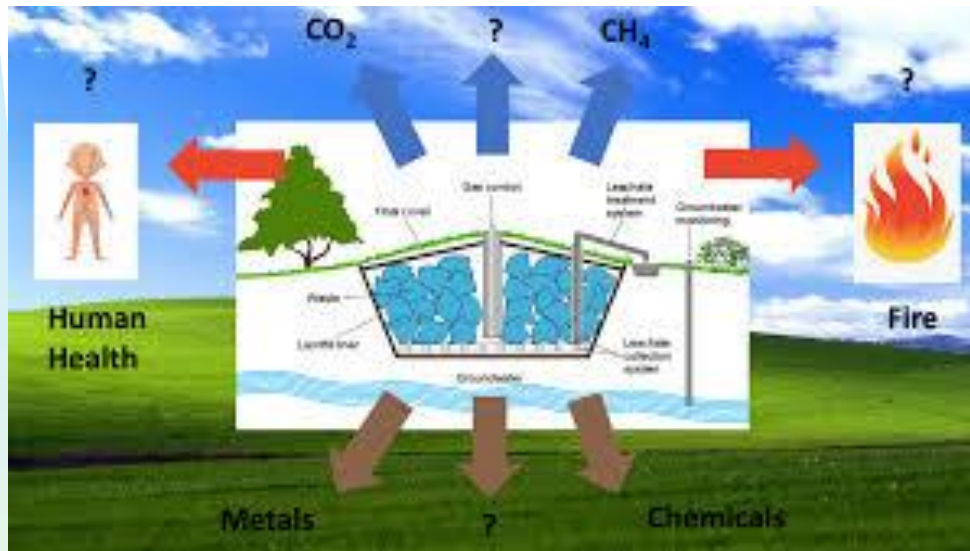
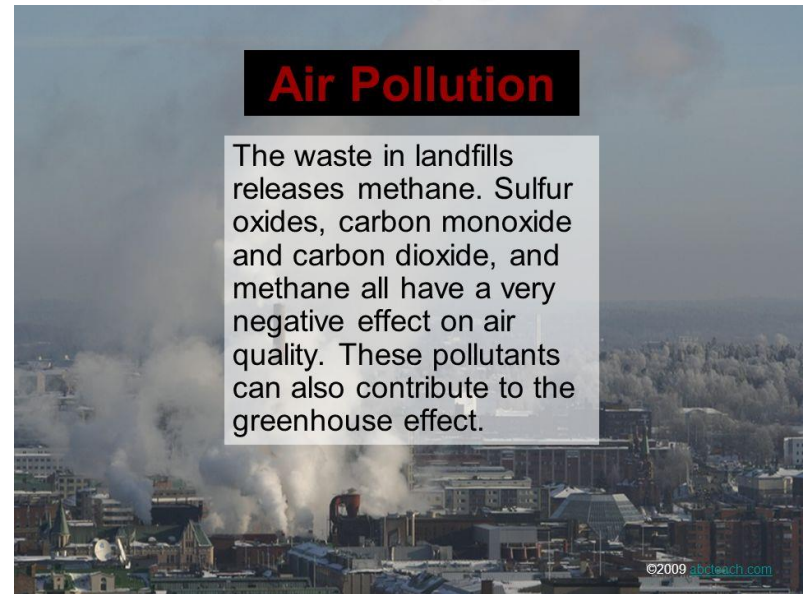
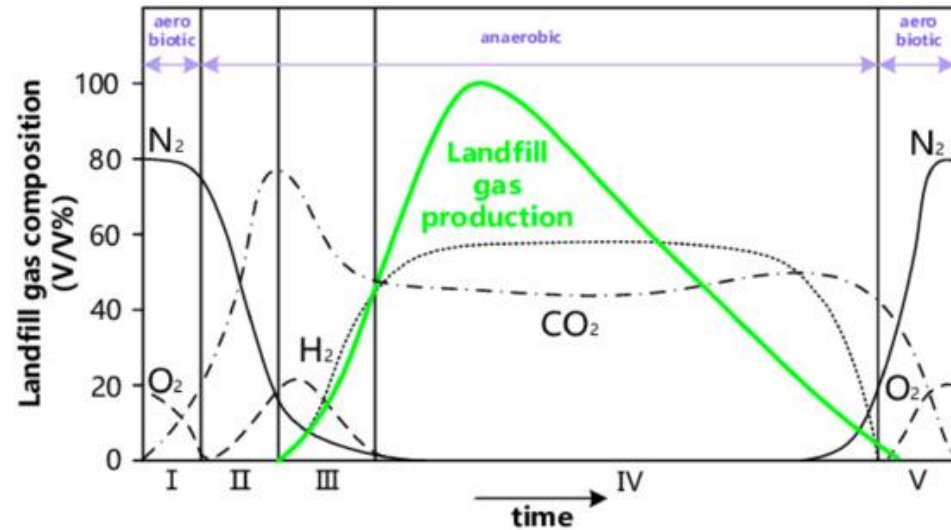


Figure 1. Potential impact of landfills on the environment.

Air pollution

Composants	Ordures ménagères
CH ₄ % vol	50-60
CO ₂ % vol	38-34
N ₂ % vol	5-0
O ₂ % vol	1-0
H ₂ O % vol	6 (à 40 ° C)
Total % vol	100
H ₂ S mg/m ³	100 - 900
NH ₃ mg/m ³	-
Aromatiques mg/m ³	0 - 200
Organochlorés ou organofluorés mg/m ³	100-800

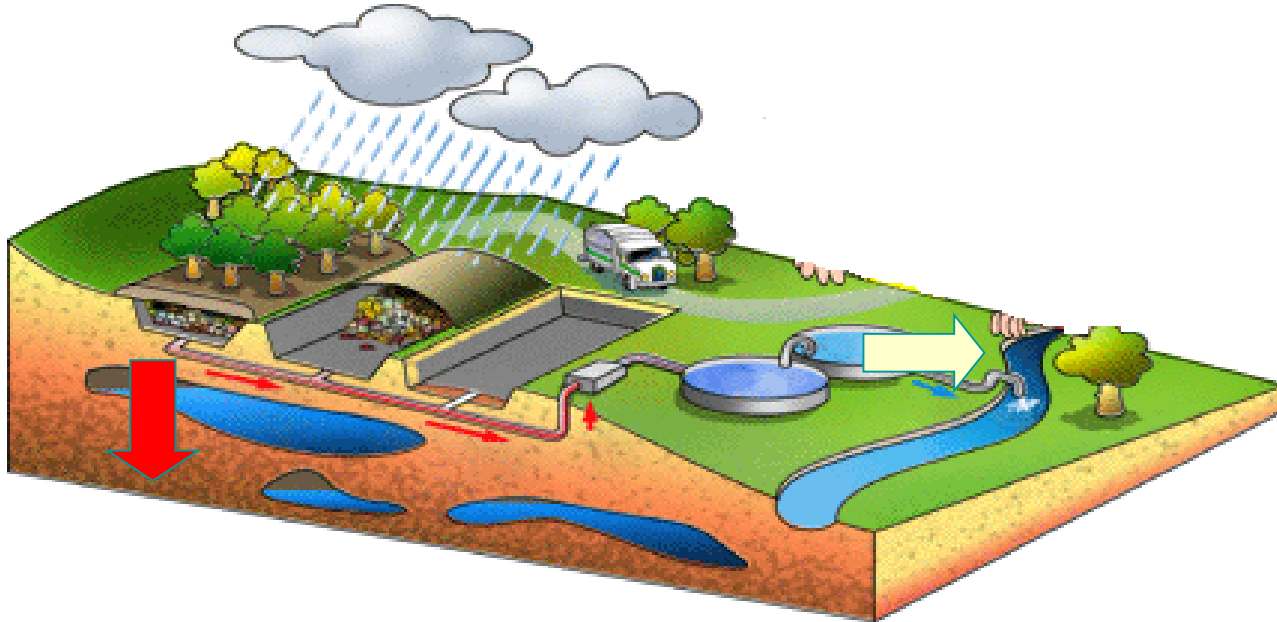


Air Pollution

The waste in landfills releases methane. Sulfur oxides, carbon monoxide and carbon dioxide, and methane all have a very negative effect on air quality. These pollutants can also contribute to the greenhouse effect.



MSW Landfill leachates impacts



1

Transfers of micropollutants through the sealing barriers



Contamination of subsoils and groundwater

2

Recalcitrant micropollutants to leachate treatments



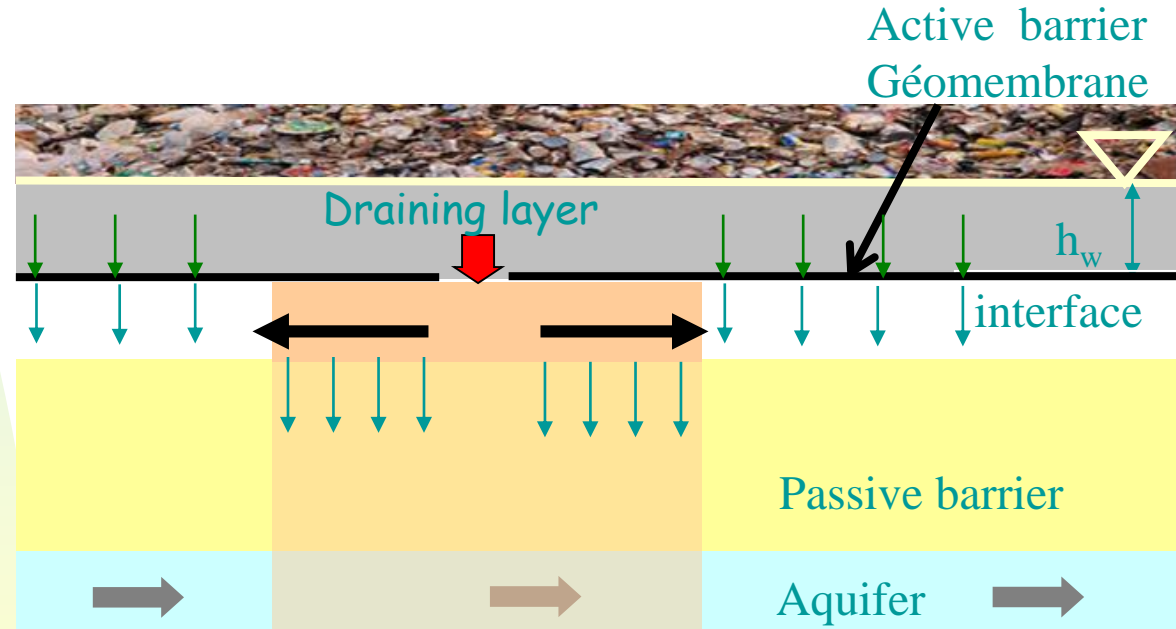
Contamination of surface water



Transfers of micropollutants through the sealing barriers

Two basic modes of transfer in the sealing barriers :

- **advective transfers (defects in the geomembrane)**
- **diffusive transfers**



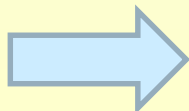
: Diffusive transfer through the intact geomembrane



Micro-pollutants found in leachates

Database under access grouping:

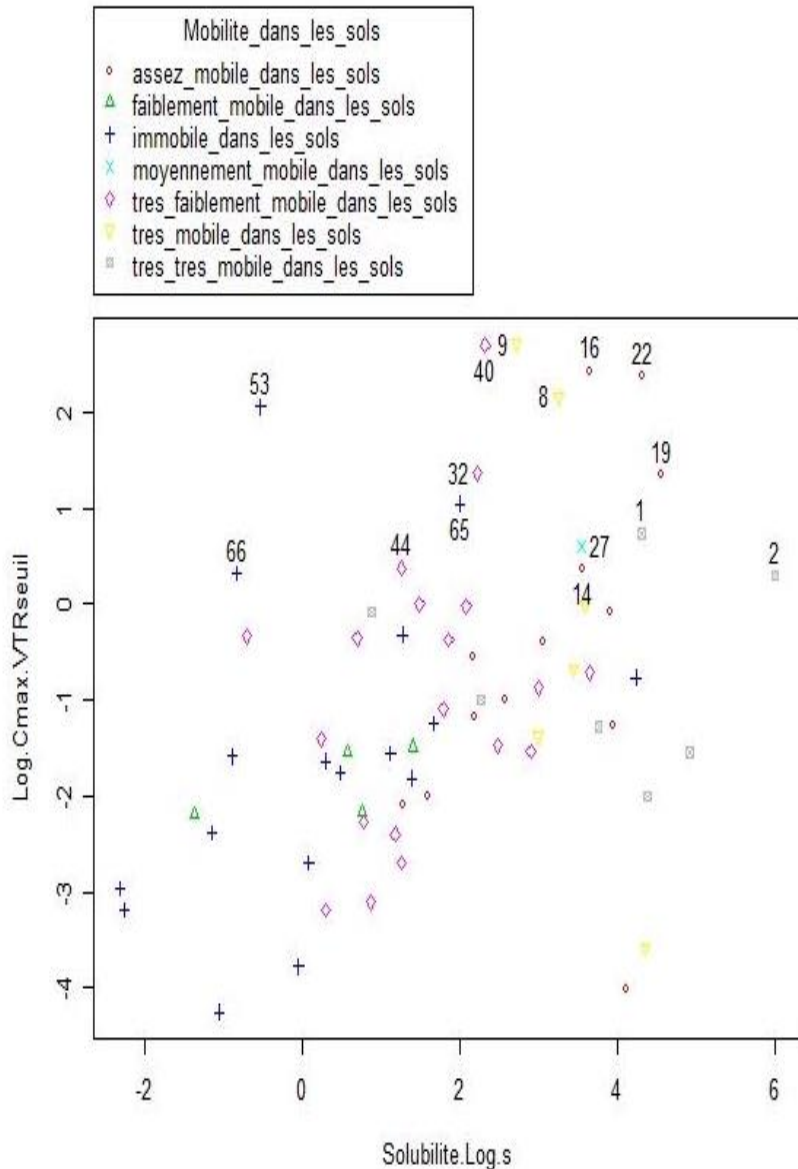
- 33 publications and study reports
 - 100 different ISD
 - 311 leachate samples
 - 402 organic compounds
- The physical-chemical properties (solubility, Koc ...)
- The toxicological properties of pollutants (TRV, CMR classification ...)



no public data in France



Selection of compounds for impact analysis



- 1: Dichloromethane
- 2: 1,4_Dioxane
- 8: Benzene
- 9: Toluene
- 14: Z- 1,2_Dichloroethylene
- 16: E-1,2_Dichloroethylene
- 19: Aniline
- 22: p_Cresol
- 27: 1,1,2_Trichloroethane
- 32: Ethylbenzene
- 40: Bisphenol_A
- 44: 1,2,4_Trichlorobenzene
- 53: Bis2_ethylhexylphthalate
- 65: Aldrin
- 66: dieldrin



Composition of leachates in France: analysis campaign

The choice of leachate collection sites: 8 sites

Compounds analyzed:

- Volatile Organic Compounds (VOCs)
- Polycyclic Aromatic Hydrocarbons (PAHs)
- PolyChlorinated Biphenyls (PCBs)
- PolyBrominated Diphenyl Ethers (PBDEs)
- Phenols and bisphenol A
- Phtalates
- Pesticides
- Pharmaceutical products
- Organometallic compounds

The organic compounds were analyzed both in the dissolved and particulate phases



Analysis campaign : main results

- ❖ Presence in large quantity of bisphenol A (antioxidant) and phthalates (plasticizer) which are plastic additives with reprotoxic properties
- ❖ Presence also of some VOC (mono-aromatic, chlorinated solvent ...) with carcinogenic properties
- ❖ Presence of PAHs, PCBs and PBDEs mainly on the particulate phase because these compounds are not very soluble
- ❖ Pharmaceuticals and hormones have not been found

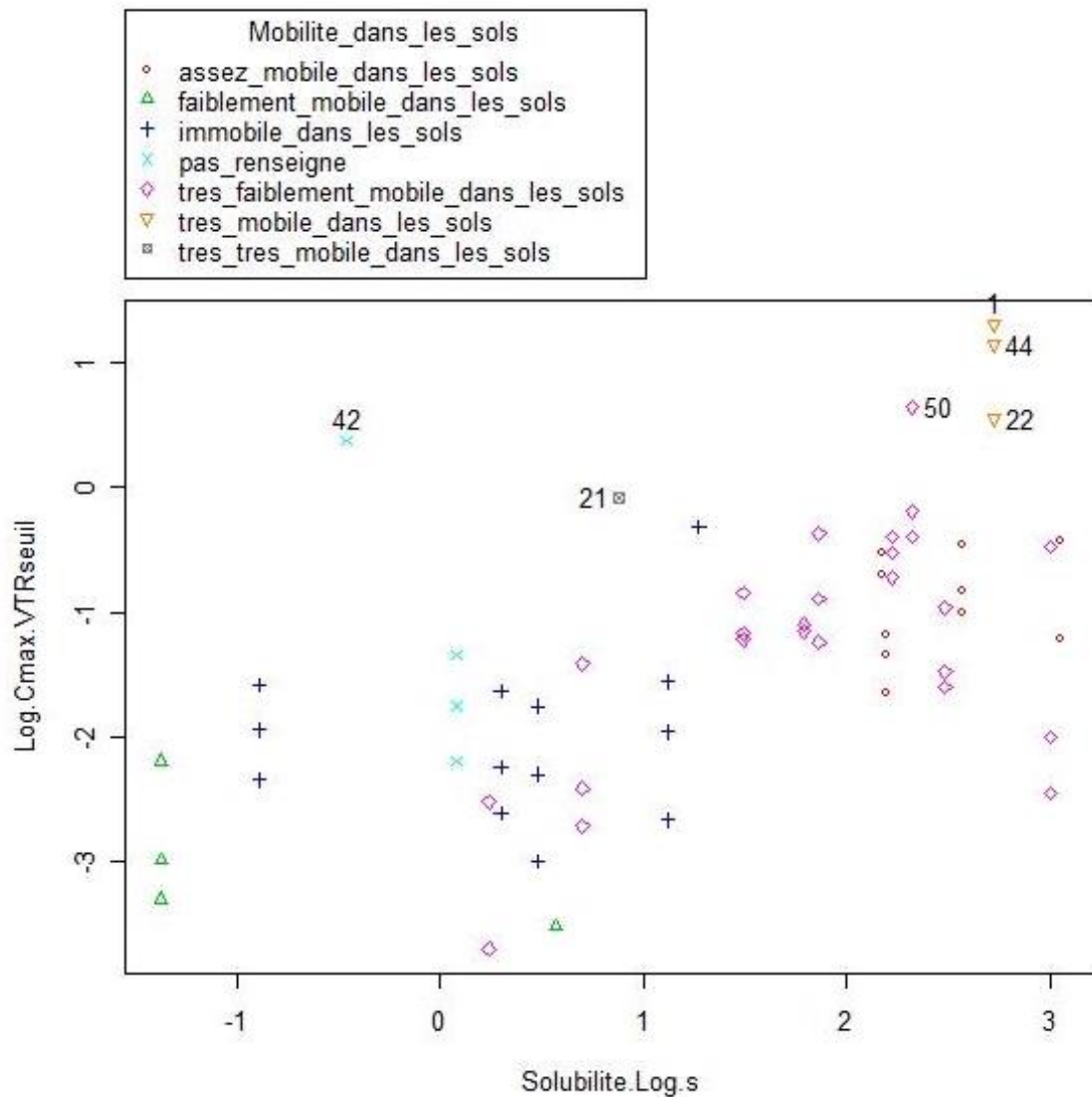


CMR compounds found in leachates

Compounds	CMR Classification	Tracking frequency (%)
Dibutyl phthalate	REPRO 2 / REPRO 3	100
Bisphenol A	REPRO 3	100
Toluène	REPRO 3	100
Benzène	CARC1/MUTA2	100
Dichlorométhane	CARC 3	100
p-dichlorobenzène	CARC3	75
Benz[a]anthracène	CARC 2	62,5
Butyl benzyl phtalate	REPRO 2 / REPRO 3	37,5
Trichloroéthylène	CARC 2/ MUTA 3	37,5
Tetrachloroéthylène	CARC 3	37,5
Benzo[e]pyrène	CARC 2	25
Benzo[a]pyrène	CARC 2/ MUTA 2/ REPRO 2	25
Heptachlor epoxide	CARC3	12,5
Heptachlor	CARC 3	12,5



Selection of compounds for impact analysis



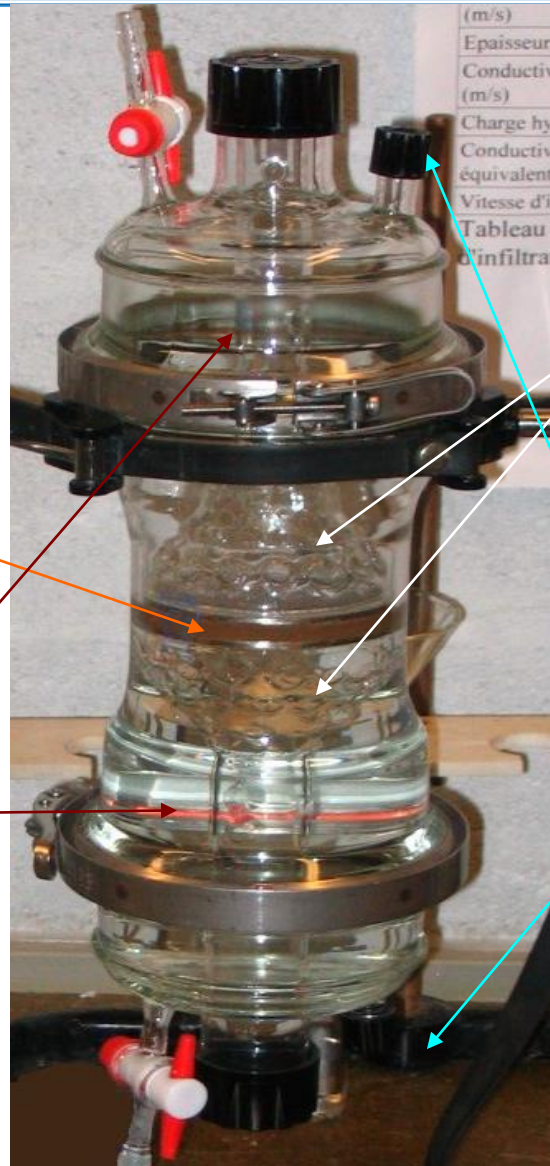
1: Toluène (DIB)
44: Toluène (OM + DIB)
22: Toluène (OM)
50: Bisphenol_A (OM + DIB)
42: Heptachlor_epoxide (OM)



Determination of diffusion coefficients

Sample

Tanks



Glass funnel

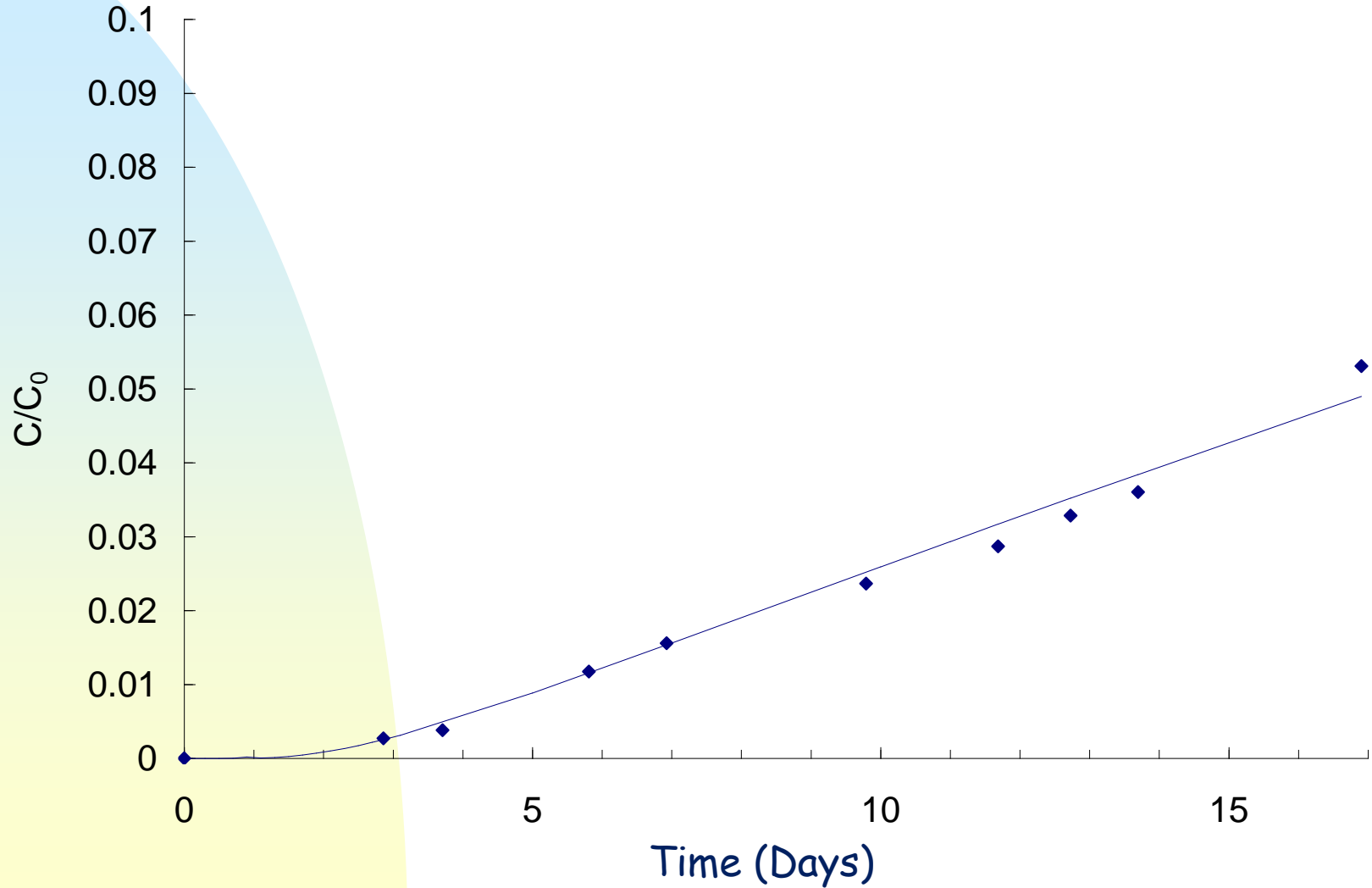
Sampling

(m/s)
Epaisseur d
Conductiv
(m/s)
Charge hyd
Conductiv
équivalente
Vitesse d'in
Tableau
d'infiltrati



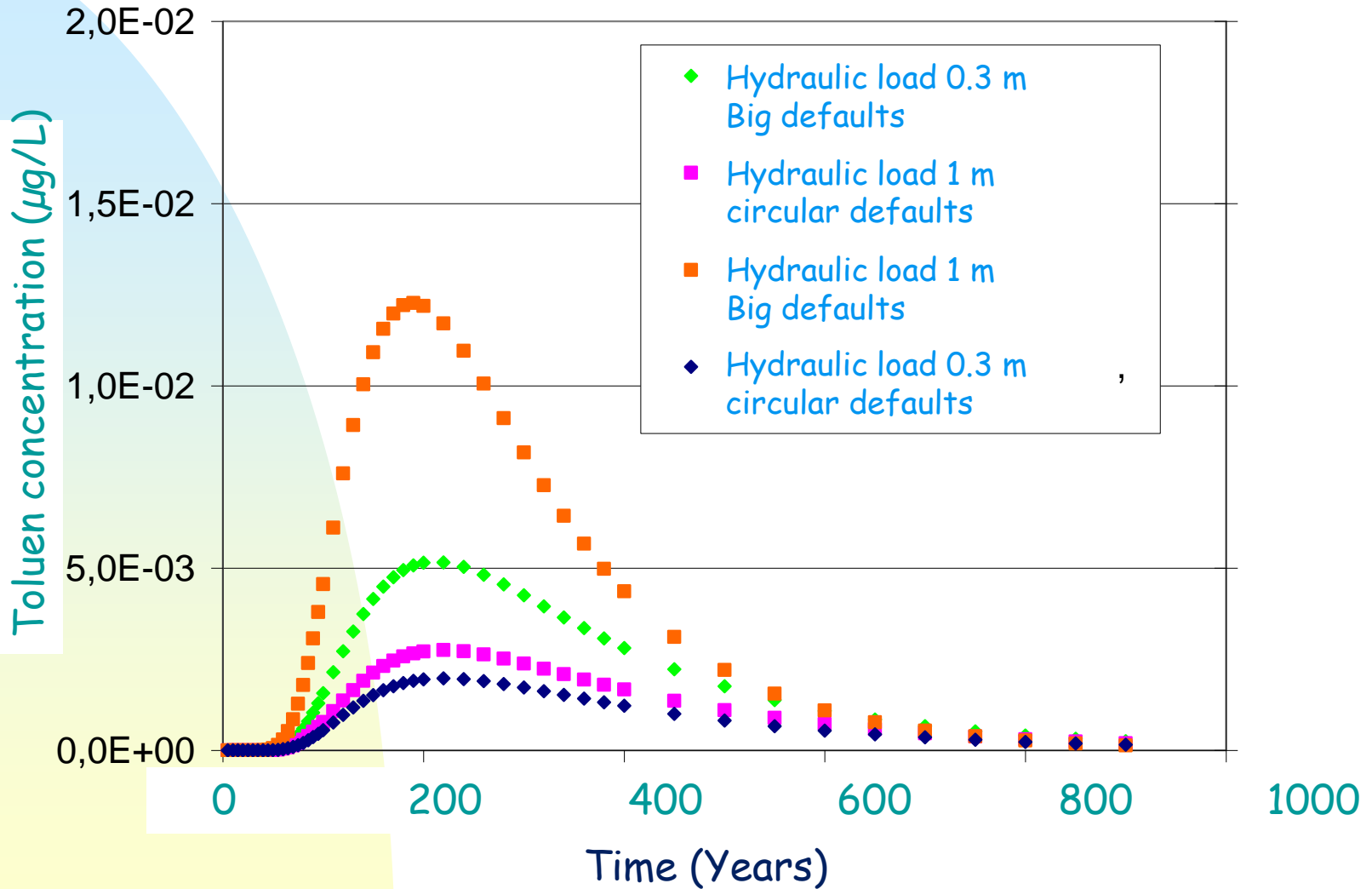
Determination of diffusion coefficients

Toluen





Calculation of the concentration in the aquifer





Effect directed analysis

Assessment of the toxicity of non-hazardous waste storage facility leachates and identification of the chemical agents responsible



Nature of analyzed leachates



Raw leachate



Aerated leachate



Treated leachate

Samples	Site	Characteristics
Site1-LB	Site 1	Lixiviât brut provenant de plusieurs casiers d'âges différents.
Site1-LA	Site 1	Lixiviât prélevé dans le bassin d'aération recevant le lixiviât site1-LB.
Site1-LT	Site 1	Perméât prélevé en sortie de traitement (évapo-concentration suivie d'une osmose inverse) du site1.
Site2-LB	Site 2	Lixiviât brut prélevé au niveau de la station de relevage du site 2.
Site2-LA	Site 2	Lixiviât prélevé dans le bassin d'aération recevant le lixiviât site2-LB.
Site2-LT	Site 2	Effluent de sortie de traitement (réacteur membranaire suivi d'une filtration sur charbon actif) du site 2.



Evaluation of the toxicity of the organic fraction

❖ Toxicity test

Targeted mechanisms References	Methods	Detected molecules	
Génotoxicité	SOS Chromotest	Genotoxics et pro genotoxics: HAP, nitrosamin, pesticides...	Quillardet et Hofnung, 1985
Dioxin receptor (AhR)	EROD activity	Dioxins et dioxin-likes, HAPs, PCBs	Laville et al., 2004
Estrogen receptor (ER)	Luciferase activity	Steroids naturels et synthetics, Alkylphenols, Bisphenol A...	Pillon et al., 2005

❖ Toxicity tests results

	Genotoxicité	Activity	
		Dioxin-like	Estrogenicity
Site 1 -Raw	+	++	+++
Site 1 -Aerated	-	+	+
Site 1 -Treated	-	-	-
Site 2 -Raw	-	++	++
Site 2 -Aerated	-	+	++
Site 2 -Treated	-	-	-

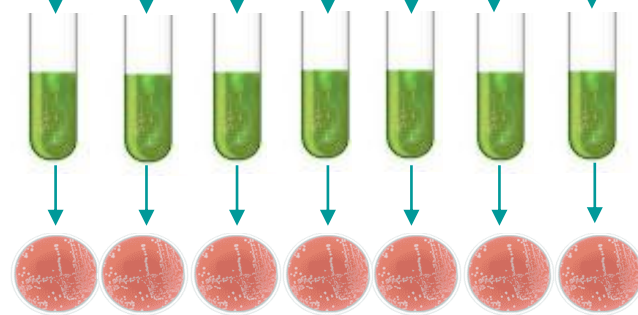
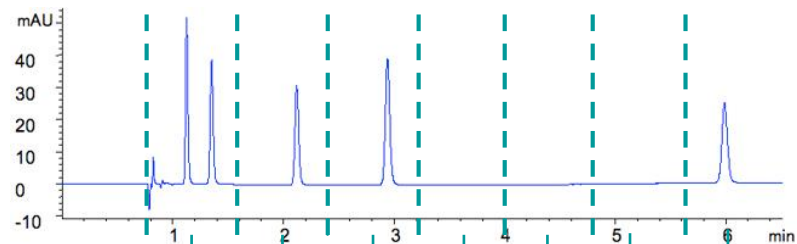


Principle of the effect directed analysis approach

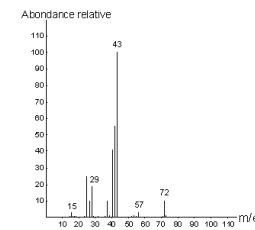
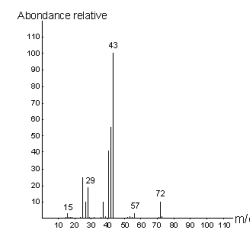
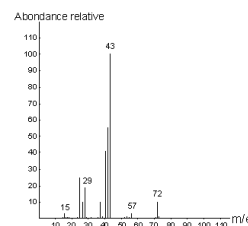
Fractionation of the leachate organic fraction by HPLC

Identification of toxics fractions by toxicity tests
(Genotoxicity, Estrogenicity)

Identification of molecules present in the fractions presenting toxicity by chemical analysis

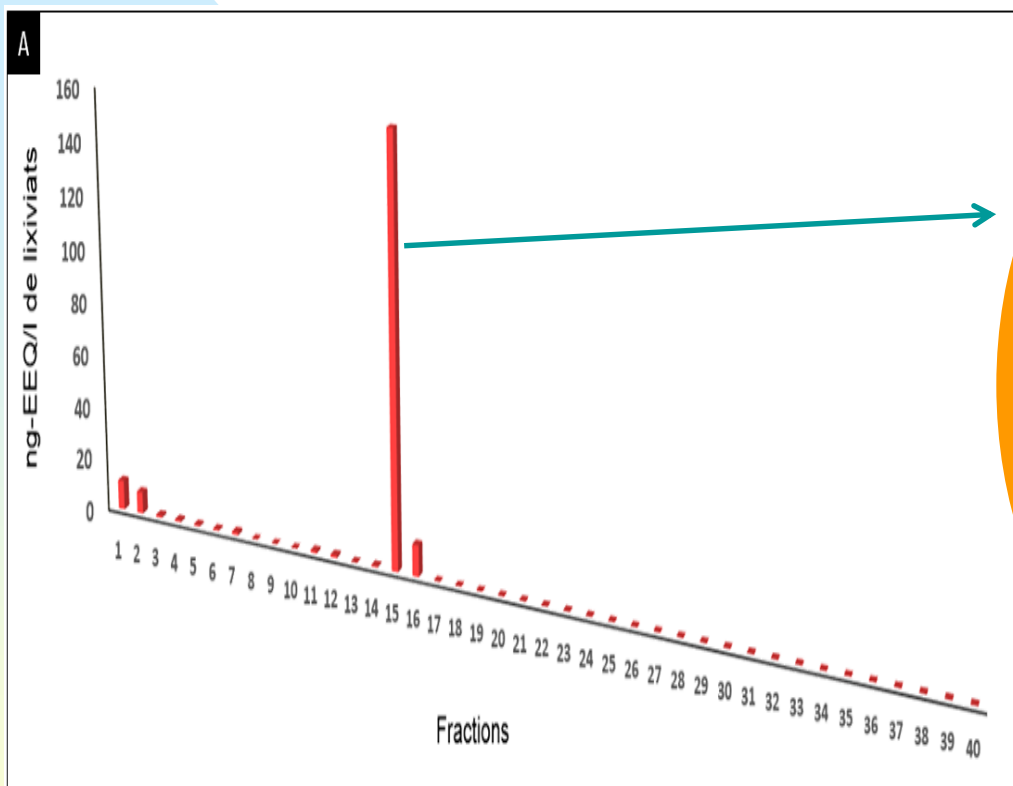


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EDA approach to ISDND leachates

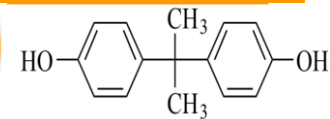


**Estrogenicity origin
of the landfill leachate**

Non explained

11%

**Explained by
Bisphenol A**

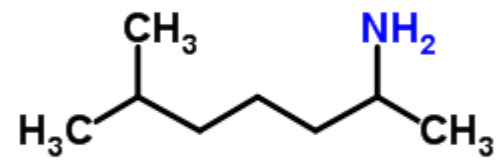
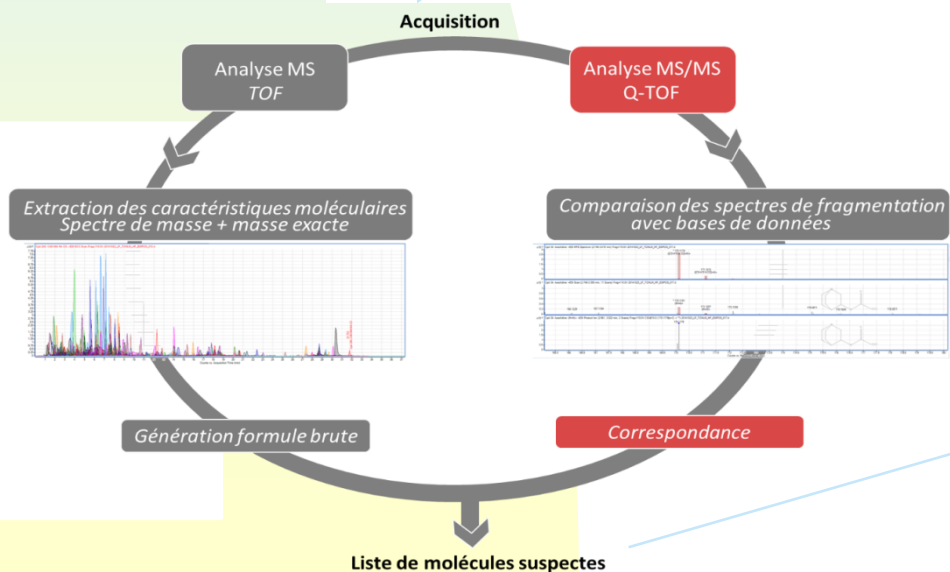
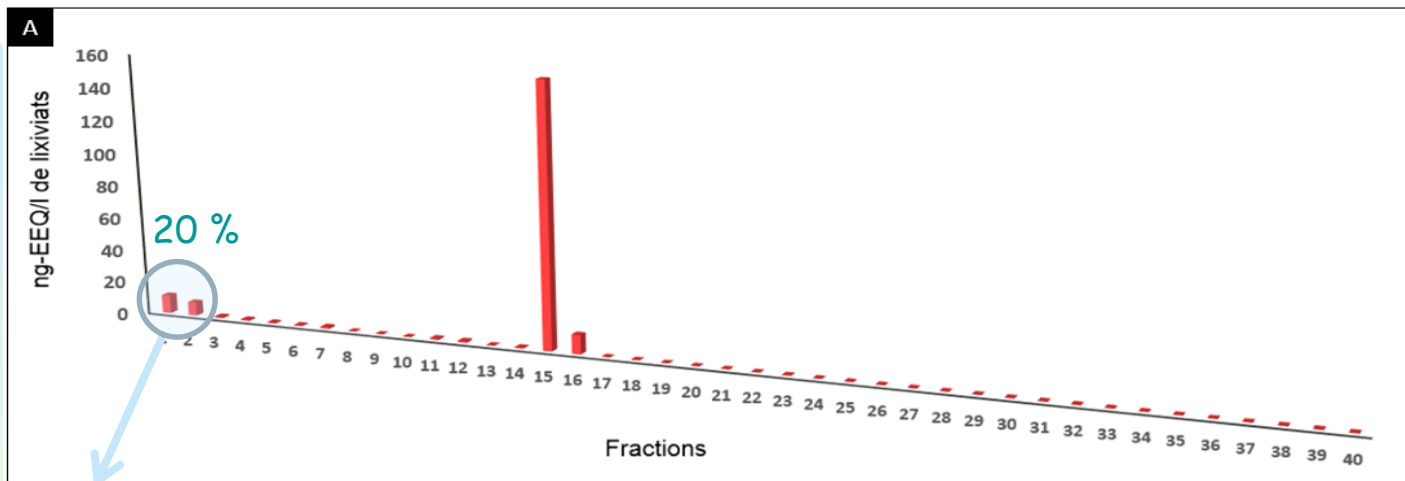


89%





Identification of the responsible compounds



Octodrine



Concentrations of metals in leachates

Concentrations in mg/l

	Danemark	Germany	England	Drinking water
Cd	0.006	0.005	< 0.04	0.005
Zn	0.67	0.6	< 0.47	5.0
Cu	0.07	0.065	< 0.17	1.3
Cr	0.08	0.28	< 0.05	0.1

Levels of metals in leachates are low.

↳ Metal trapping in waste as a precipitate (sulphide, carbonate...) or complexes with organic matter

However, in the long term, there may be significant release of metals when returning to aerobic conditions.



Sulfooxidation: a long-term risk?

sulfo-oxydation

Consumption of sulphides in the presence of oxygen or nitrates
(DMA) :

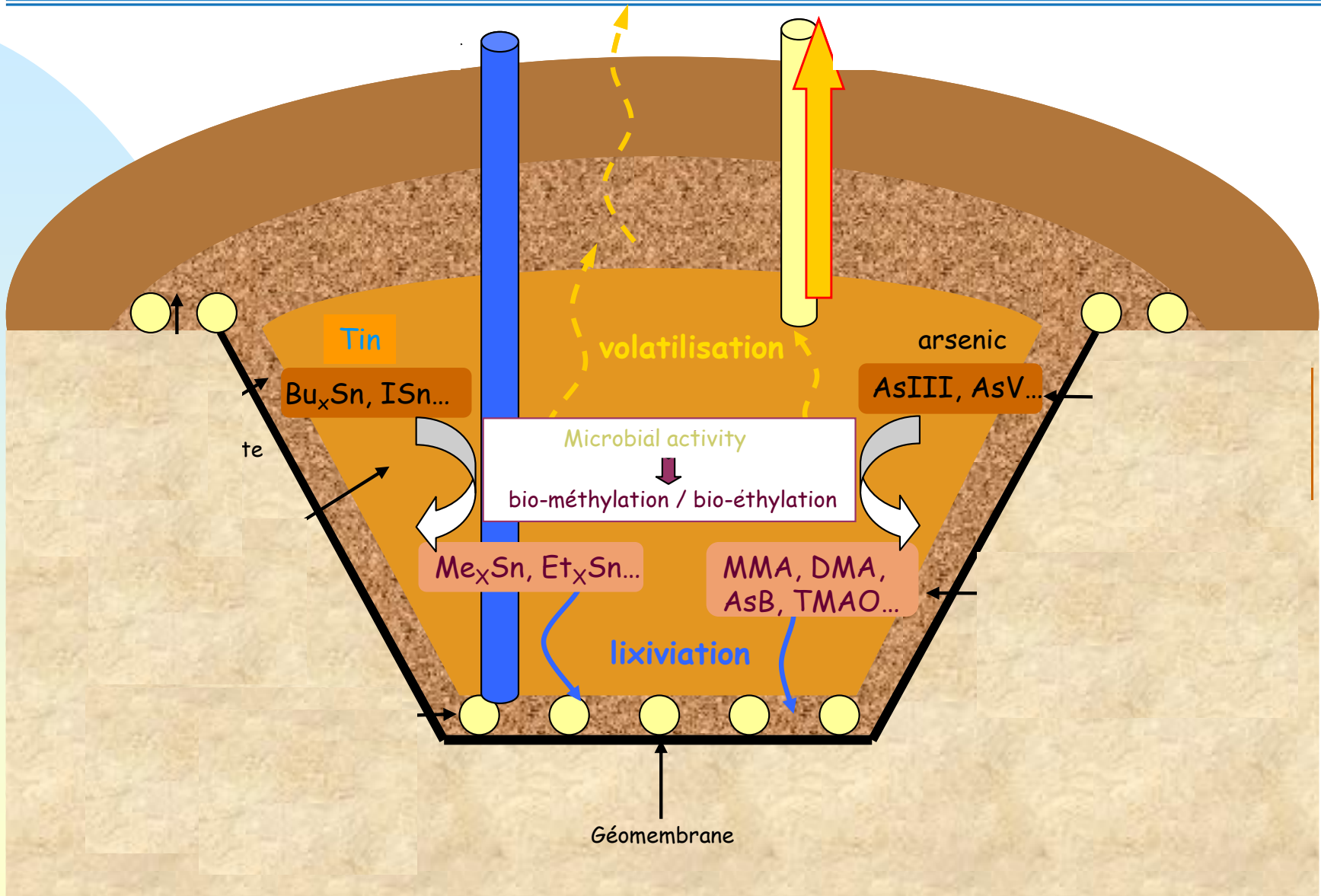


Consequences :

- Significant drop in pH
- Resolubilization of sulphides, hydroxides and carbonates



Metals biogeochemical cycles in MSW landfill



Municipal solid waste landfill

- Context
- Municipal solid waste landfill conception
- Anaerobic degradation in landfill: influence on leachate composition
- Landfill leachate recirculation optimisation
- Micropollutant in waste and landfill leachates
- Landfill mining



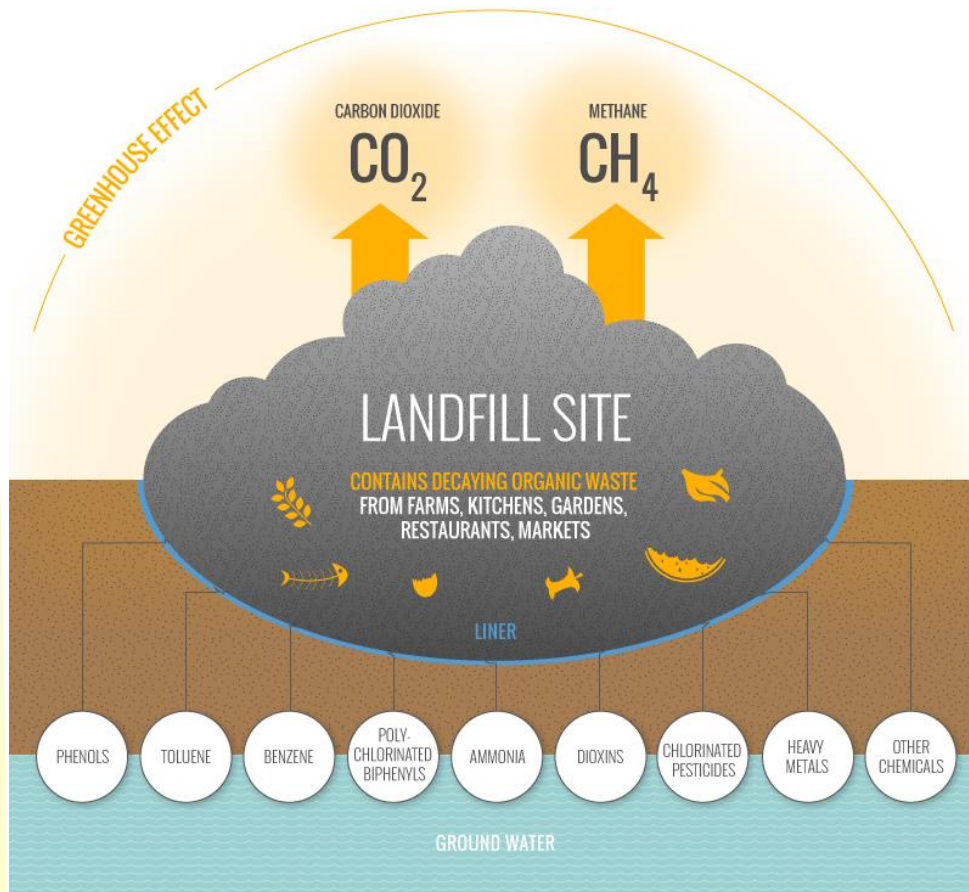
Landfill Mining





Why Landfill Mining ?

Environmental drawbacks of landfilling



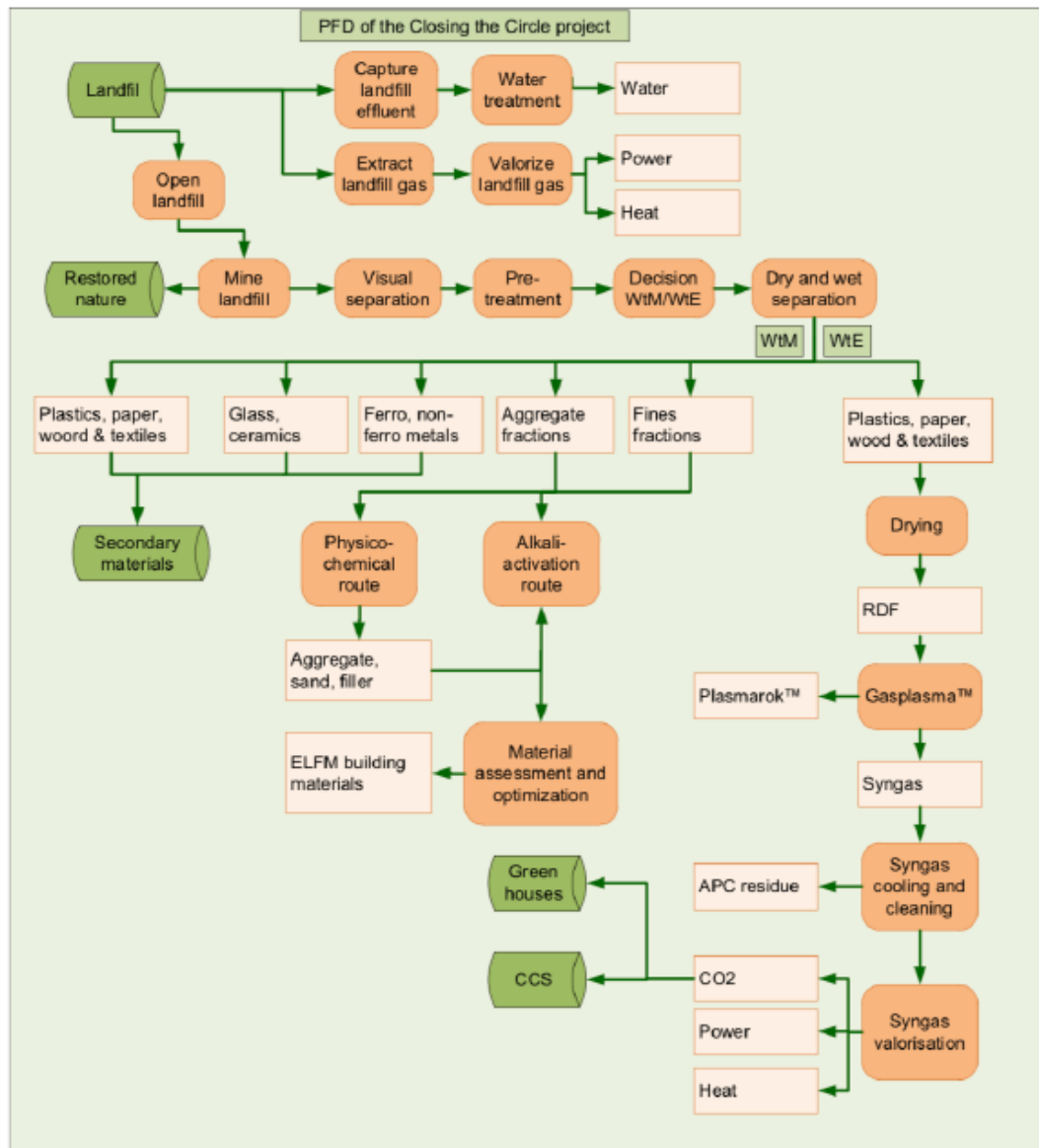
Global warming
contributor

Soil pollution
contributor

Groundwater
pollution
contributor



Example of Landfill Mining on the Remo Landfill (Belgium)





Landfill Mining advantages

CO₂ equivalent savings

New green energy sources

Region's materials autonomy
improvement

Soil and groundwater pollution
sources reduction

New construction materials

Jobs creation

Land reclamation



Landfill Mining applications

LFM applications around the World



Landfill mining projects map: designed for Life reclaim LIFE12\ENV\GR\000427 (2013)

