Appropriate Management of Waste Disposal Site in Southeast Asia

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What a Waste Disposal Site (Landfill) is in the Society

“Primitive” Stage of Waste Management

Environmental capacity vs Urbanization

Poor collection
Disposal to street/channel

Vermination/odor
Projection hazard/Landslides

Generation → Open dump

Public Health
Conservation of QOL

Open Dumps

Most primitive way of waste handling

Natural born
Posteriori

Bad Practice

Direct discharge into river

Cracked channel

Open Burning

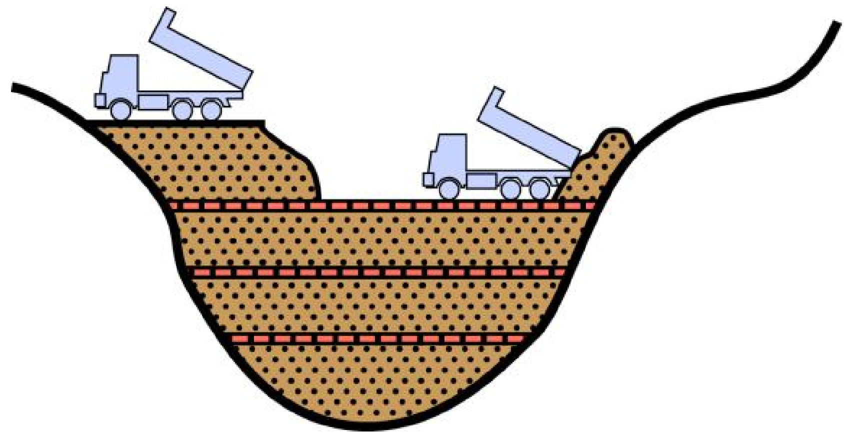
Developing Stage of Waste Management

Informal recovery
Translation of pollution source

Unused ?
Neglect ?

Anaerobication
Delay of stabilization
GHGs

Generation → compost → Sanitary LF



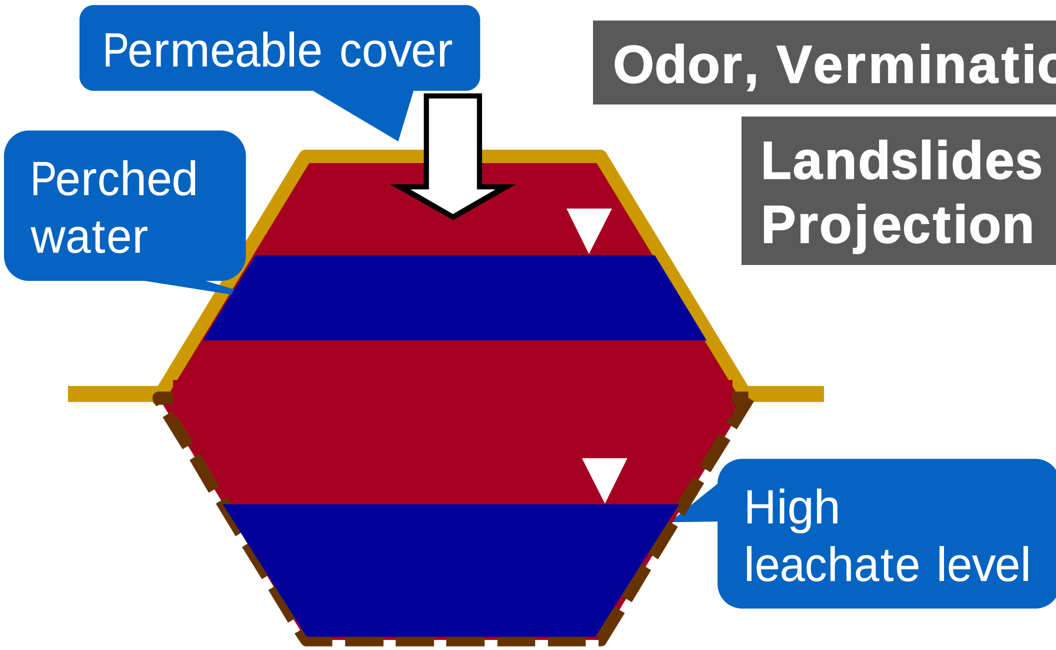
Waste amount increases by population and collection coverage

Waste stream becomes more complicate

Landfills are constructed far from urban area

Anaerobic Sanitary Landfill
Structure that easily generate Methane

Traditional Sanitary LF



No or incomplete drainage -> **Leakage**

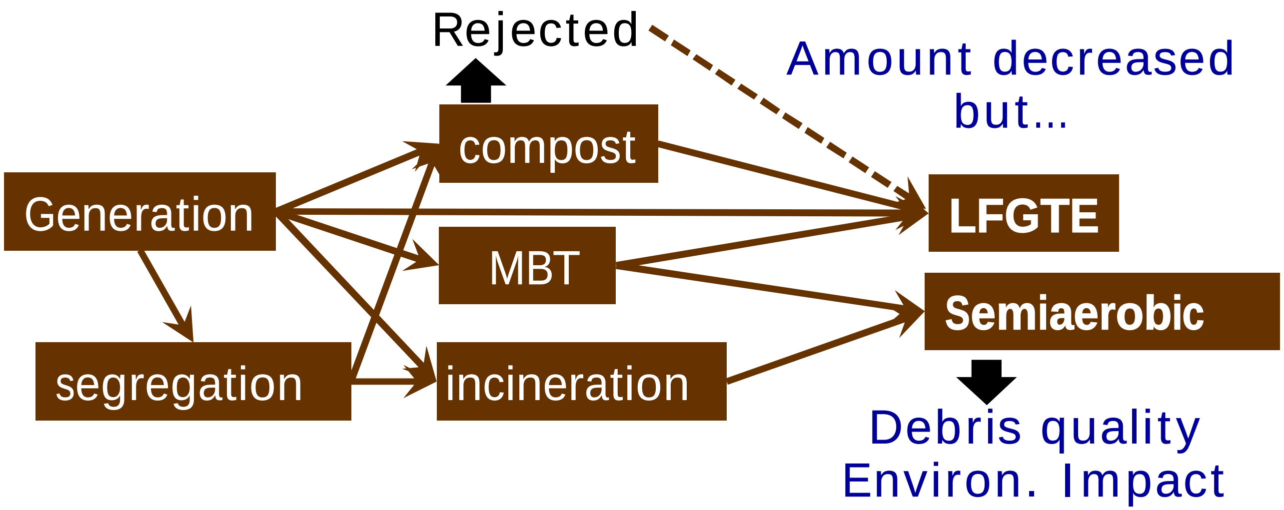
Odor, Vermination

Landslides Projection

GHGs, Air pollutants

Aquatic Pollution

Disposal Site in Advanced Waste Management

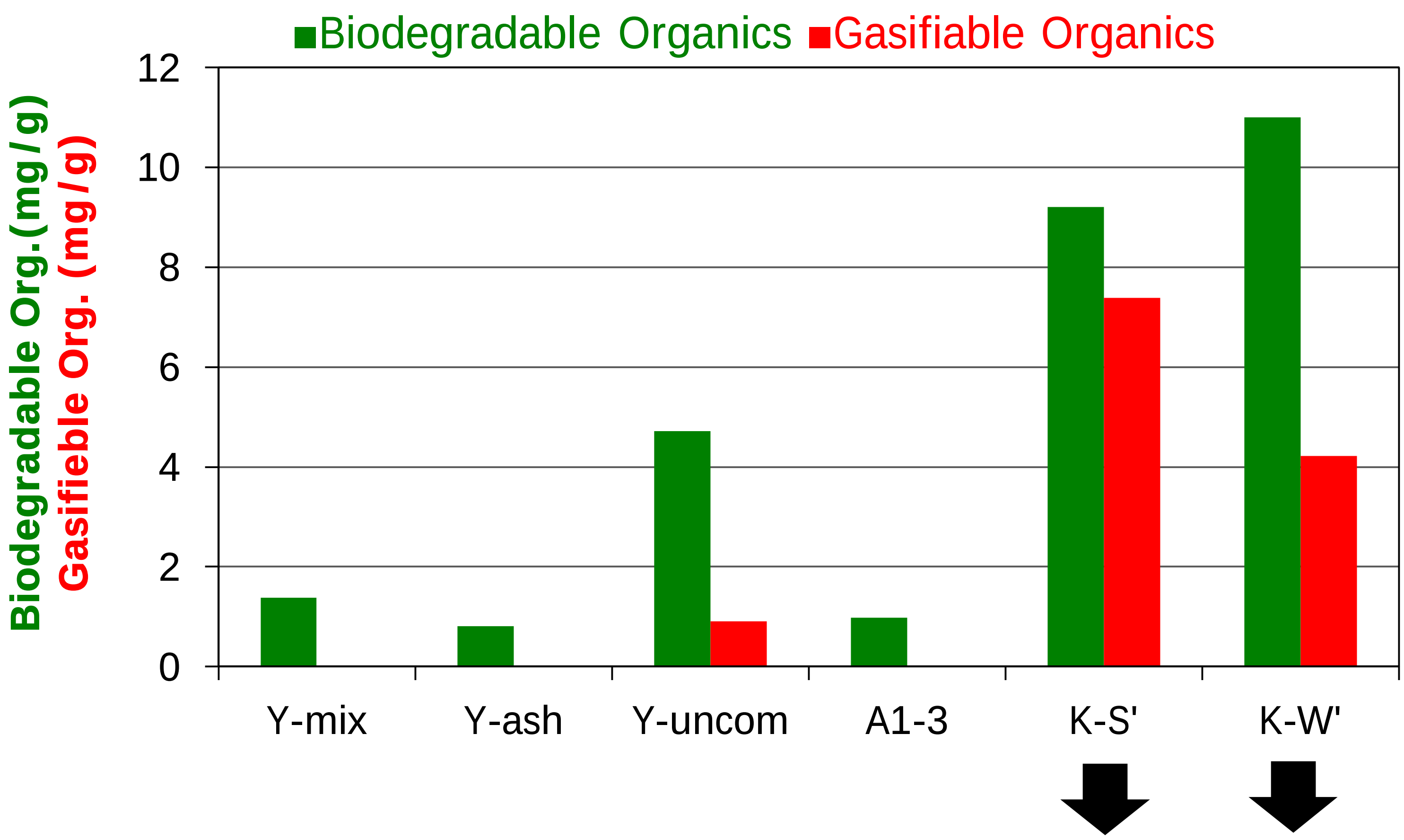


Debris quality become worse (concentrated) and inhibit growth of plants or microbes in landfills

Prolonged gas and leachate problem

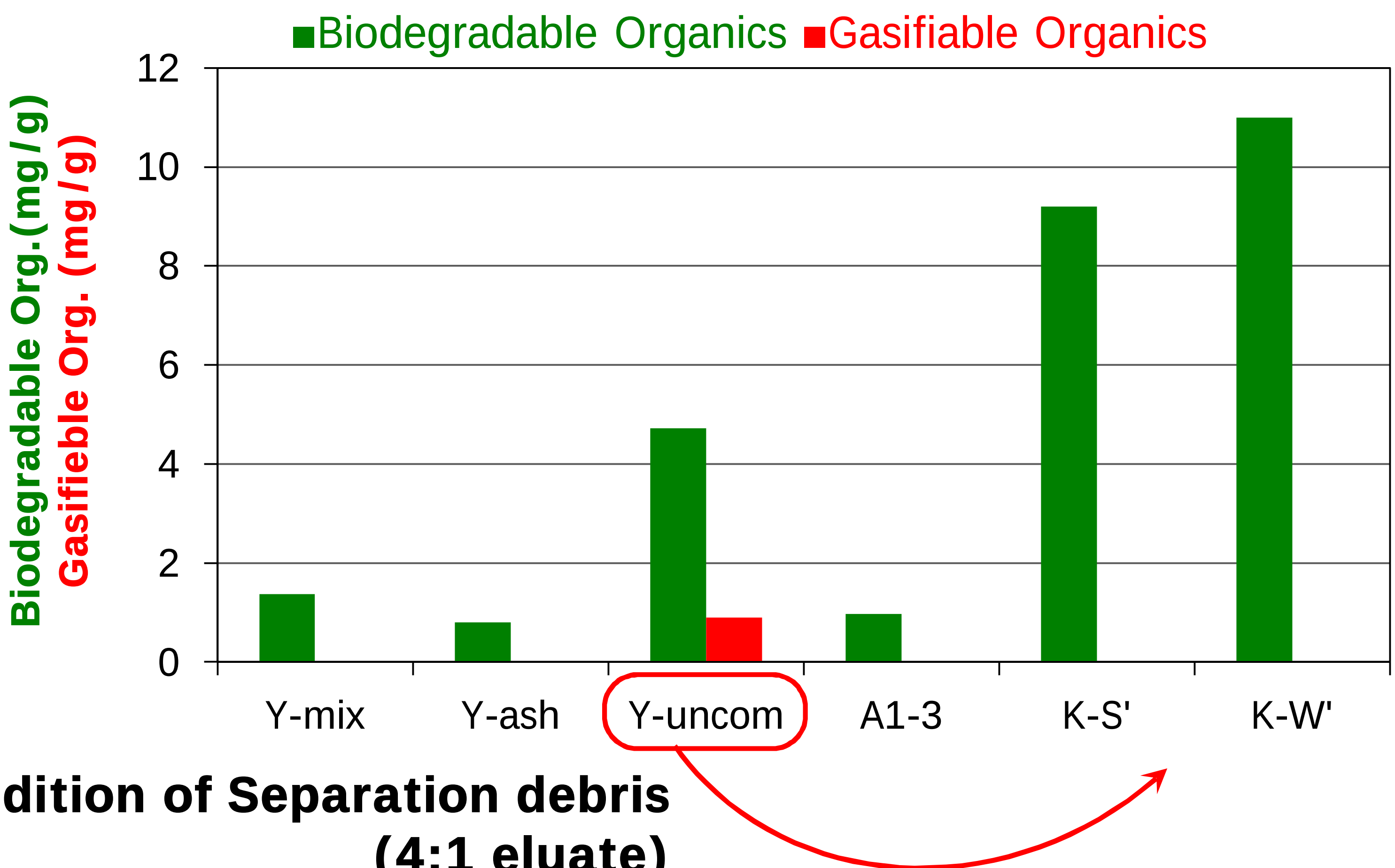
Costly for all WM -> Sustainability

Toxic Effect of Debris from Recycle Facility



Easily degradable waste under anaerobic condition

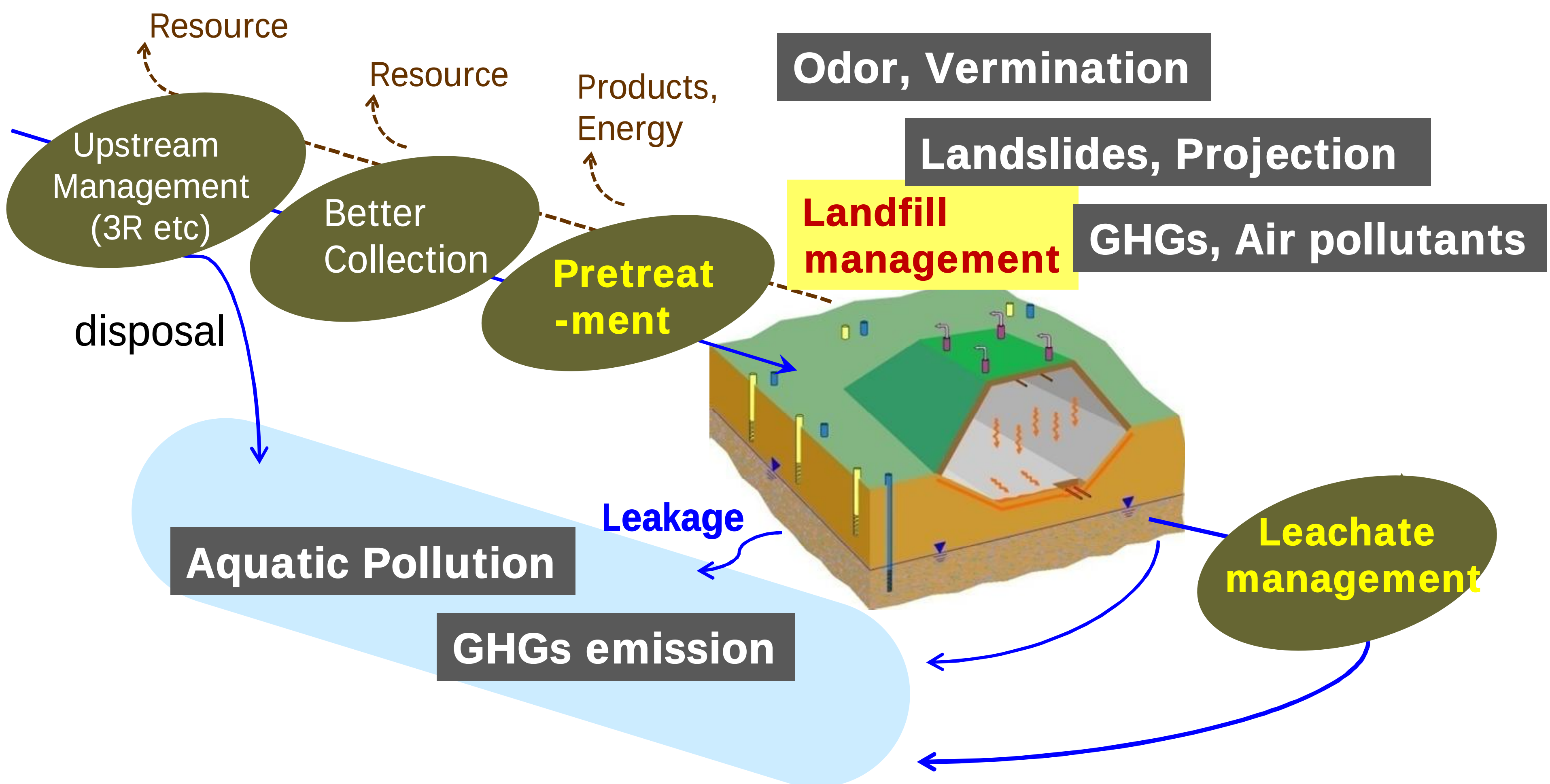
Toxic Effect of Debris from Recycle Facility



Addition of Separation debris (4:1 eluate) inhibited anaerobic gasification

pH	EC	Al	Cu	Mg	Zn
8.9	33 mS/m	0.70	0.11	0.17	0.094

Integrated Waste Management for Comprehensive Solution

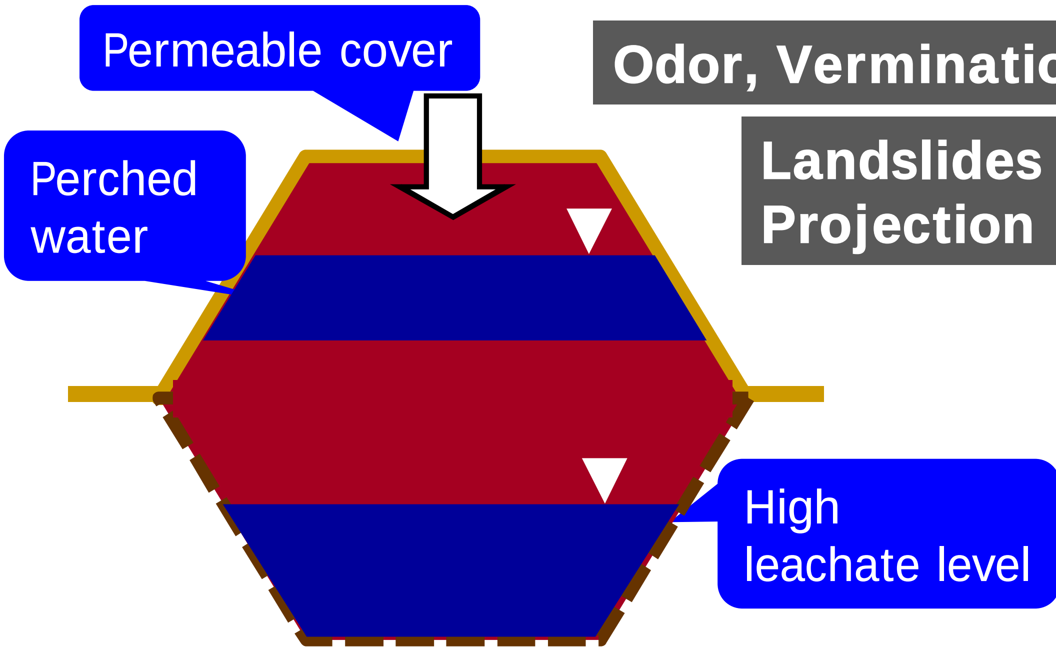


Applicability of Semiaerobic Landfill (SAL) for Tropical region

Anaerobic Sanitary Landfill

Structure that easily generate Methane

Traditional Sanitary LF



No or incomplete drainage -> **Leakage**

Odor, Vermination

Landslides Projection

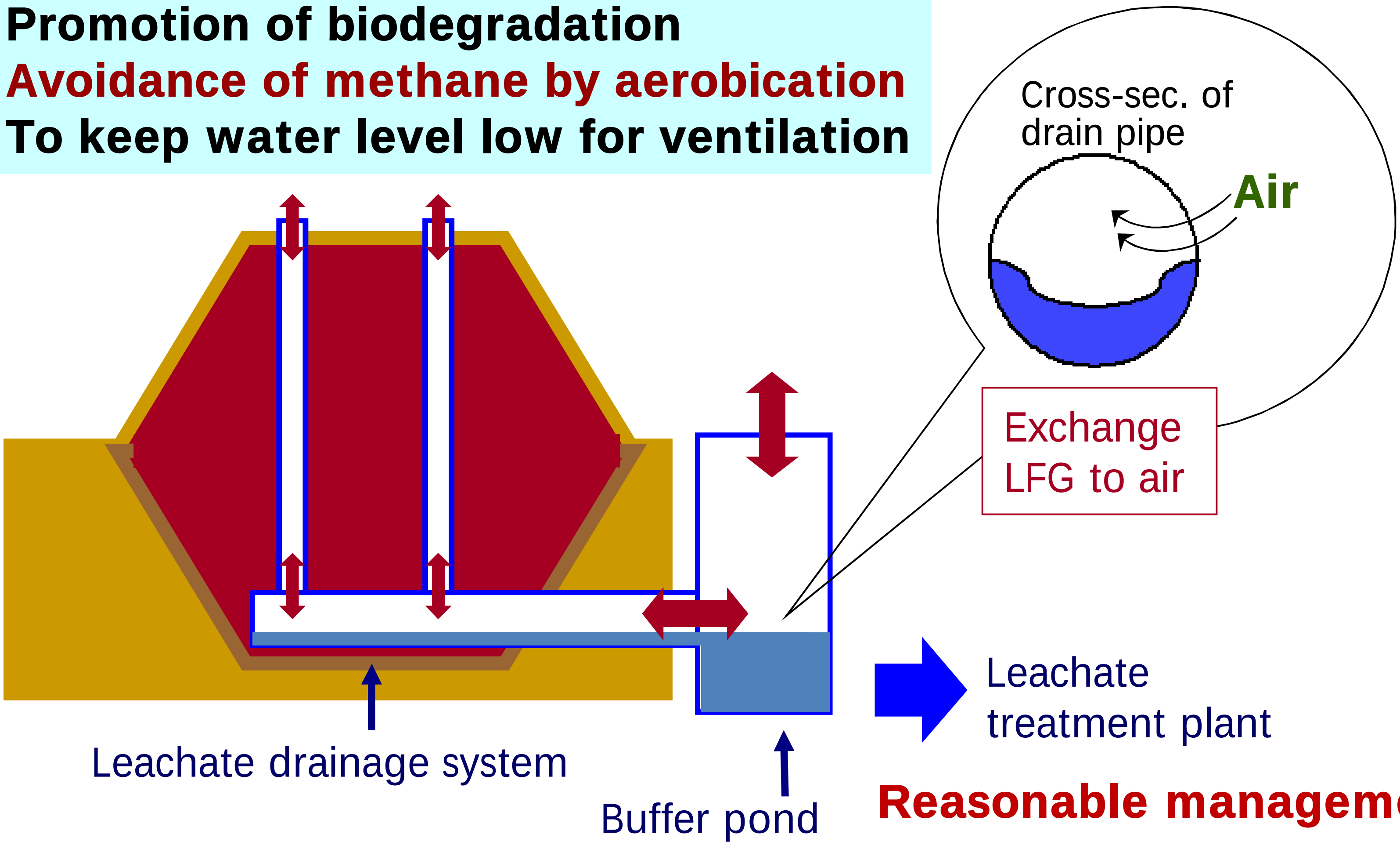
GHGs, Air pollutants

Aquatic Pollution

Semiaerobic Landfill (passive ventilation)

Ventilation of waste layer, promotion of waste degradation

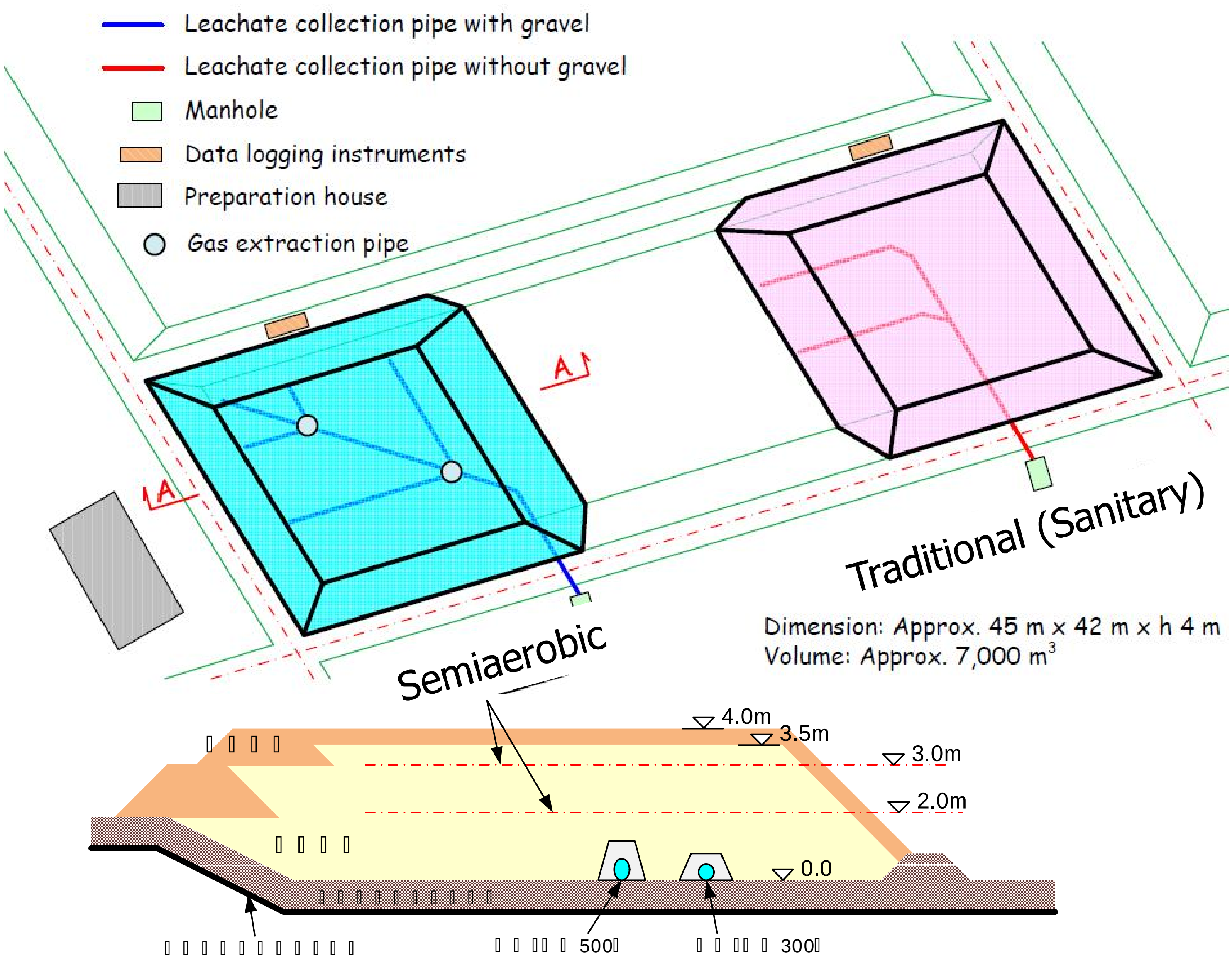
Passive Ventilation (LFG out, Air in)
Promotion of biodegradation
Avoidance of methane by aerobication
To keep water level low for ventilation



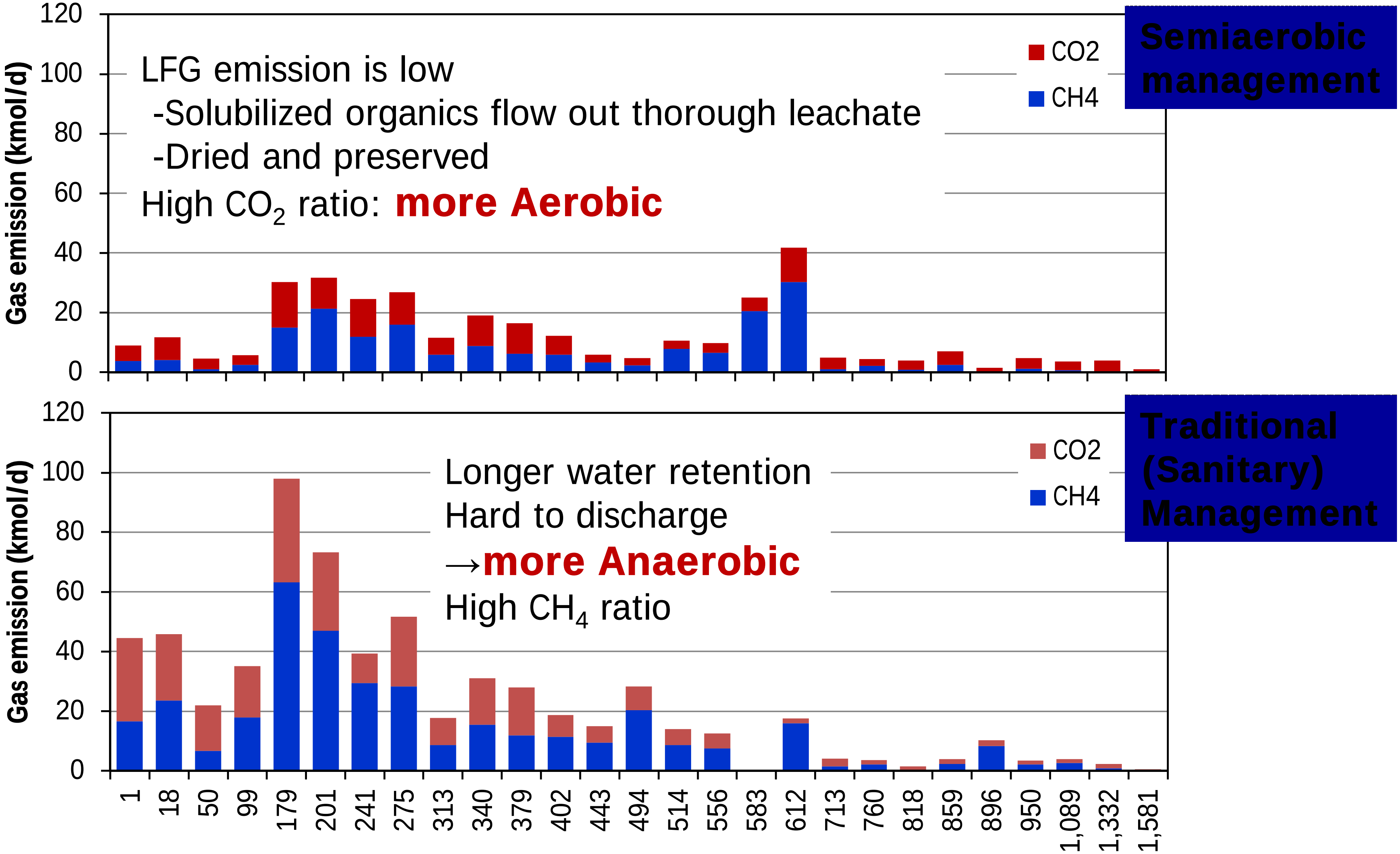
Reasonable management in SEA

Drained leachate management

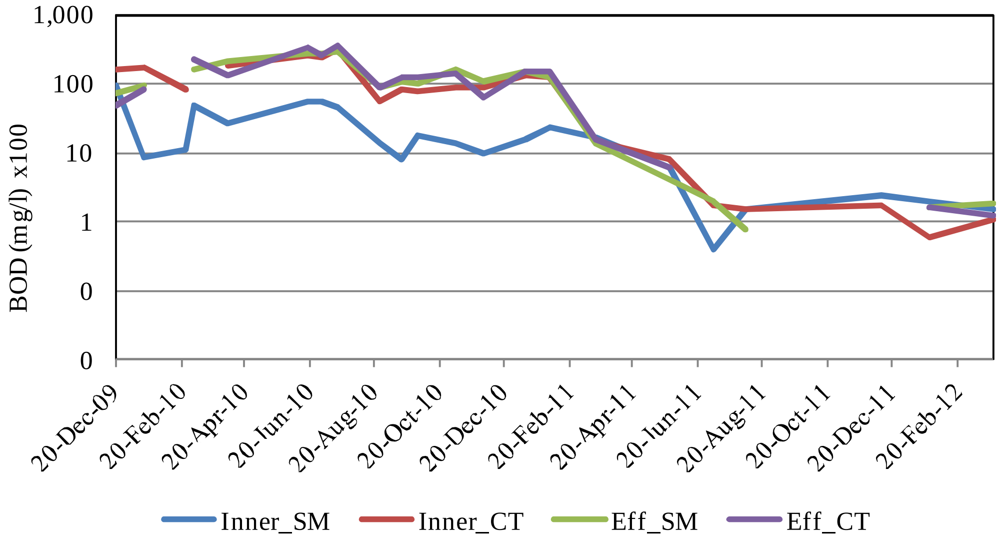
Test cell experiment in the MSW landfill in Thailand



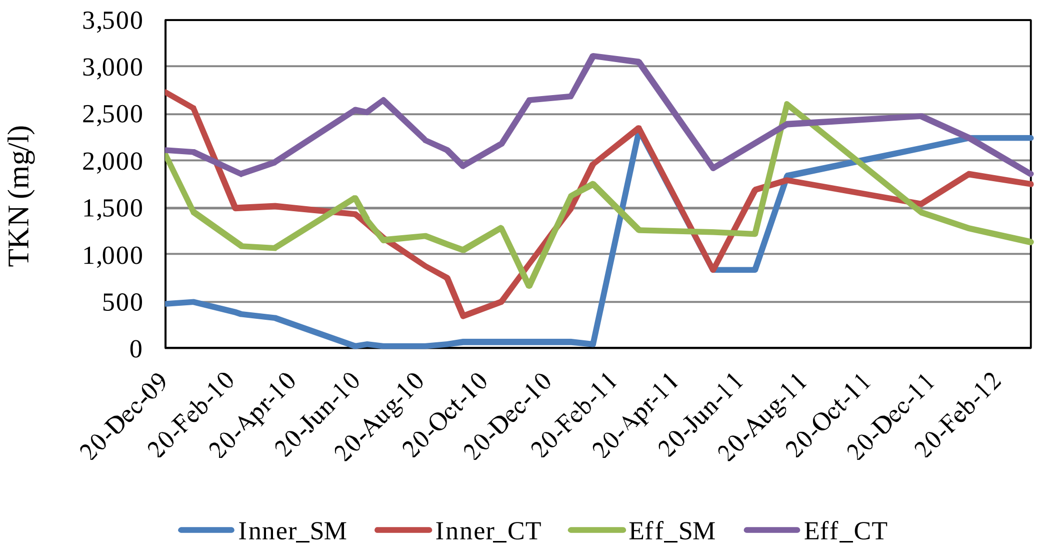
Gas emission from each landfill operation



Leachate Quality



BOD: Insignificant difference



TKN: Low in SAL

→promotion of aerobic reaction

Development of GHGs emission model expressing simultaneous aerobic/anaerobic degradation

Dissolution **Hydrolysis**

$$C_{i,T} = W_{i,T} \cdot DOC \cdot \left[\left(1-e^{-k^{dis}}\right)\cdot\left(1-e^{-k^{hyd}}\right)\right]\cdot\theta$$

$$L_{i,T}=L_{i,T-1}+C_{i,T} - G_{i,T} - F_{i,T}$$

$$F_{i,T} = \left(L_{i,T-1}+C_{i,T-1}\right)\cdot\left(\frac{\theta}{\theta+I}\right)\cdot I$$

Solubilisation

Anaerobic deg. **Aerobic deg.**

$$G_{i,T} = L_{i,T-1} \cdot \left(e^{-k_i \cdot f_{O2}} + e^{-k_{i*} \cdot f_{AN}} \cdot \eta_e\right)$$

$$A_{i,T} = L_{i,T-1}\cdot\left[\left(1-e^{-k_i \cdot f_{O_2}}\right)\right]$$

Gasification

CH_4 emission= $[\Sigma_x(EF_i \cdot A_{i,T})- R_T] \cdot (1- OX_T)$

$$f_{O2} = \left(1-\frac{S_{O2}}{K_I+S_{O2}}\right)$$

Inhibition on anaerobic degradation by O_2 existence

$$f_{AN} = \left(\frac{S_{O2}}{K_{I*}+S_{O2}}\right)$$

Inhibition on aerobic degradation by O_2 shortage

Precipitation
- 5 mm/y(D)
- 400 mm/y(W)

η: 0.5

O_2: [CT]
- 4.5% (D)
- 1.0% (W)

O_2: [SM]
- 6.8% (D)
- 4.5% (W)

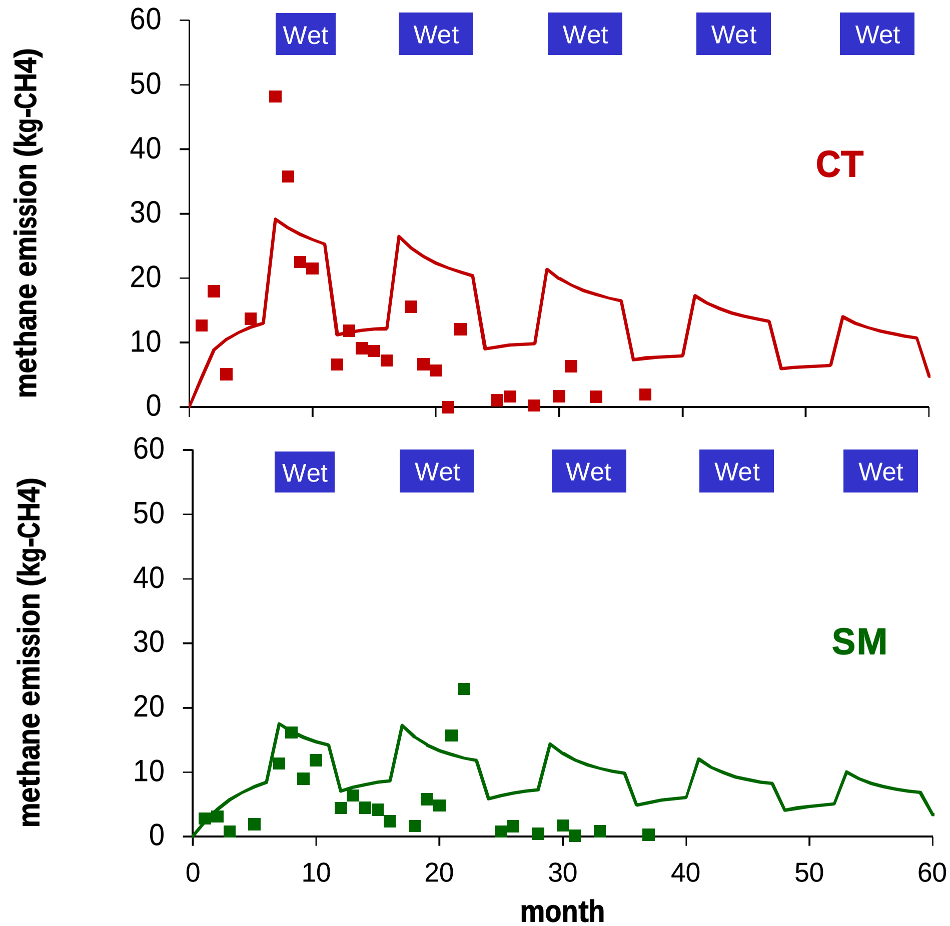
$C_{i,t}$: Solubilized DOC

$L_{i,t}$: DOC in liquid state

$F_{i,t}$: Discharged DOC

$G_{i,t}$: Gasified DOC

$A_{i,t}$: Anaerobically degraded DOC



Technical Guidance of SAL in Thailand (in SEA)

End of drainage pipe must be open to air, not be in sunk

Air permeation in SEA highly depended on the condition of drainage end than that in Japan, because of lower difference of temperature between atmosphere and inner landfill.

Over (rapid) drainage will cause the lack of moisture in landfills

Control of moisture (Operation of leachate irrigation)
Control of drainage (Design of drainage system)

Rapid drainage may also link to water environment pollution

Poor surface may contribute to air permeation, but it also increase the potential of gas/water leakage

Comprehensive management of Waste and Water (precipitation control, moisture control, leachate management) must be necessary taking into consideration of Co-benefit

Applicability of Mechanical Biological Treatment (MBT) for Pretreatment of Landfilling

Waste Treatment in MBT

M: Mechanical (Physical) Process

B: Biological Process

Aerobic degradation

Biodrying

Anaerobic digestion

Resource Recovery

Biogas (energy)

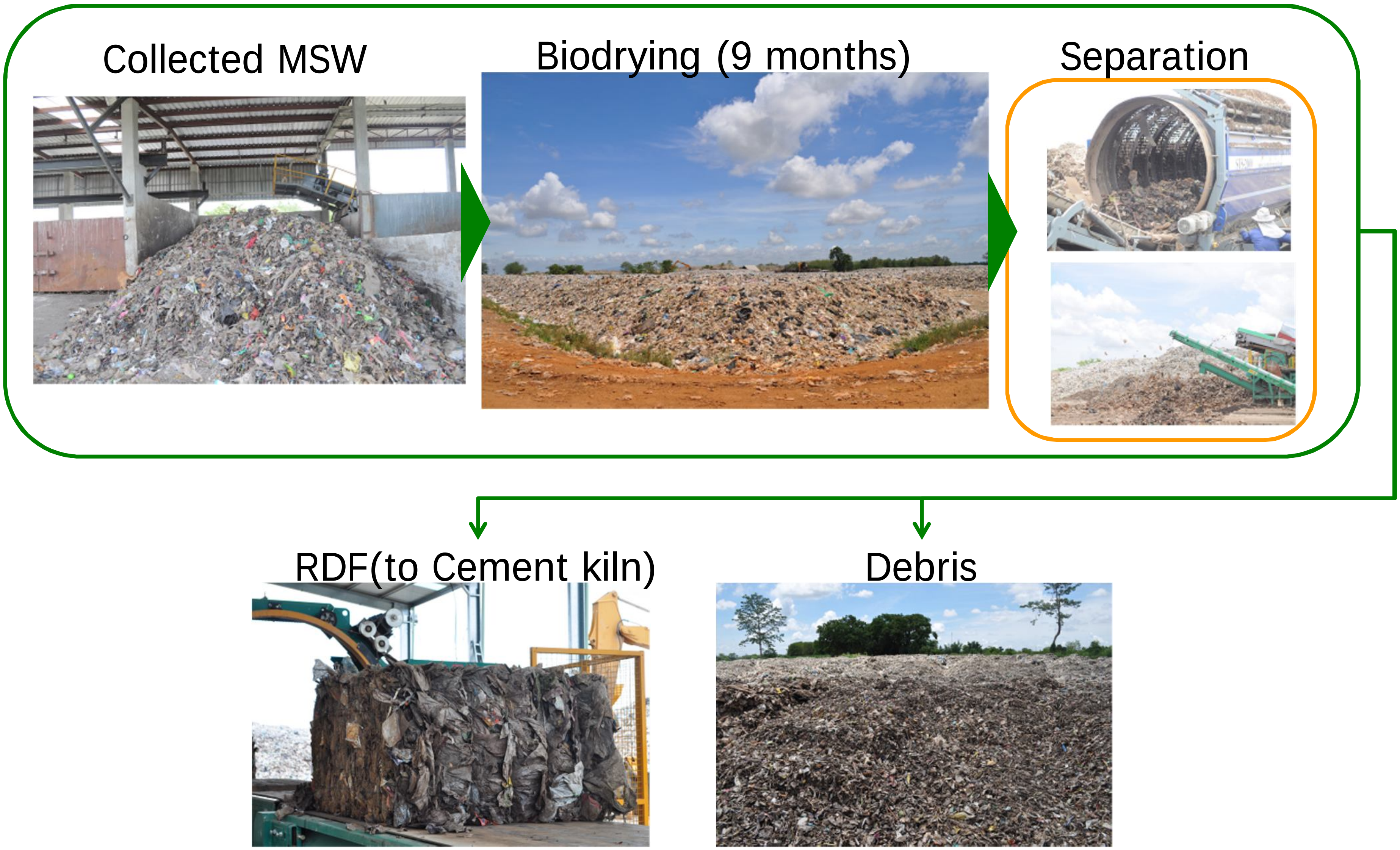
Solid Recovered Fuel

to Industry or MSW incineration

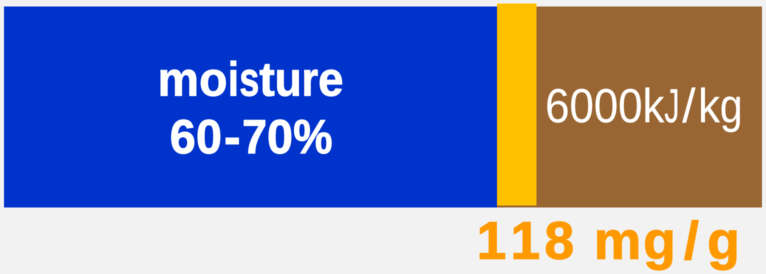
Debris

to Landfill

Survey on MBT Plant in Thailand



Features of MBT in Thailand



High moisture by garbage
High degradable fraction / low calorie

Waste: High moisture and Degradable fraction
Money: Limitation of Budget
Output: Limitation of RDF Consumer

Allowed by Cement furnace only (but highly rejected)
Not pelletized but bulk RDF was transported

Mass balance in MBT plant in Thailand

MSW
18,000 t/y
(100%)

Biodrying Process

Loss
CO_2, H_2O
(64%)

36%

Mechanical Separation Process

Necessity of drying first because of bad separation of wet waste
Effect of volume reduction

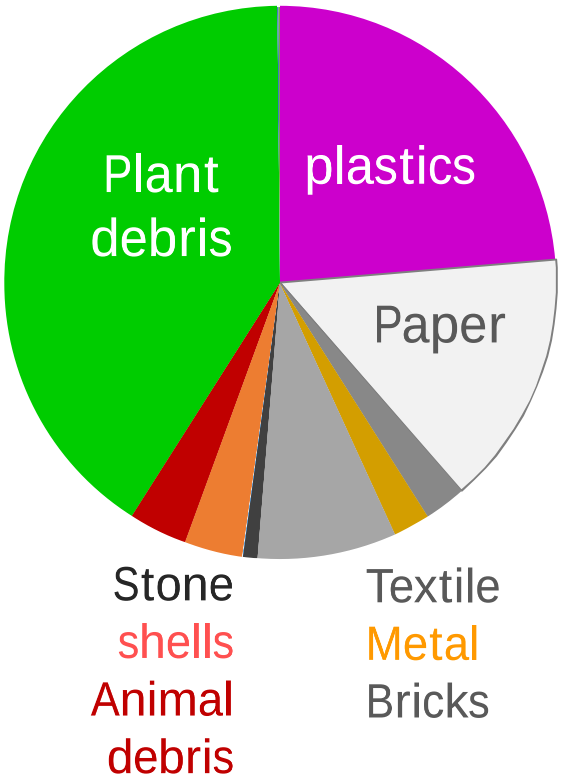
Fuel
(28%)

Debris (7.5%) ...> 15-20%?
1350 t/y

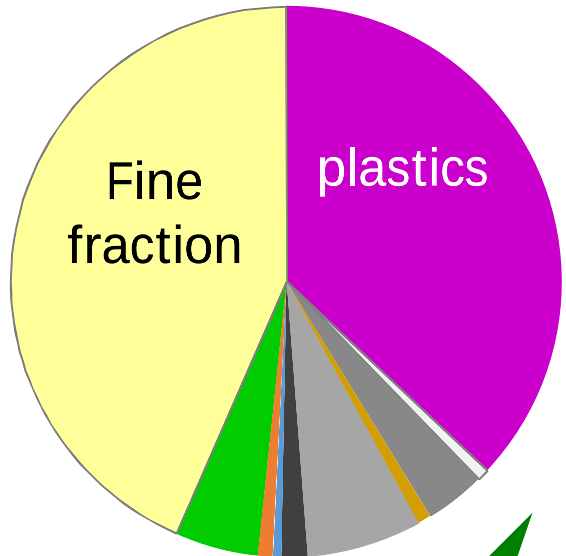
Rejected for 20-30%

Composition of Debris

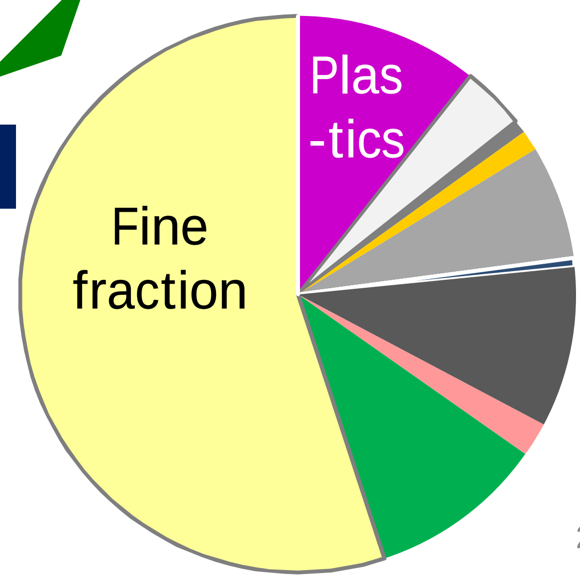
Initial MSW



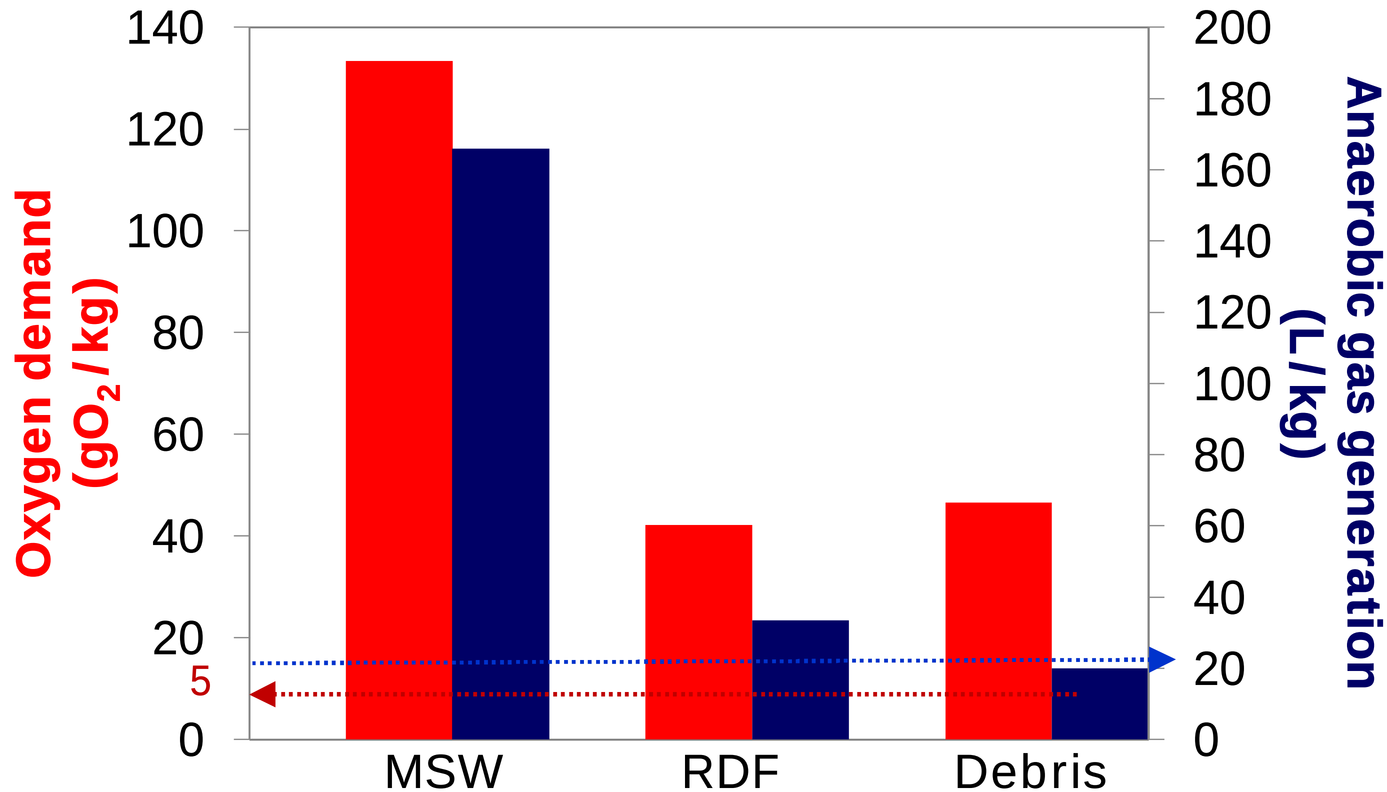
After Biodrying



Debris



MBT as Pretreatment of Landfilling



	MSW	RDF	Debris
(kJ / kg)	5,200	12,400	6,100
C / N	140	304	17

Organics potential of landfilling was reduced (70-80%)
Not enough from viewpoints of emission from landfills
Separation efficiency will affect the organics in debris

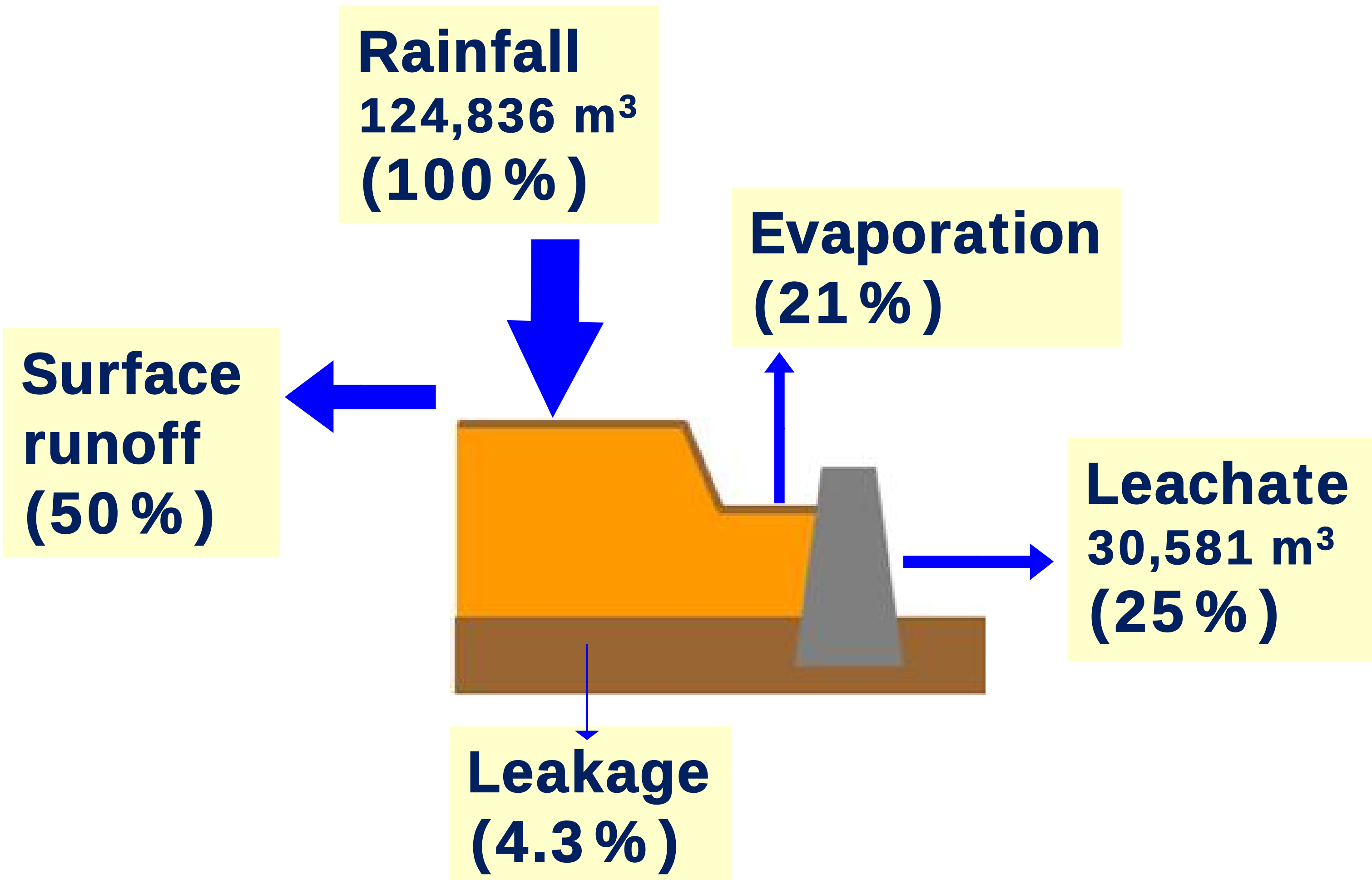
Applicability of Constructed Wetland for landfill leachate in Tropical region

Function of Leachate Pond

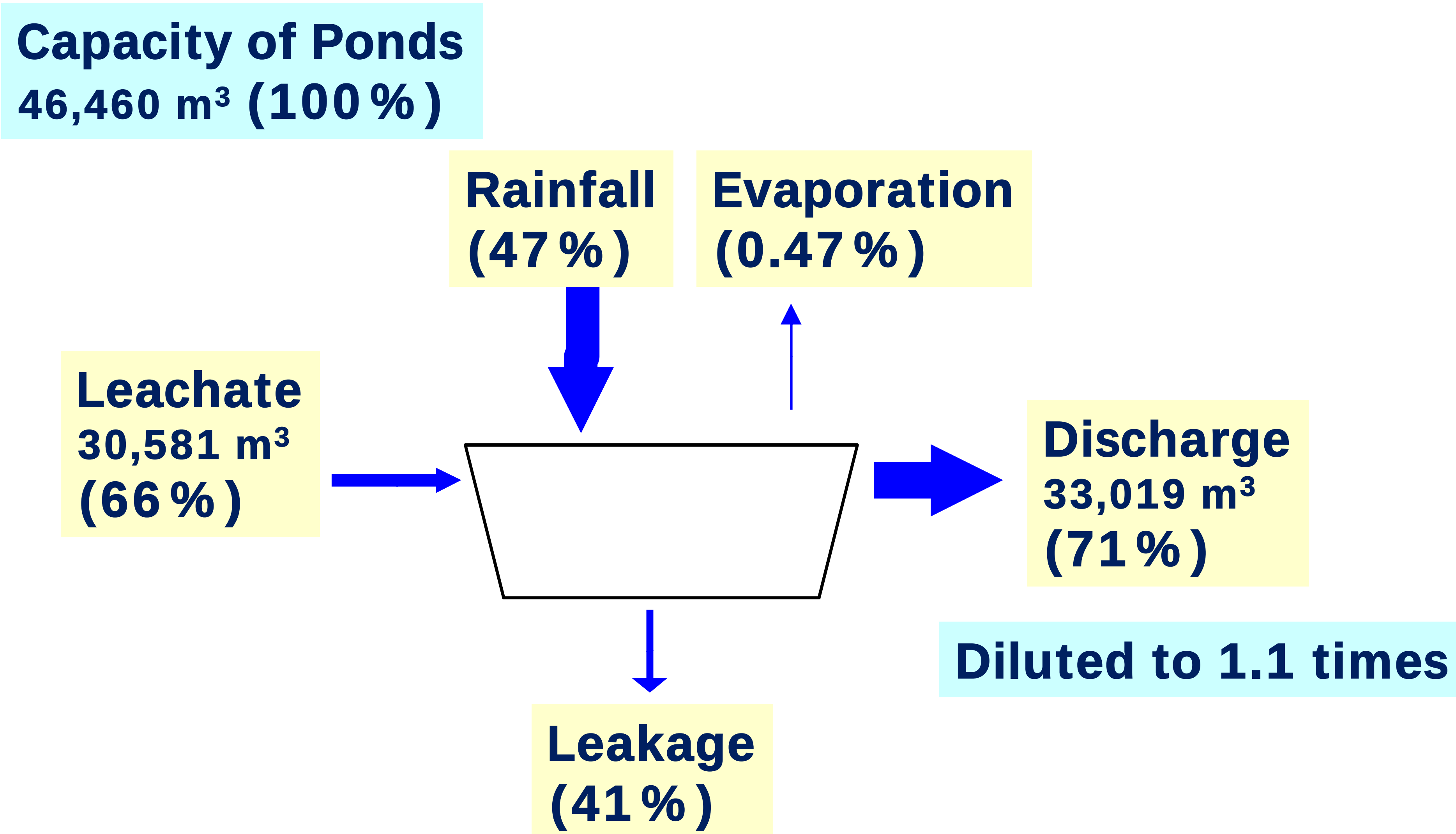
- Buffer zone before discharging
- Natural purification
- Dilution
- Evaporation
- “better than nothing”

More proactive approach on pond
Wetland management
-Natural Wetland
-Constructed Wetland
Increase capacity of purification
Transpiration

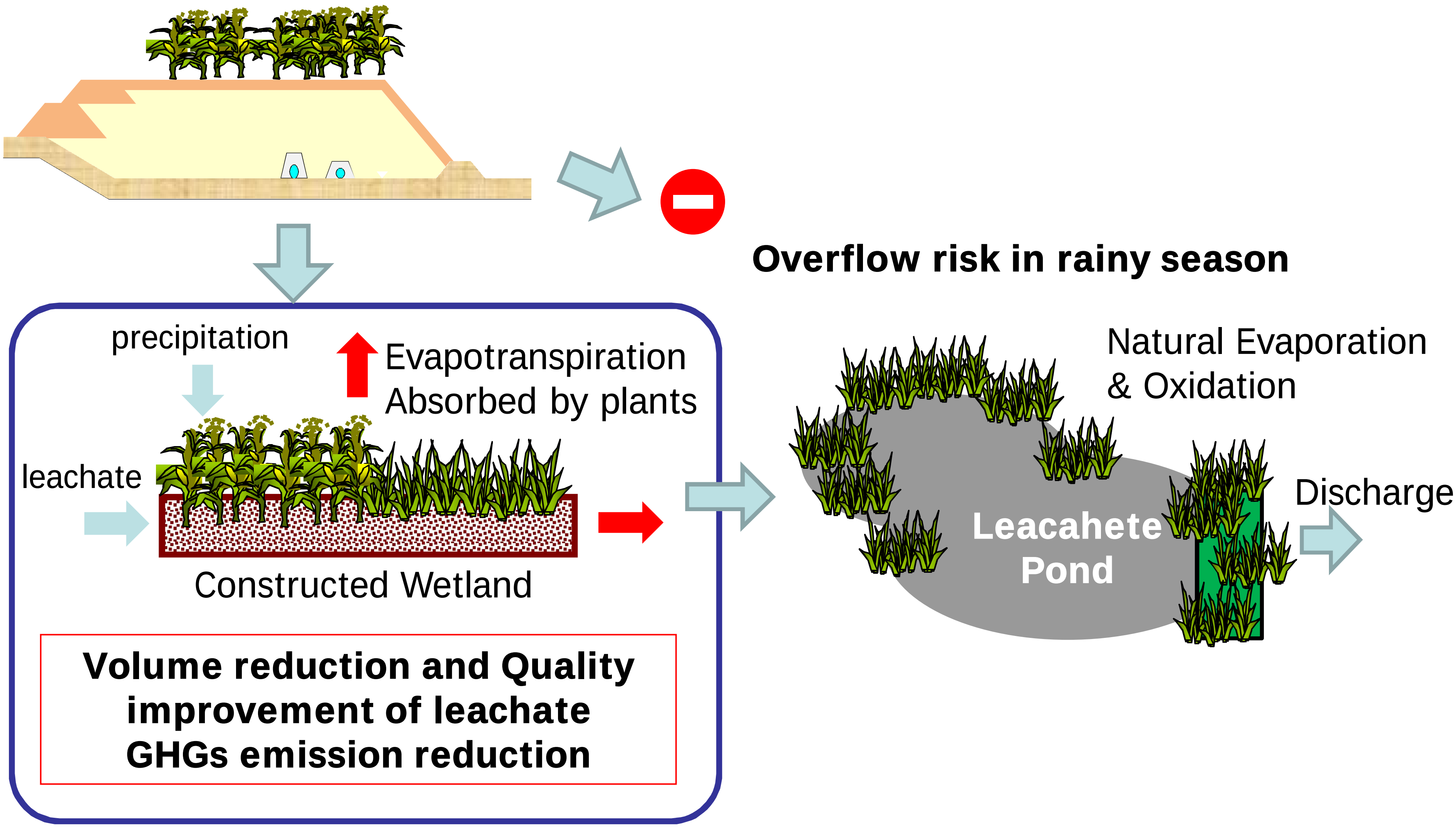
Water Balance at landfill in Rainy Season



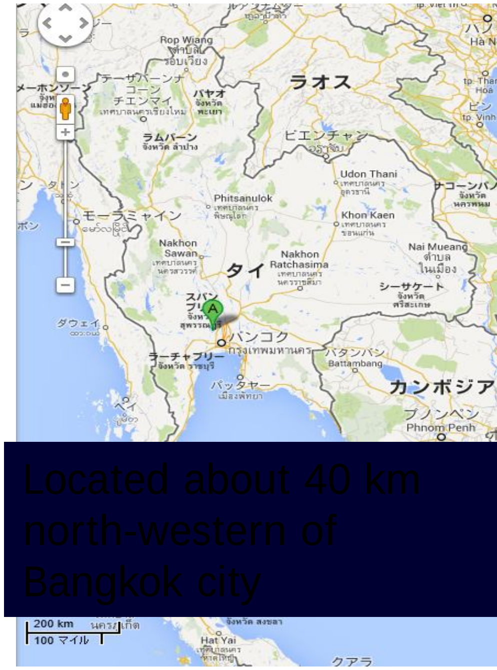
Water Balance at pond in Rainy Season



Benefits of Constructed Wetland for Landfill Leachate Management



Site Description



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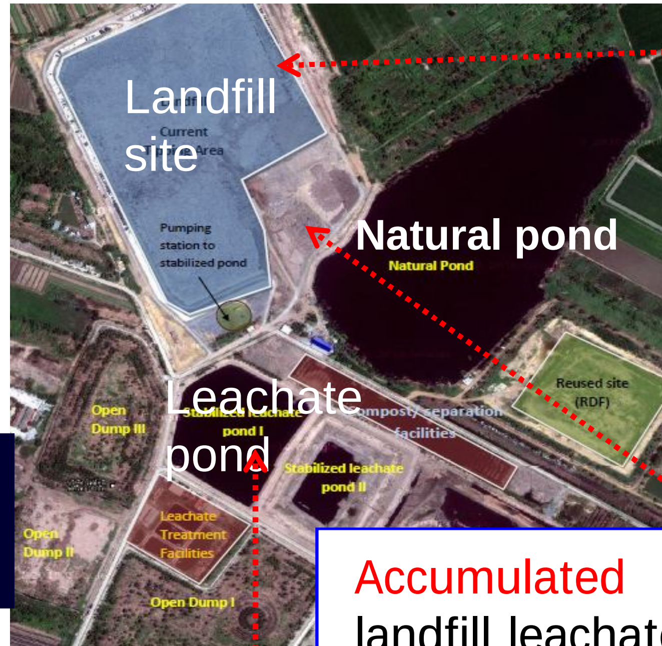


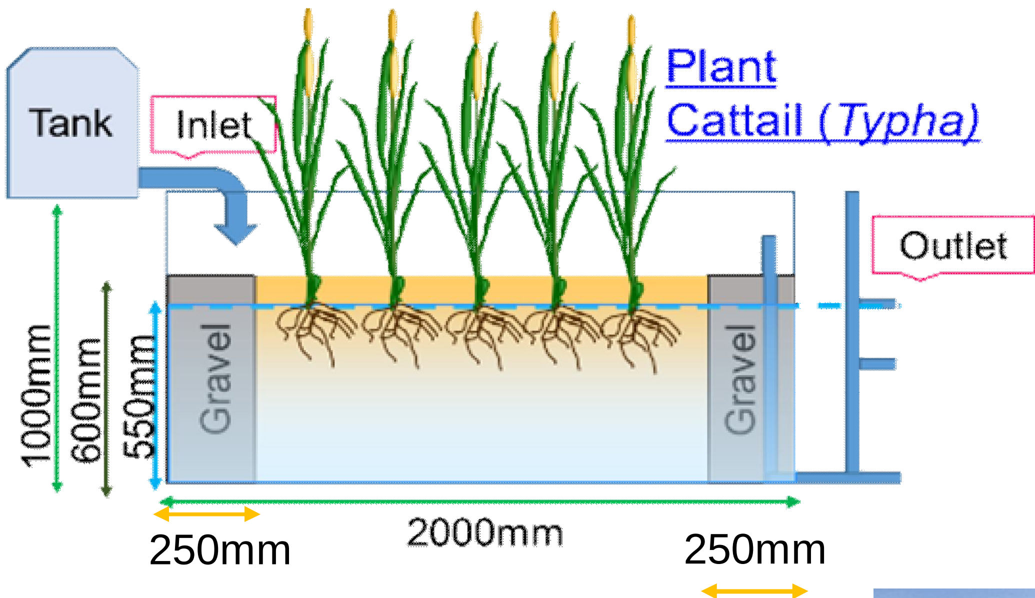
Direct landfill

Accumulated landfill leachate surrounding waste layer

■ Treatment of landfill leachate

Water analysis [Median (min-max)]
pH9.5 (9.3-10), EC 16.4 (10.1-21.0) (mS/cm), TS 14,400 (11,000-16,800), SS 190 (160-320), CODcr 1,800 (960-2000), TOC 620 (340-670), TP 7 (6-11), TN 73 (51-81) (mg/L)

Pilot-scale of CW

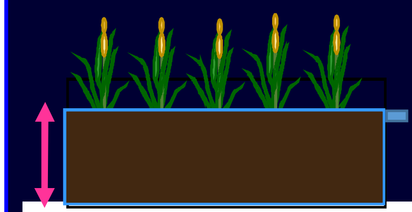


Native cattail

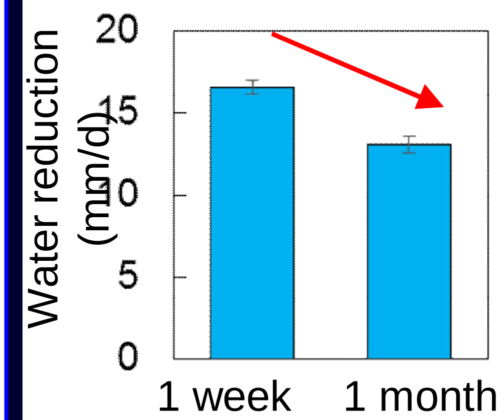
made of concrete with dimensions of (1.0 m [width] x2.0 m [length]x 1.0 m [depth])

Effects of Operation of Constructed Wetland

Free Water Surface



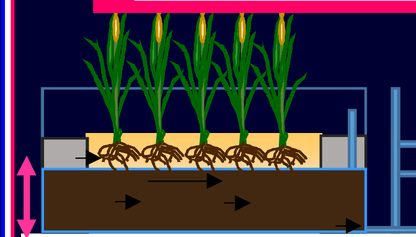
Water level kept above surface medium



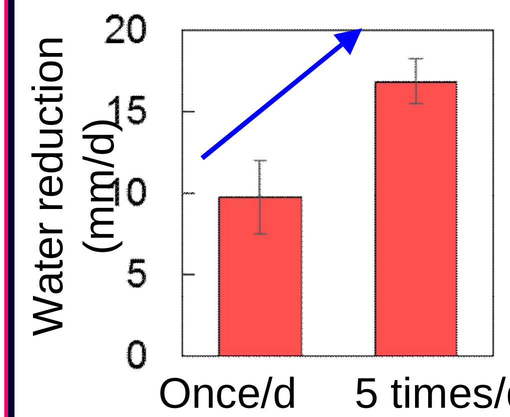
Gradually dried

Water reduction rate was gradually decreased

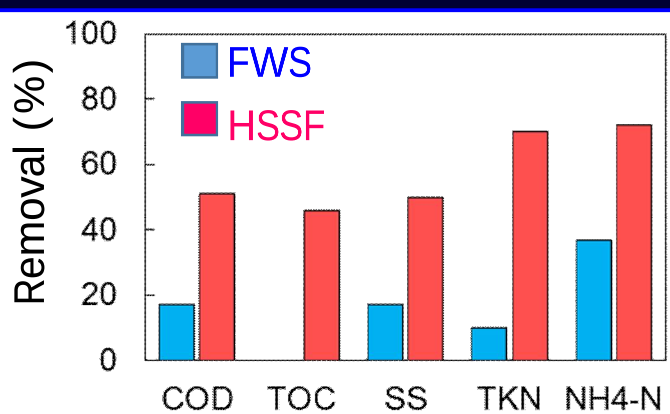
Horizontal Sub-Surface Flow



Water level kept under surface medium

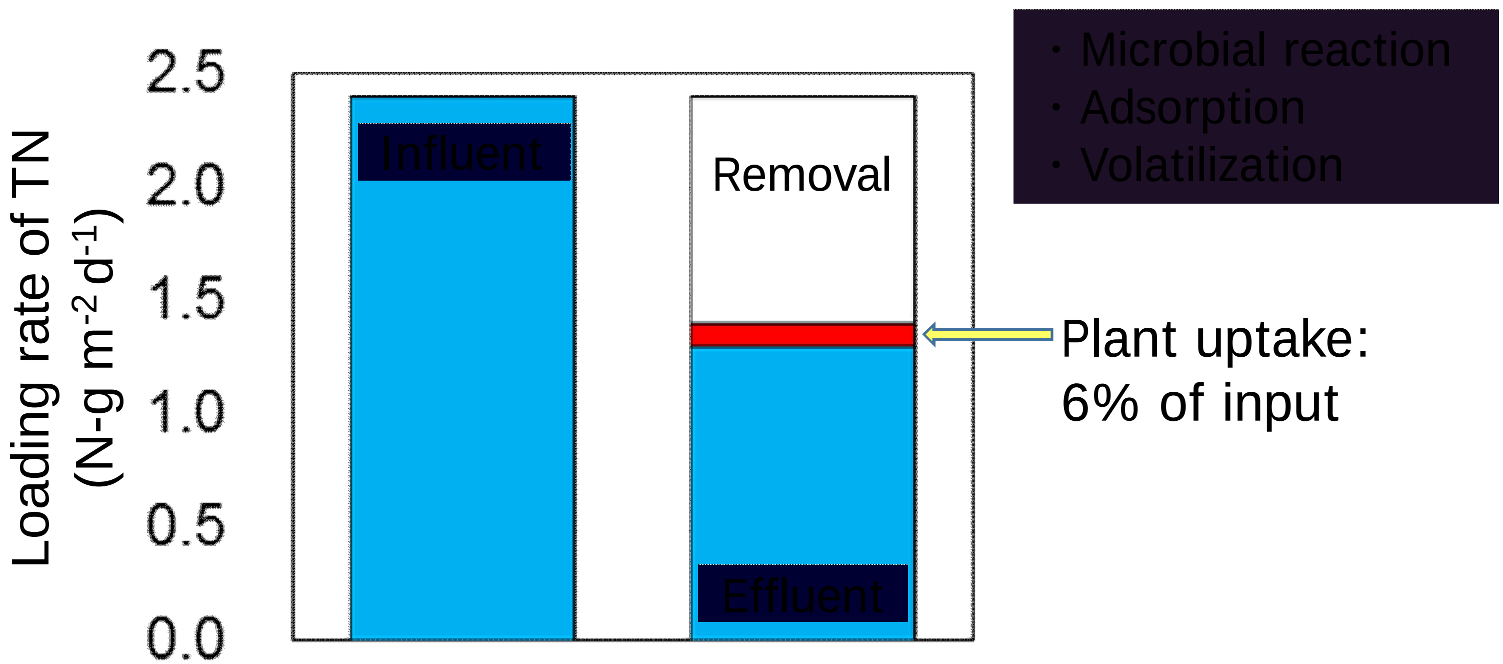


Frequent water feeding increased evapotranspiration, as well as FWS



Removal efficiency of the contaminants in HSSF is higher than that in FWS

Nitrogen Balance



Low contribution of plant uptake of nitrogen will save the work for harvesting of plant

Application of Constructed Wetlands to landfill Leachate Management

- Constructed Wetlands are reasonable technology to sustainably manage the landfill leachate
  - indigenous plant, low operation labor, cost, energy
  - Effective reduction of the risk of overflow
- Operation mode must be optimized for scale-up implementation
- Constructed Wetlands (and other leachate treatment system) must not stand alone.
- Leachate quality control with the landfill operation will be required

Comparison of Impact of Landfill Management

(10 years landfill +20 years PCC)

Objective

- To evaluate the impact of comprehensive landfill management in tropical Asia
  - [Landfill management] x [Leachate management]
  - landfill construction and operation, post closure care, leachate management
  - GHGs, Leachate impact, Financial Cost, Energy

Landfill Management

- Open Dump
- Sanitary Landfill
- LFGTE (with anaerobic landfill)
- Semiaerobic landfill

×

Leachate Management

- Oxidation Pond
- Leachate Treatment Plant
- Constructed Wetland

From Impact Assessment
(10 years landfill +20 years PCC)

- "Open dump" is not cheap but finally cost from environmental viewpoint
- Impact of Pond (Lagoon) management will cancel benefit of advanced landfill treatment
- **Semiaerobic management** can reduce impact of water pollution (**+CW** is the best)
- LFGTE possess high potential for GHGs reduction
  - High leachate impact must require advanced LTP
- **Package management of landfill and leachate must be necessary**

Summary

- Landfills must play an important role in the material cycle society or advanced waste management system
- Consideration of reduction of environmental emission from Whole waste management
- Tropical condition may result in the fail/difficulty of advanced landfill management.
  - Adaptive management must be required
- Combination of MBT x Semiaerobic Landfill x Constructed Wetlands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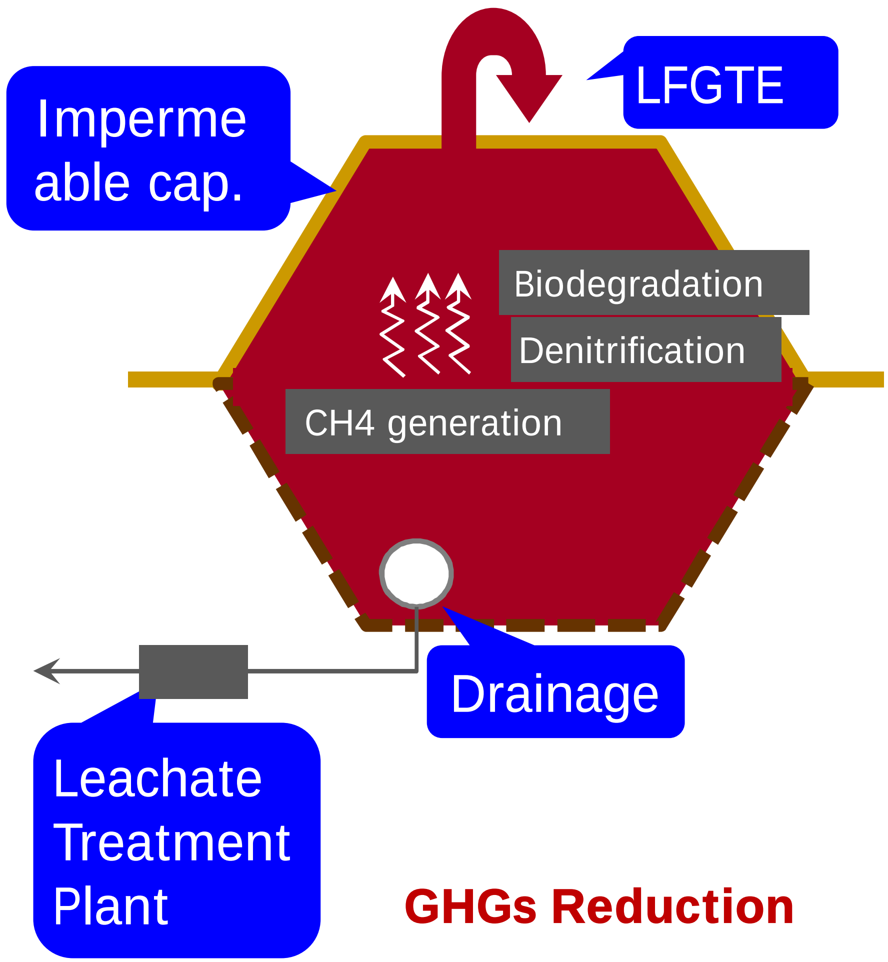
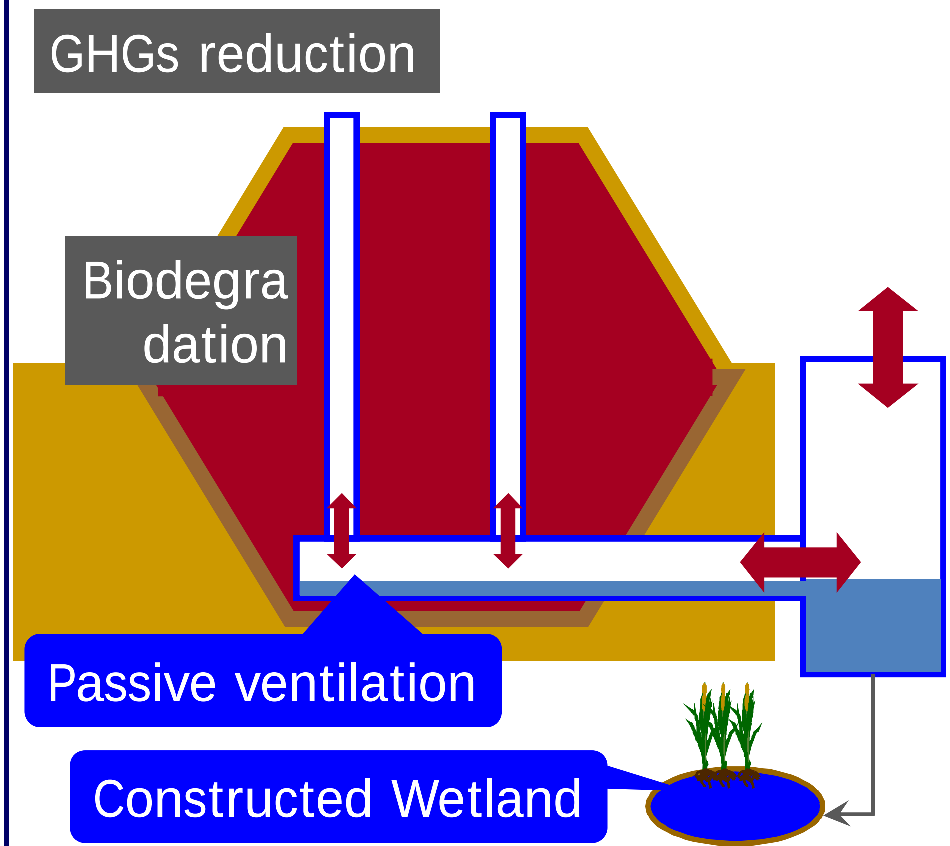
Suggested Package of Landfill Management

LFGTE with capped landfill x Leachate Treatment Plant



GHGs Reduction

Semiaerobic Landfill x Constructed Wetland



Reduction of Impact of Water Pollution

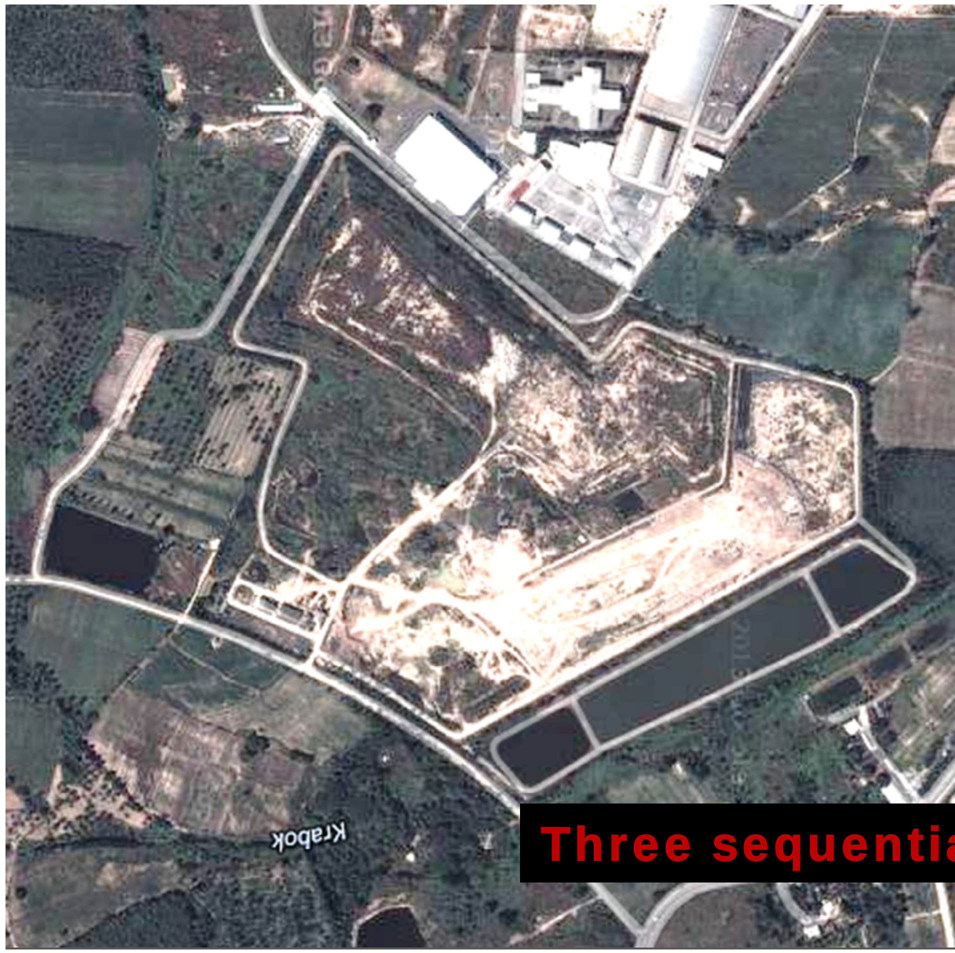
Evaluation of Water Balance through landfill management in Tropical Asia (case study in Thailand)

Field monitoring x meteorological statistics x expert assumption

Model Landfill

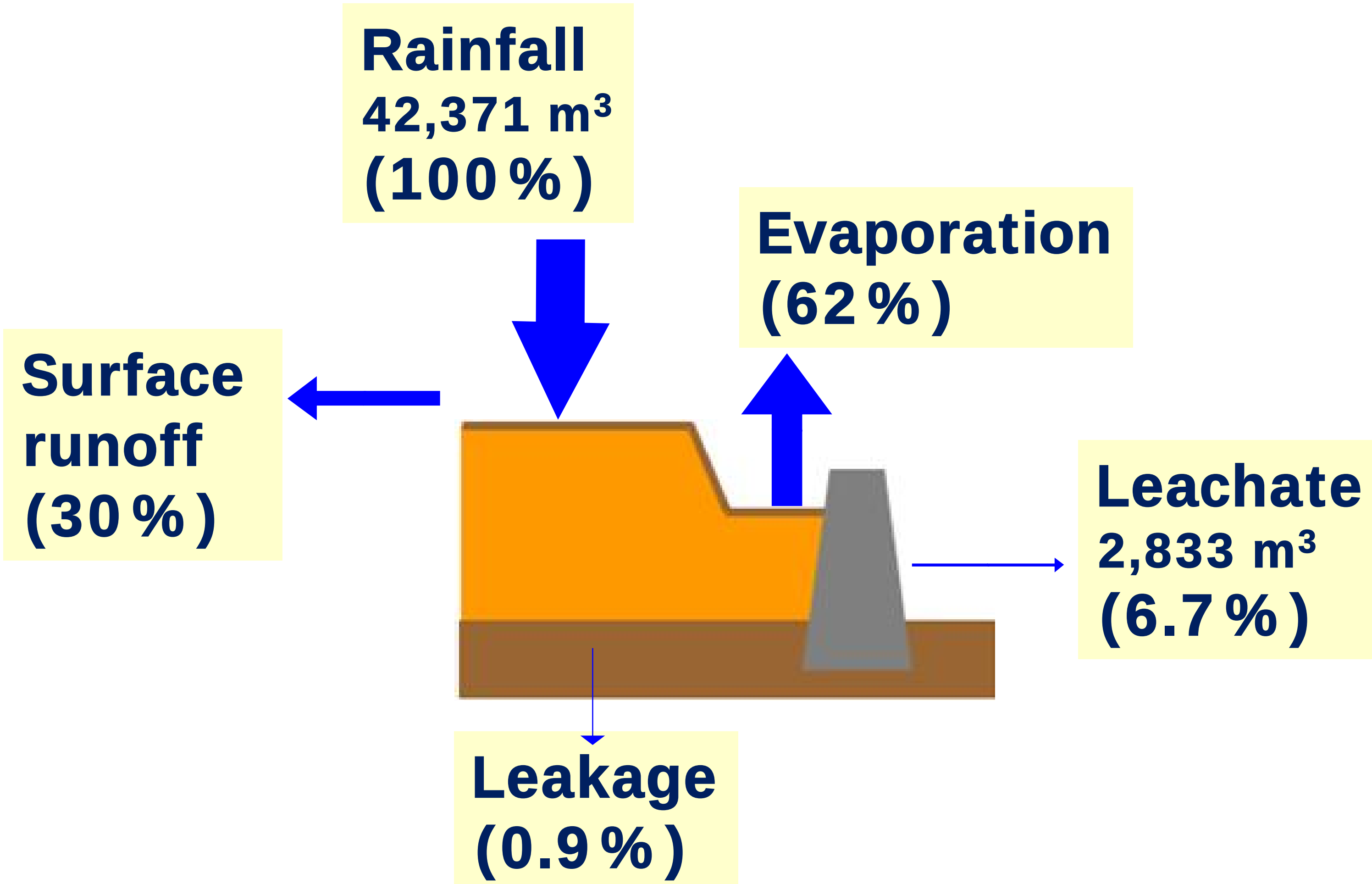
Landfill area:
126,480 m^2

Landfill volume:
527,640 m^3

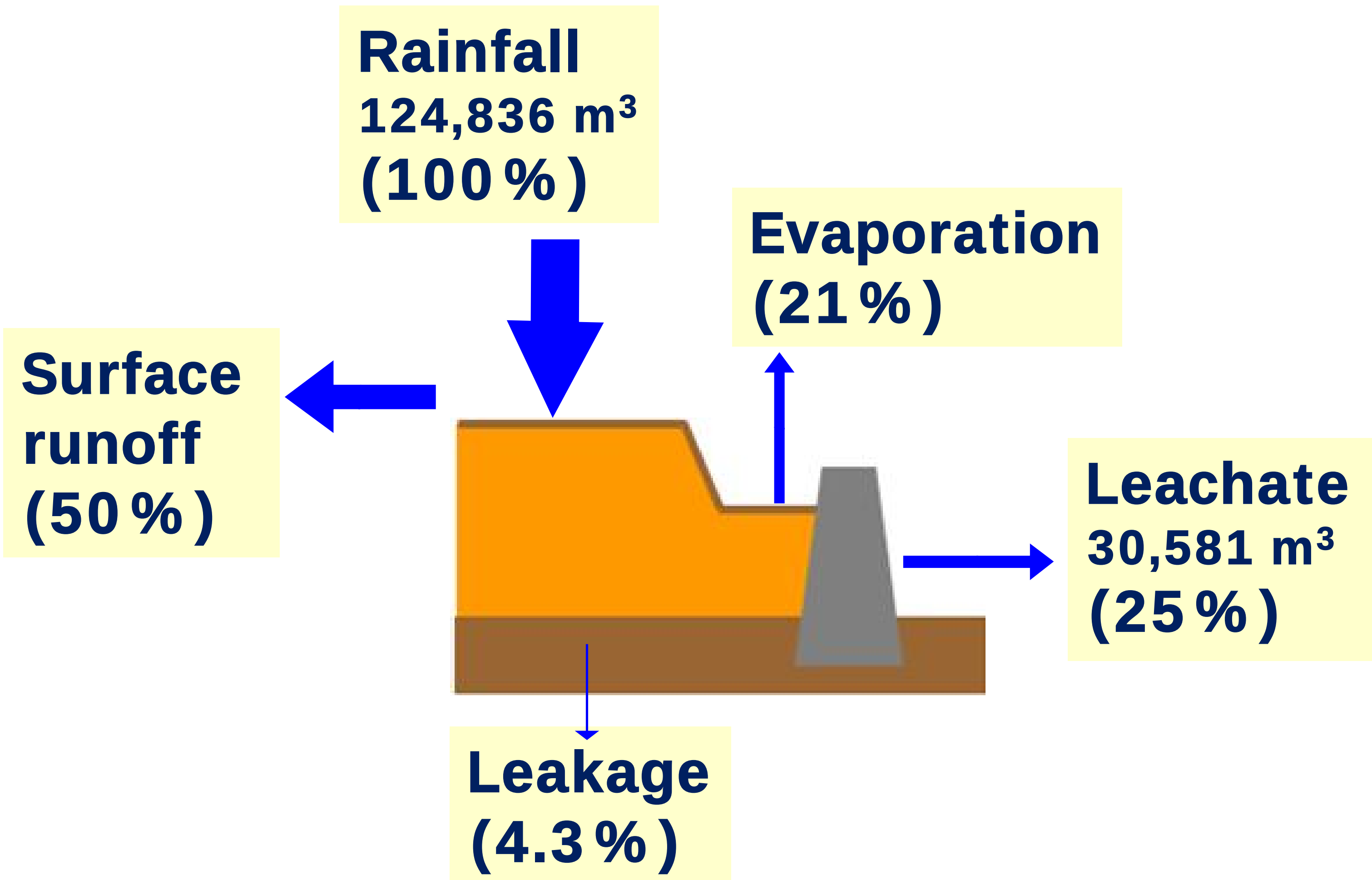


Three sequential leachate pond

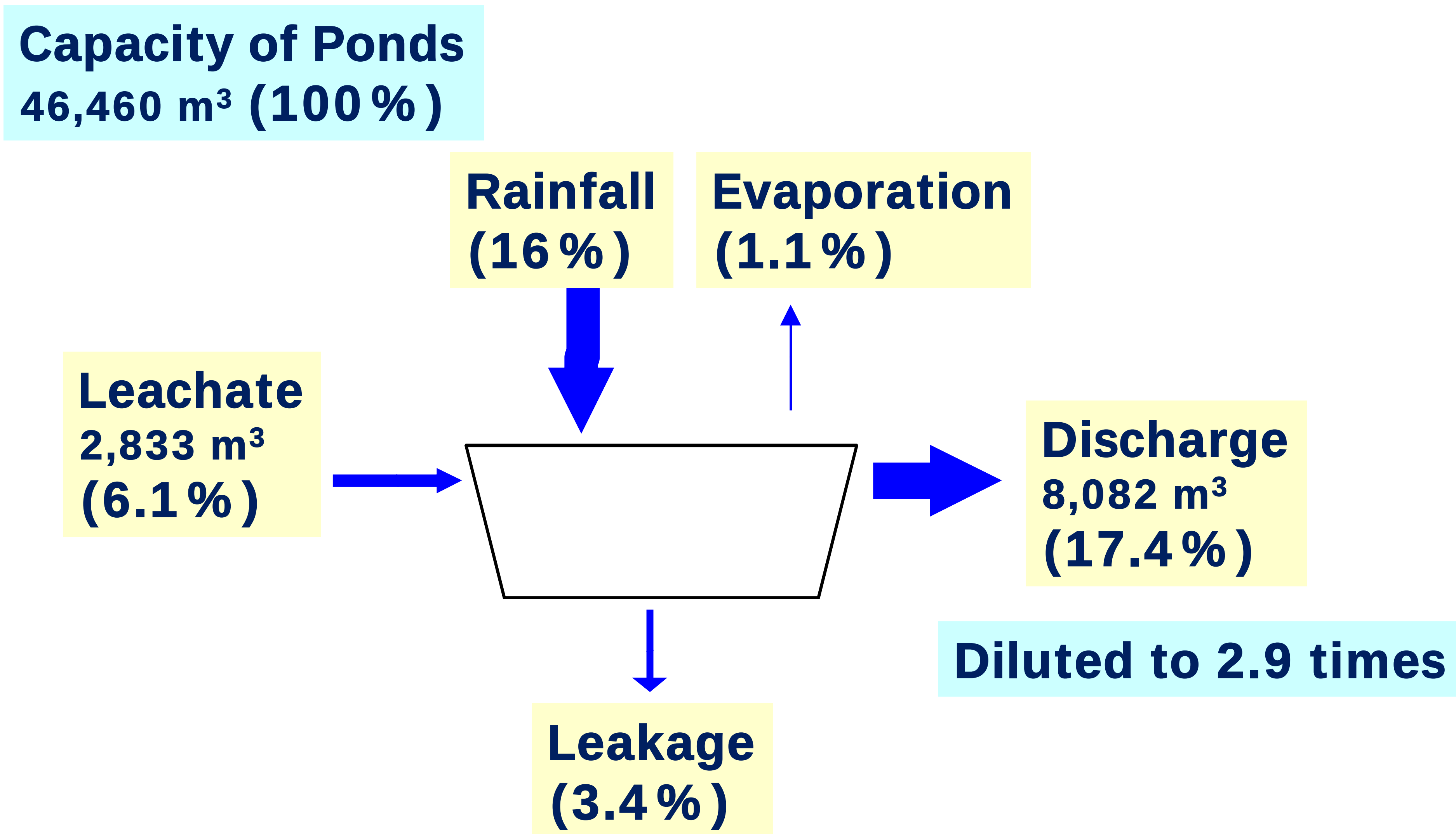
Water Balance at landfill in Dry Season



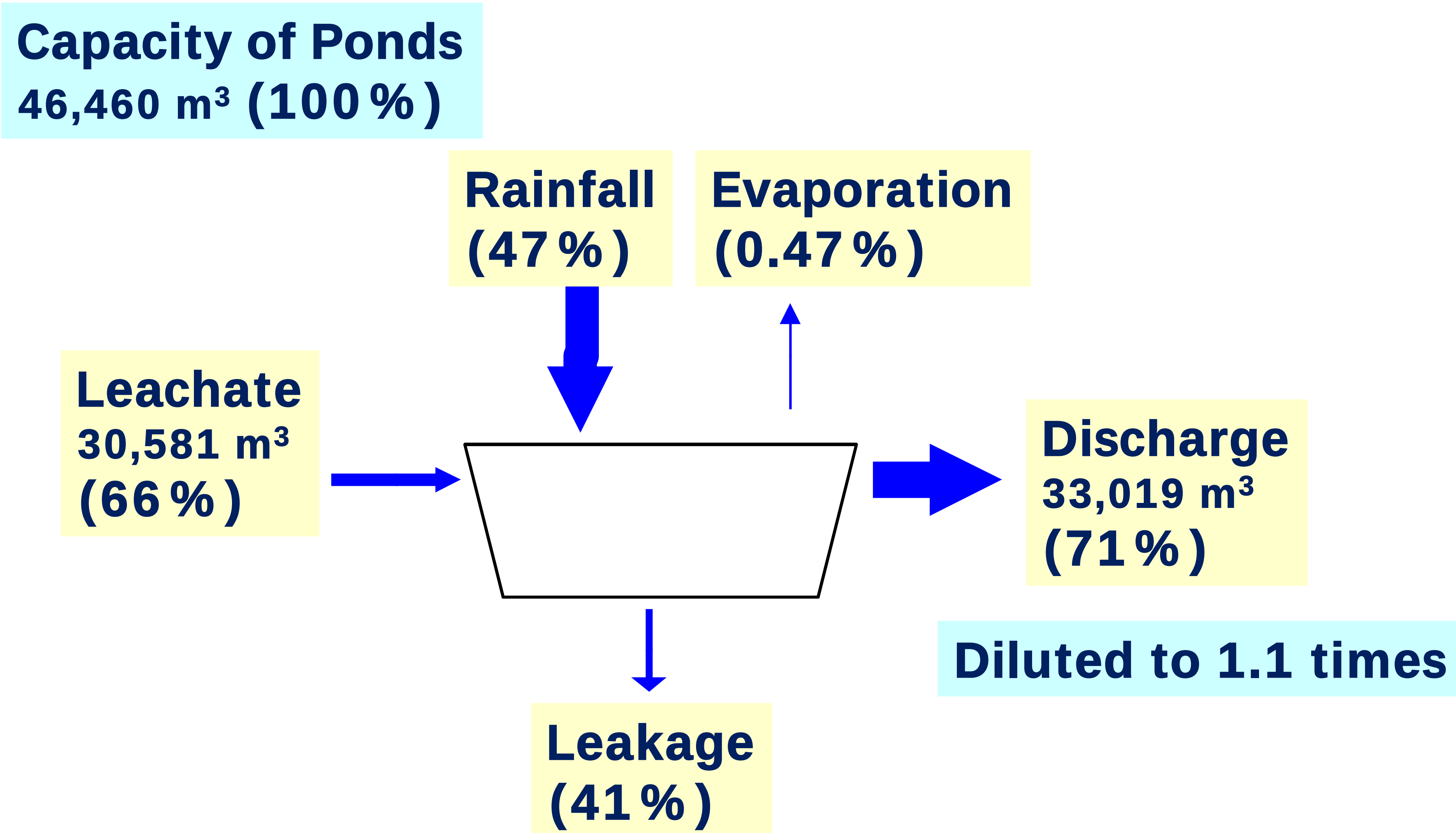
Water Balance at landfill in Rainy Season



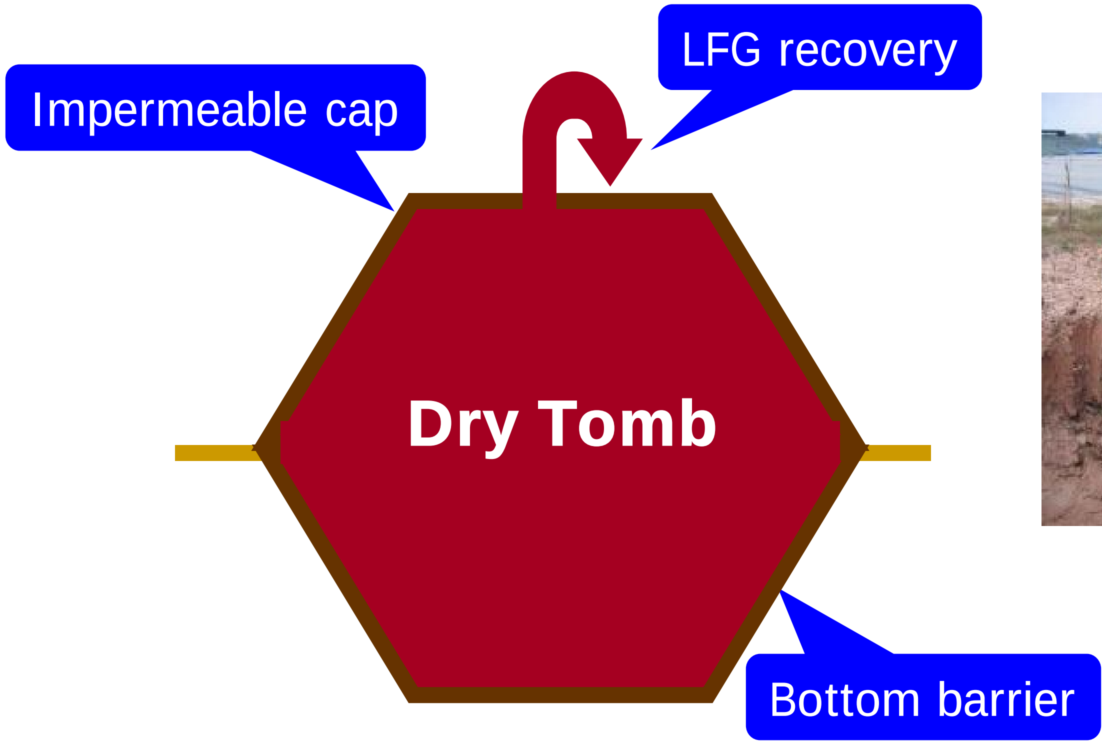
Water Balance at pond in Dry Season



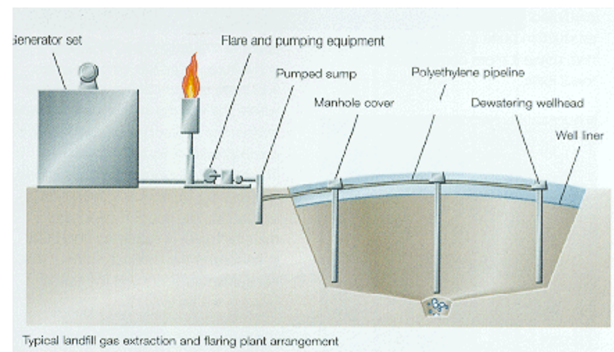
Water Balance at pond in Rainy Season



Landfill Gas to Energy (LFGTE) with capped Anaerobic Landfill



Minimize leachate



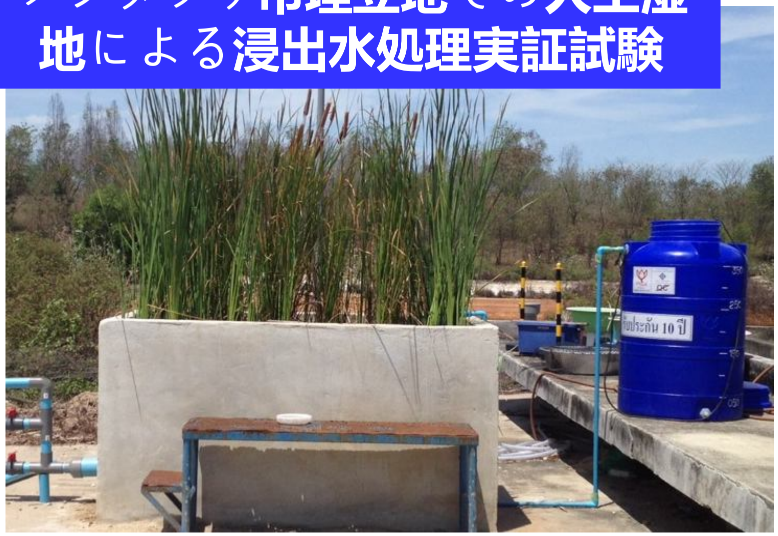
Typical landfill gas extraction and flaring plant arrangement

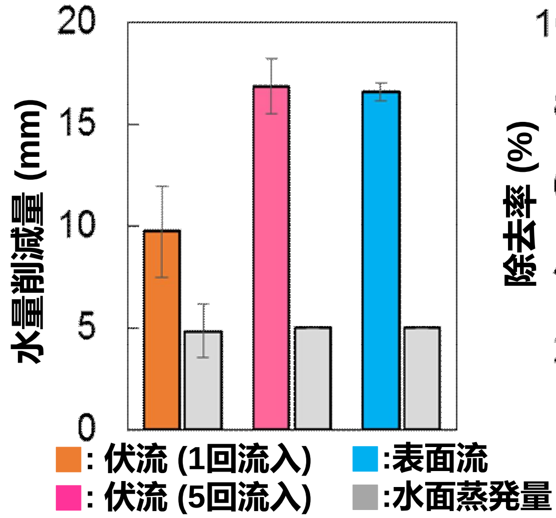
Impossible to prevent penetration in pluvial climate
Energy grid (transmission capacity, distance)

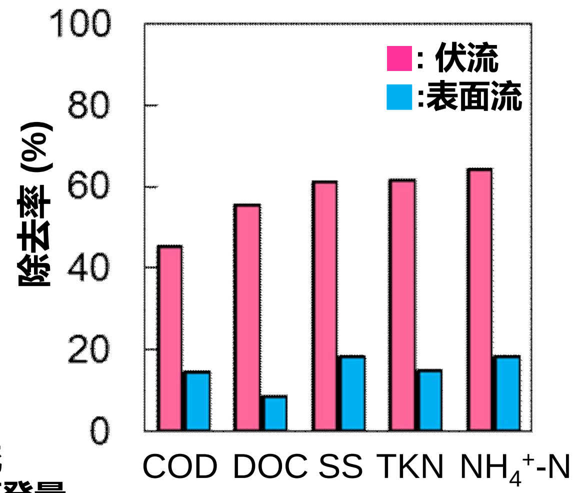
Failure case

Low efficiency of Surface exclusion
Ineffective drainage
Escape LFG
Long-term leachate pollution

ノンタブリ市埋立地での人工湿地による浸出水処理実証試験







伏流・間欠流入により水量削減と水質浄化の両立

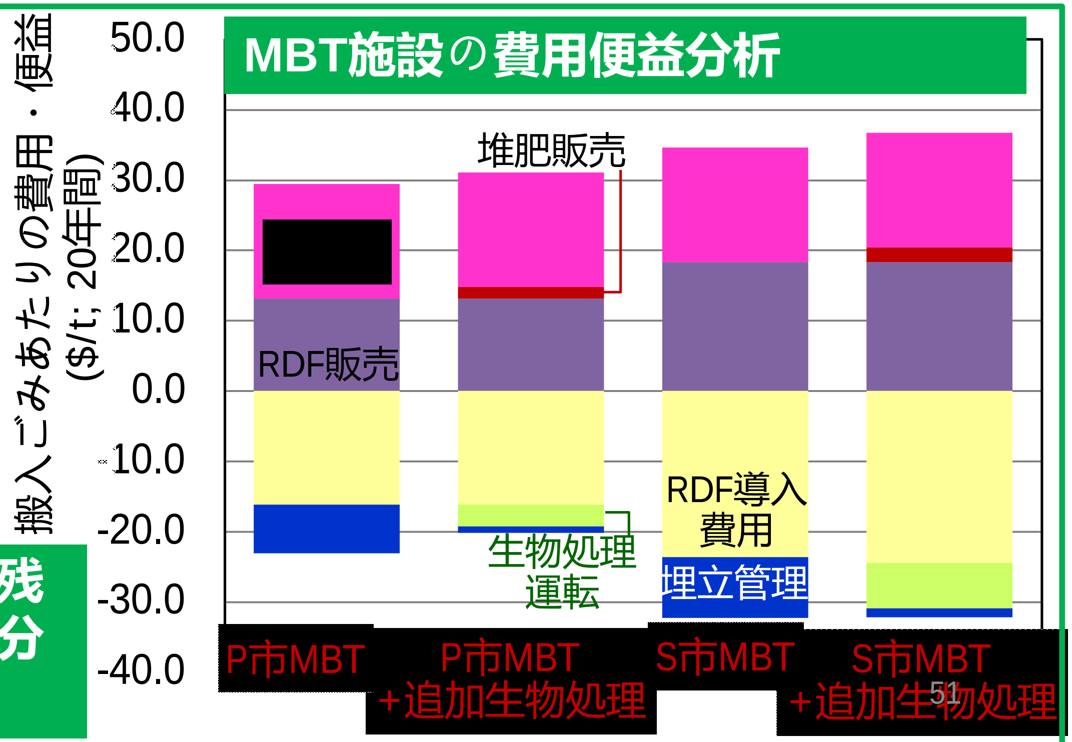
アジアでのMBT適用可能性調査

ピサヌローク市のMBT処理状況調査

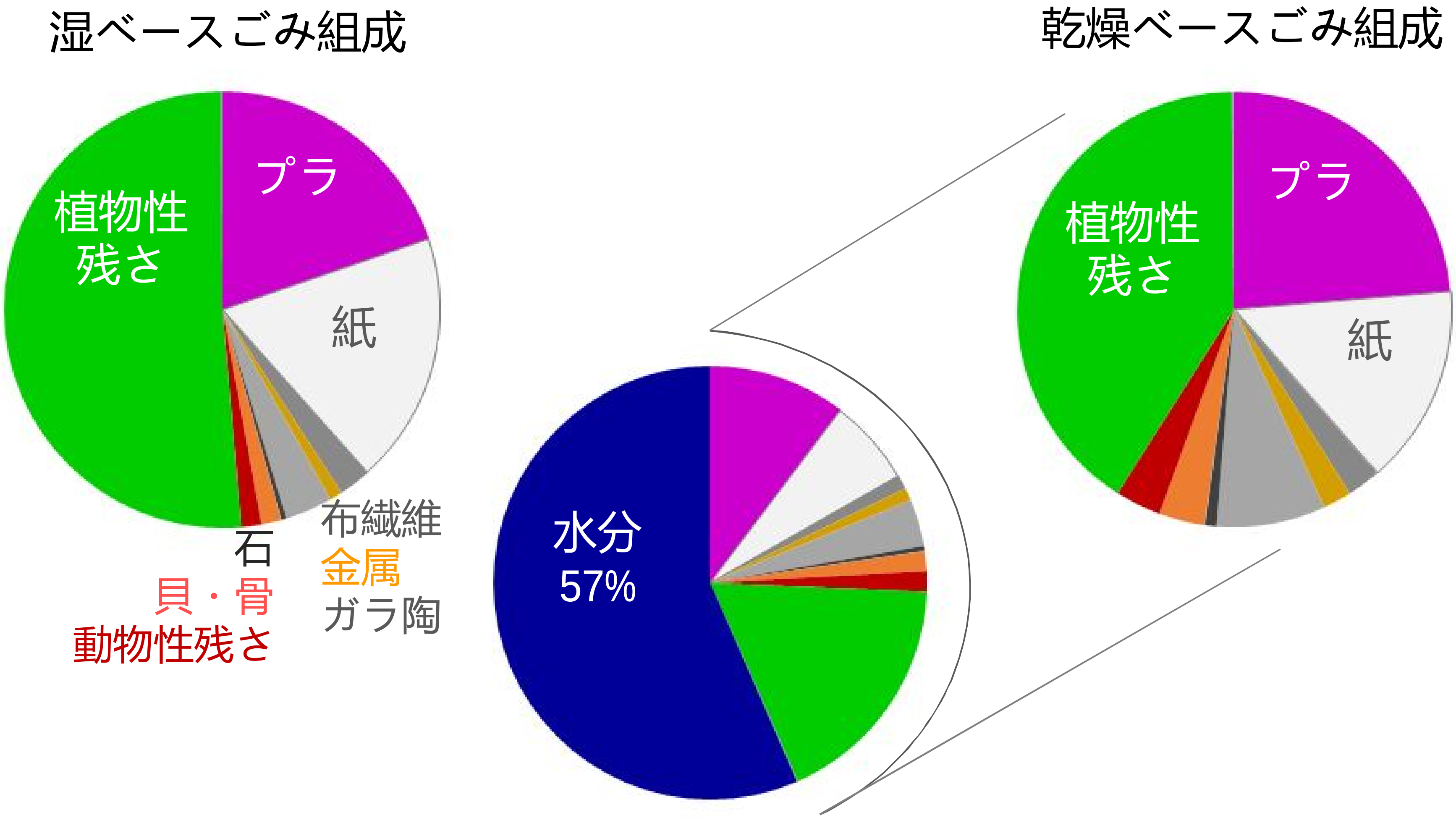
搬入物組成→RDF・残さ成分分析

産業側の受け入れ状況調査

既存MBT後段への生物処理導入による残さのコンポスト転換→売却益・埋立処分費用圧縮で費用便益比改善



搬入ごみの組成



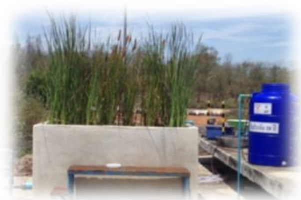
湿ベースごみ組成
プラ
植物性
残さ
紙
布繊維
金属
ガラ陶
石
貝・骨
動物性残さ
水分
57%
乾燥ベースごみ組成
プラ
植物性
残さ
紙

H27年度主要成果：準好気性埋立技術のアジア地域に適した設計手法の開発

目的及び達成目標：準好気性埋立について熱帯域に適合し、浸出水処理法を含めた構造ならびに維持管理要件を示す。

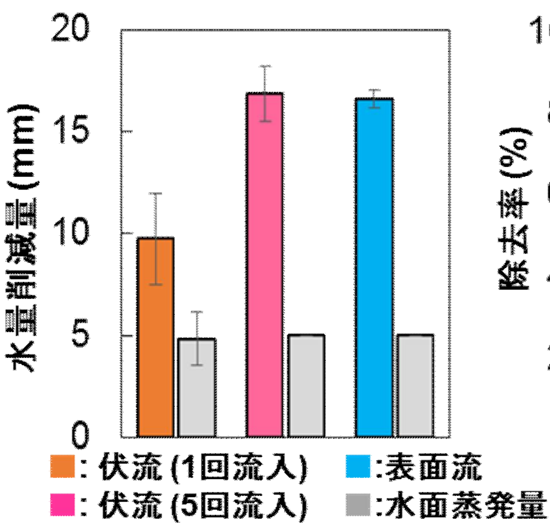
埋立地技術と浸出水処理の一体的評価

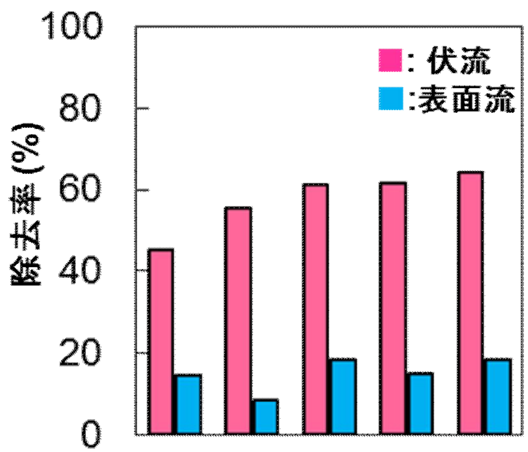
ノンタブリ市埋立地における人工湿地による浸出水処理の適用性実証試験



アジアでの埋立負荷の削減方策の検討～MBT適用可能性調査（ピサヌローク市）

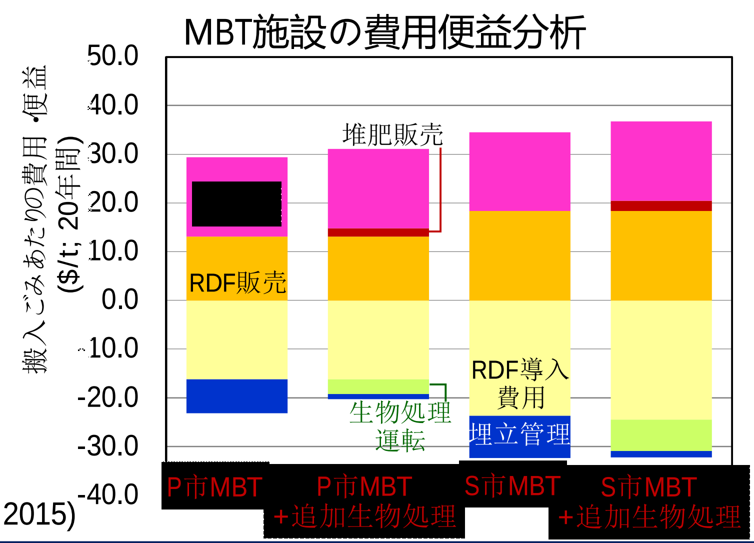
・搬入物組成
・残さ成分性状
・RDF品質と産業側の受入状況調査





（Ogata et al, Waste Management, 2015)

MBT施設の費用便益分析

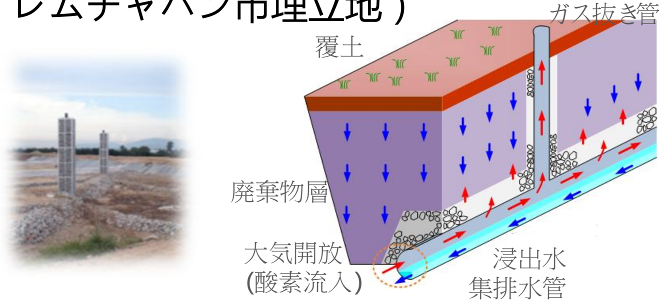


主要成果と**活用実績又**は**見通し**：**人工湿地**による**浸出水処理**において、**適切**な**流入方式**の**選択**（**伏流・間欠流入**）により**水量削減**と**水質浄化**の**両立**が**可能**であることが**示**された。**埋立負荷削減策**のためには**MBT残さ**の**追加的処理**が**必要**であることが**示**された。

第３期の主要成果：準好気性埋立技術のアジア地域に適した設計手法の開発

目的及び達成目標：準好気性埋立について熱帯域に適合し、浸出水処理法を含めた構造ならびに維持管理要件を示す。

準好気性埋立の長期実証試験
（レムチャバン市埋立地）



好気・嫌気分解による埋立地ガス発生挙動を表現するモデルの構築

低分子化　加水分解

$$C_{i,T} = W_{i,T} \cdot DOC \cdot \left[\left(1-e^{-k^{dis}}\right)\cdot\left(1-e^{-k^{hyd}}\right)\right]\cdot\theta$$

$$L_{i,T}=L_{i,T-1}+C_{i,T}-G_{i,T}-F_{i,T}$$

$$F_{i,T} = \left(L_{i,T-1}+C_{i,T-1}\right)\cdot\left(\frac{\theta}{\theta+I}\right)\cdot I$$

可溶化

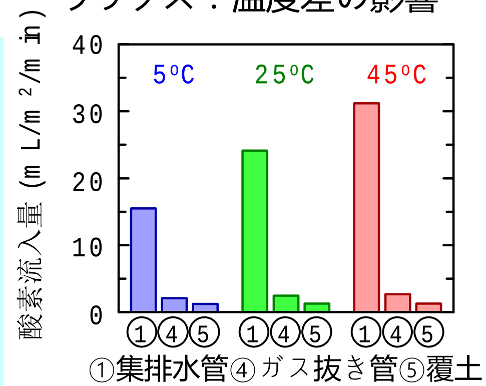
嫌気性分解　好気性分解

$$G_{i,T} = L_{i,T-1}\cdot\left(e^{-k_i \cdot f_{O2}} + e^{-k_{i*} \cdot f_{AN} \cdot \eta_e}\right)$$

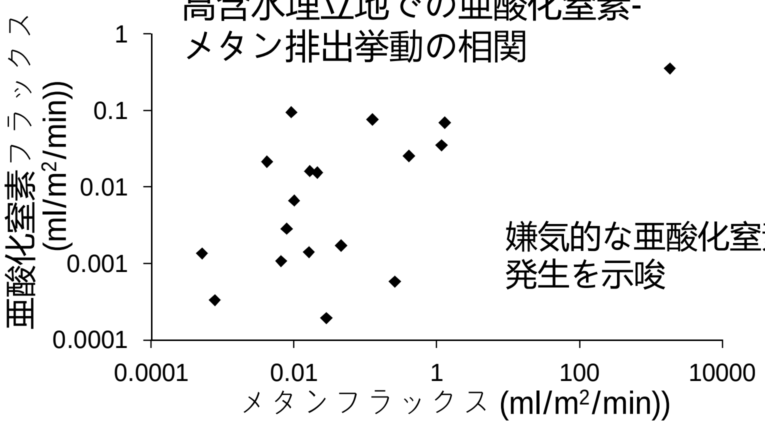
$$A_{i,T} = L_{i,T-1}\cdot\left[\left(1-e^{-k_i \cdot f_{O_2}}\right)\right]$$

ガス化

埋立3年次における酸素フラックス：温度差の影響



高含水埋立地での亜酸化窒素-メタン排出挙動の相関



アジアにおける準好気性埋立の設計・管理基準の提案

集排水管末端状態の確認・水没防止
　温度差の大きい日本以上に集排水管の状態に左右される
過剰排水による乾燥防止
　埋立地内部の水分量のコントロール（例：浸出水循環）
溶存態炭素の系外排除による水環境負荷
表層・法面からの空気浸透

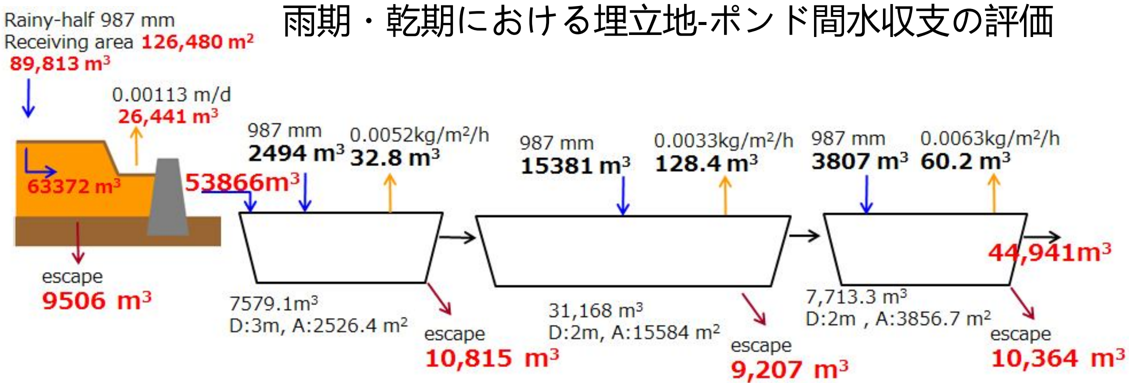
コベネフィットに考慮しつつ、廃棄物・水の一体的管理（処分場への降雨浸透、埋立層水分管理、浸出水管理）が同時に必要

主要成果と活用実績又は見通し：実埋立地での準好気性管理の実証試験から、好気・嫌気同時分解によるガス化モデルを構築した。酸素の浸入は集排水管に依存しており水没させない維持管理の重要性が示された。高含水率埋立地での嫌気的な亜酸化窒素発生挙動が観測された。

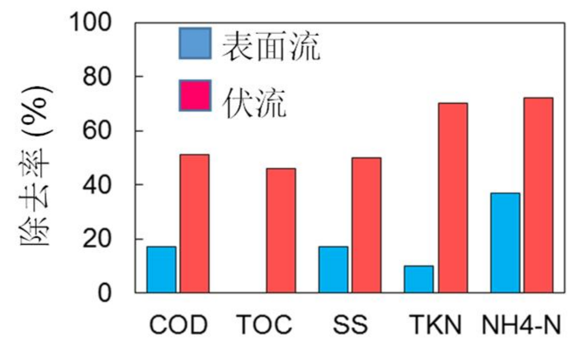
第３期の主要成果：準好気性埋立技術のアジア地域に適した設計手法の開発

目的及び達成目標：準好気性埋立について熱帯域に適合し、浸出水処理法を含めた構造ならびに維持管理要件を示す。

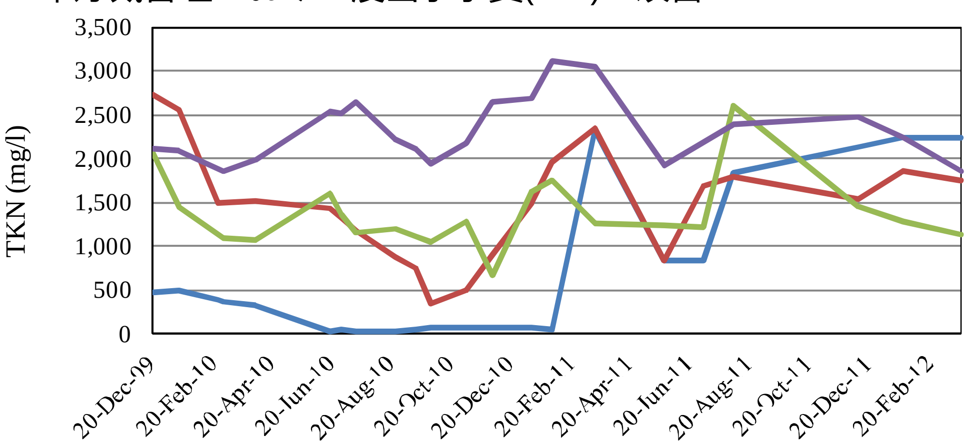
雨期・乾期における埋立地-ポンド間水収支の評価



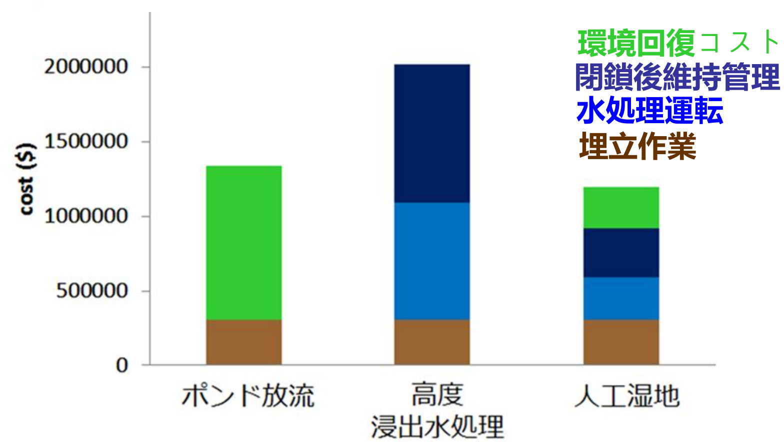
人工湿地による水質負荷削減と流下方式の影響



準好気管理における浸出水水質(TKN)の改善

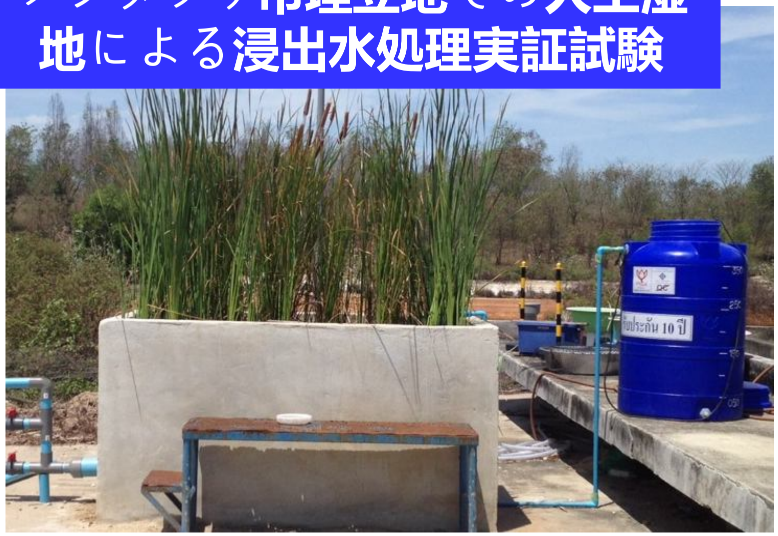


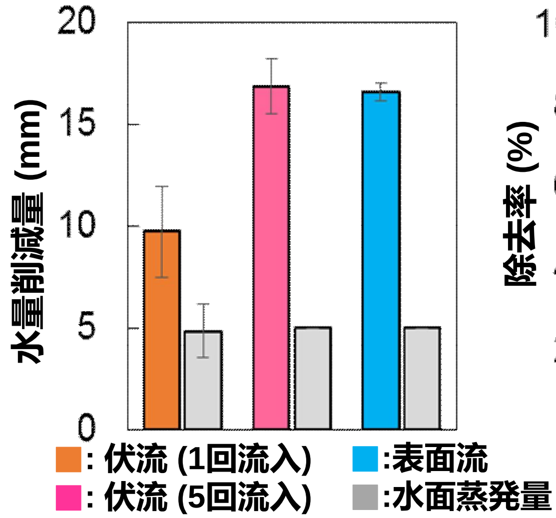
準好気性管理における水処理プロセスの比較

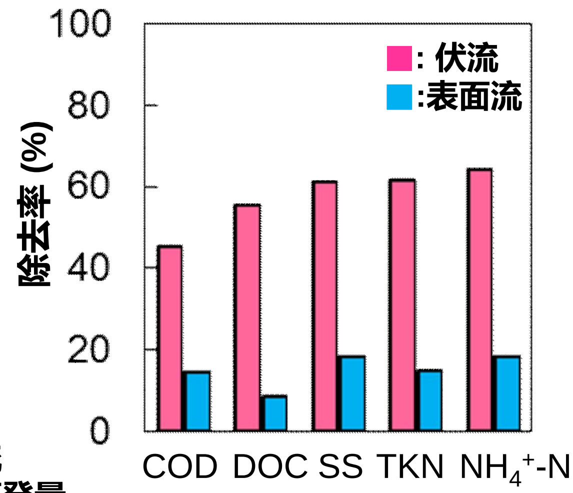


主要成果と活用実績又は見通し：降水量の変動の大きい熱帯アジアにおける埋立地水収支を解明した。準好気的管理による有機態窒素負荷の緩和効果により、人工湿地が持続可能で合理的な処理方式であることが示された。埋立有機物負荷の削減を含めた一体的な廃棄物管理の有効性が示された。

ノンタブリ市埋立地での人工湿地による浸出水処理実証試験







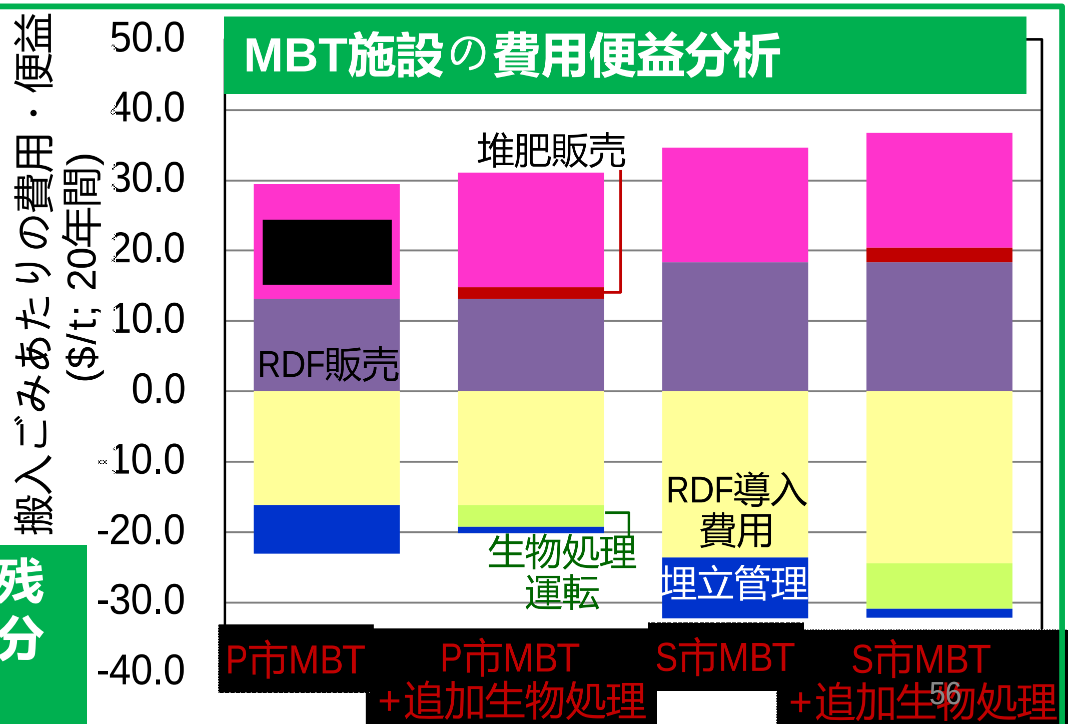
伏流・間欠流入により水量削減と水質浄化の両

アジアでのMBT適用可能性調査

ピサヌローク市のMBT処理状況調査
搬入物組成→RDF・残さ成分分析
産業側の受け入れ状況調査

既存MBT後段への生物処理導入による残さのコンポスト転換→売却益・埋立処分費用圧縮で費用便益比改善

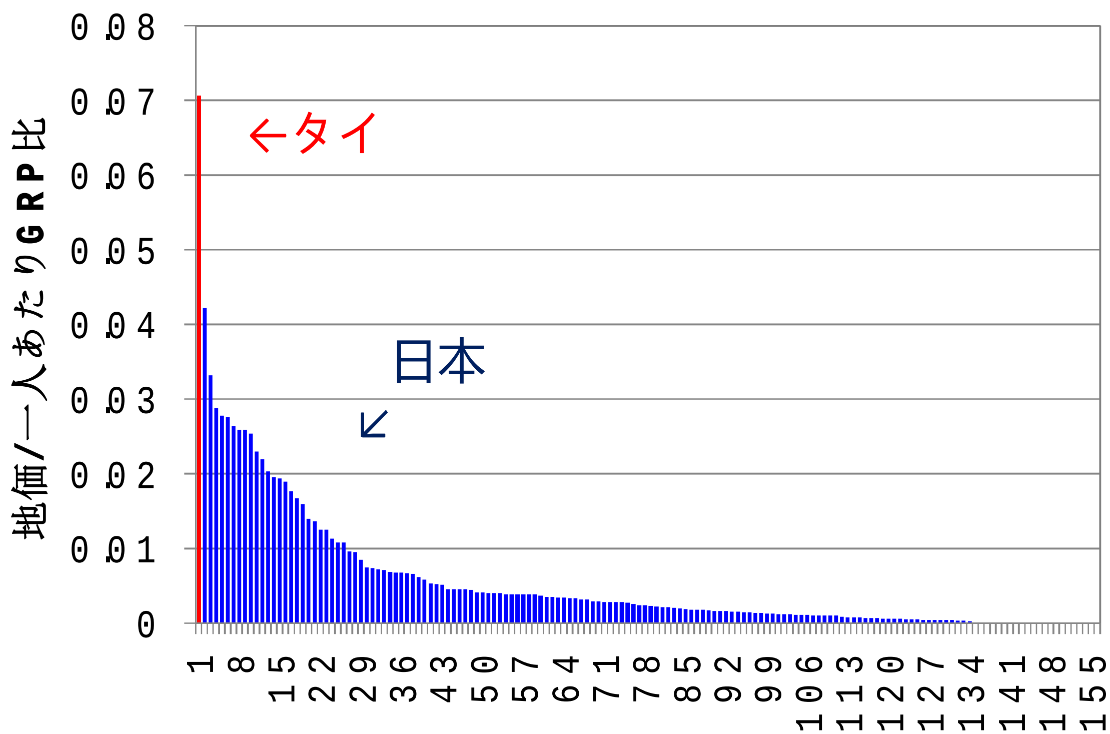
MBT施設の費用便益分析



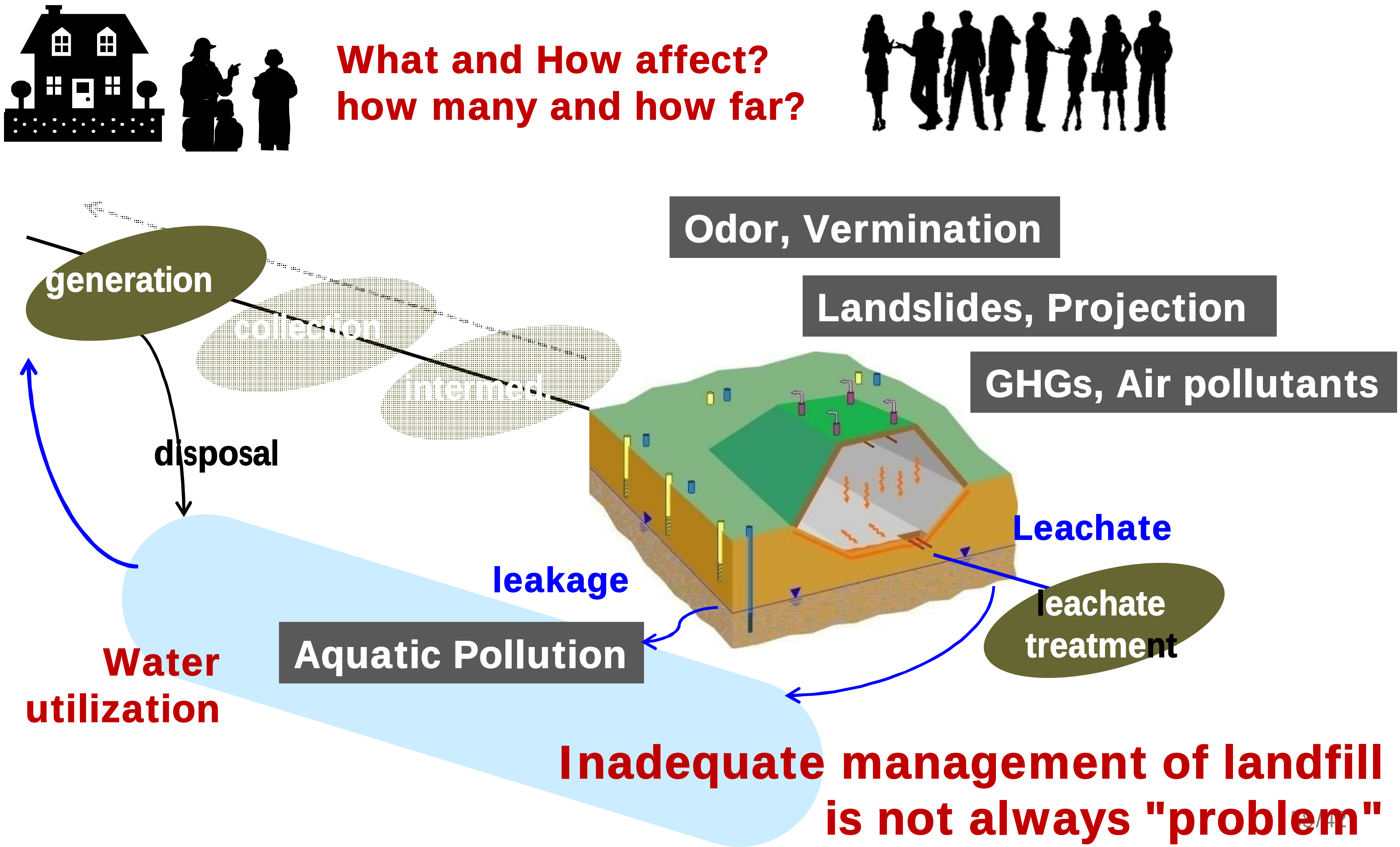
（処理費がかかるのに）MBTが成立する可能性

減容化率が**高い→埋立量**の**削減**に**効果的**
既存の**埋立地管理**に**対**する**不信・懸念**
処分場用地の**価格**が**高い**（**下図**）
エネルギ**ー（収入）**への**期待**に**反**し、**低品質SRF**の**却下率**、**受入**れ**可能**な**産業炉**の**数**も**限定的**で、**実質上**のエネルギ**ー消費側**

処分量の削減に迫られているが、焼却を導入する財政力にも欠ける地域では導入可能性が考えられる



Landfills in Waste Stream



Landfills in Waste stream