MECHANICAL BIOLOGICAL PRE-TREATMENT OF SOLID WASTE PRIOR TO LANDFILL

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ABSTRACT

The traditional landfilling system does not promote sustainable waste management due to uncontrolled emissions which potentially degrade the state of the environment. In this regard, pre-treatment of solid waste prior to landfill significantly enhance waste stabilization and provides various advantages. In this view, the mechanical biological pre-treatment of waste in combination with landfill is a useful technology that improves landfill behavior, characteristics, and operation. Thus, a sustainable landfilling system which conserves and preserves the environment with resource recovery is indispensable and will be the prevailing system in the near future.

INTRODUCTION

Accelerated industrialization, urbanization, and population growth caused rapid accumulation of solid waste and the existing disposal system is unable to tackle the waste in sustainable manner. The open dump approach which is the prevalent disposal system in developing countries creates considerable environmental, health and safety hazard. Soon, it was realized that landfilling system is the most economical and dependable municipal solid waste (MSW) disposal method and was practiced worldwide. It plays an indispensable role in integrated solid waste management schemes. Based on the fact that all waste processing methods generates wastes/residues that cannot be further reused and recovered must be landfilled. Moreover, landfilling was historically practiced without envisioning its stability and behavior until it was recognized to create detrimental environmental dilemma.

Generally, MSW composition in developing countries in Asia represent large fraction of biodegradable wastes. Importantly, the organic portions of waste in the landfill cause the emergence of harmful pollutants that may agglomerate and affect the quality of the environment. In this regard, waste pre-treatment is necessary to minimize landfill emissions and potential for resources recovery. Thus, direct landfilling is not environmentally sound approach wherein various potential risk and hazards associated with landfills could create imbalance ecosystem. Such impacts include emissions of landfill gas which is regarded to cause global warming; generation of leachate that constitute toxic effects on water environment; depleting land resources; aesthetic nuisance; and the risk associated with landfill stability. These issues led to establish an insight that the need for waste pre-treatment system prior to landfill is crucial.

LANDFILLS AND ITS IMPACT

Landfill plays an important role in integrated solid waste management. The current landfilling situation in Asia constitutes various problems related to cultural and climatic differences, along with the waste composition and improper waste management. The significant environmental impacts of landfill create detrimental effects to air, water, and soil environment. The uncontrolled production of landfill gas that consists of methane, carbon dioxide and traces of non-methane volatile organic carbons and halocarbons lead to ozone depletion and eventually contribute to global warming effect. The unregulated formation of leachate generation by percolating rain water and contain runoff of organic and inorganic compounds results in contamination of soil, surface, and groundwater. This may be exacerbated by the fact that leachate generated at any point in time is a mixture of leachates derived from solid waste at different ages. All these significant emissions were associated with landfills. Moreover, the issue related to aesthetic nuisance is mainly due to foul odour, noise, dust, appearance, and susceptibility to explosion/fire hazards. Nevertheless, the risk in landfill stability was one of the major geotechnical tasks in landfill design and operation and has been a problem for years (Kosch and Ziehmann (2004). Heterogeneous waste composition, obstacles in determining waste strength parameters, and insufficient knowledge on the principles of waste mechanics resulted in considerable uncertainties in landfill stability.

Figure 1 illustrates the emission tendency from different types of landfills with time. Among them, the traditional landfill which is simply an open pit without precautionary measures pose critical long term emissions and the tolerable emission level reached after many years only. Dry tomb landfill is designed with liners and cover material to prevent potential environmental emissions. However, after some time the liners/cover material may leak; thereby causing emission. Secured landfill is designed with impervious liner, leachate/gas collection and treatment system. Like in dry tomb landfill, the emission from secured landfill was just only delayed but after some time inevitable emission was generated. Importantly, a sustainable landfill is not just a landfill but it employs pre-treatment of waste prior to landfill. In any means, the emission from sustainable landfill is below the tolerable level at any point of time.

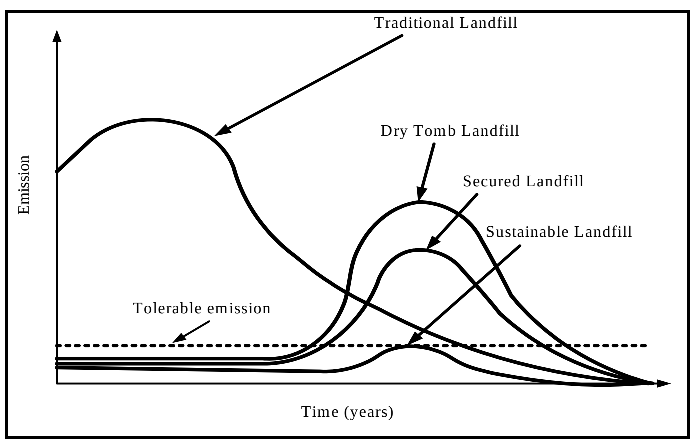

Figure 1: Emission tendency from different types of landfills

LANDFILL MANAGEMENT BREAKTHROUGH

The criteria for landfill are mounting with the urban population growth along with limited land resources. Figure 2 predicts the land requirement in Bangkok metropolitan for the next 15 years. The trend of the forecasted space requirement is increasing with time. Furthermore, ARRPET (2004) reported the generation tendency of MSW in Asian countries is also increasing with time. If such condition is recklessly unattended, it may lead to environmental conflicts. Nevertheless, when solid waste management conditions reach critical position, there is often a tendency to implement a western approach to overcome the existing problem in waste management. This approach is generally applied uncritically and rapidly resulting in the malfunctioning and inefficient management of waste treatment and disposal facilities (Bodelius and Rydberg, 2000).

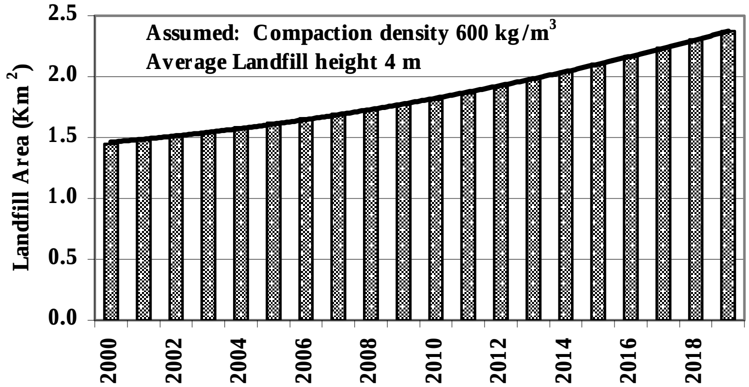

Figure 2: Land requirement for waste disposal

Importantly, cultural and climatic differences need to be considered in improving landfill design and operation. The urgent transition from traditional landfill (open dump approach) to engineered sanitary landfills has to be successfully managed in Asian context. Therefore, the design of an appropriate landfill technology demands for a comprehensive approach, followed by an optimized design and the adaptation of cost effective locally available technologies (Visvanathan et al., 2002). Suitable and feasible landfill operations are most sought after and especially those to curtail the post closure aftercare period. Moreover, Tammemagi (1999) reported that even modern landfills that employ state-of-art technologies such as liners and leachate collections systems are a quandary for it would start leaking within a few decades of their closure. For this reason, the birth of sustainable development serve as a leeway for the introduction of new approach of waste disposal that protect the health and environment, minimize the burden on future generation, and conserve resources. Proper technology should be considered to reduce the volume of solid waste ending at the disposal site. Therefore, mechanical biological waste pre-treatment (MBP) is an option to be considered to reduce the amount and potential emissions.

IMPORTANCE AND OBJECTIVE OF PRE-TREATMENT

Pre-treatment of waste prior to landfill supports sustainable landfilling by controlling/minimizing landfill emissions. Moreover, the aftercare requirement can be significantly reduced. Pre-treatment includes mechanical and biological processes. The former includes shredding, screening, sorting, and separation of ferrous components. The resulting volume reduction and increase in specific area of the waste can be attained, thereby increasing its specific density. As a result, biological performance of the succeeding biological pre-treatment step is enhanced and stabilized (Leikam and Stegmann, 1999). Biological pre-treatment stage involves degradation process that converts organic portion into useful end products potential for resource recovery. Additionally, the overall strategy promotes least hazardous chemicals introduced in the landfill. Maximum biogas production along with more leachate generation could be recovered from the waste before subjected into landfill.

The objectives of mechanical pre-treatment involve separation of waste mixtures into organic and inorganic fractions, reusable material, light and heavy fractions, and size reduction of waste. Eventually, this would provide optimum waste characteristics for biological pre-treatment. Biological processes promote waste stabilization with significant mass and volume reduction with the production of biologically stable waste. Stabilized waste residue subject to landfill for final disposal ensures stability of landfill system while consumes less landfill space.

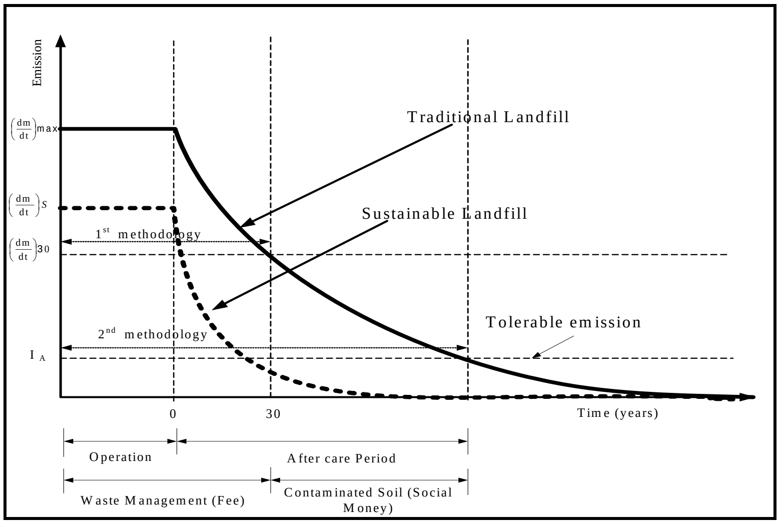

Figure 3: Comparison between first (European regulation) and second (Final storage concept) methodology

Figure 3 represents the comparison between the first and second methodology expressed by the European Regulation and from the "Final Storage" concept, respectively. The duration of aftercare phase is set for 30 years after the end of landfilling operations is the current regulation in Europe (Cossu et al., 2004). However, this was viewed as unsustainable approach because after that period, still the emission is significantly higher than the tolerable level. In this case, the time alone is an inadequate indicator to deem the landfill as adequately stabilized (Fourie and Morris, 2003). The objective of final storage ensures that the emissions/related risk associated with landfills can be considered negligible and this can only be achieved after nearly a century of closure. Importantly, sustainable landfills lead to the state of final storage prior the end of aftercare phase which is very attractive than the traditional landfills. This again highlighted the significance of mechanical-biological pre-treatment of waste prior to landfill.

ADVANTAGES OF MECHANICAL-BIOLOGICAL PRE-TREATMENT

Landfill management urgently requires suitable approaches to tackle present and future problems. MBP in combination with landfill will be a useful technology especially for the Asian regional setting. MBP provides important advantages it includes (1) Significant landfill volume/area reduction up to 40%, conserving land resources, and reducing the cost of landfilling. (2) Biodegradability of waste is reduced and stability of waste is increased by the MBP process, thereby reducing methane and leachate production on landfills (3) Potential hazardous waste contaminants in the waste stream, such as batteries, solvents, paints, fluorescent light bulbs, etc. will not reach municipal landfill sites due to waste sorting stage prior to treatment. (4) Recycling, reusing and recovering of waste materials will be maximized due to mechanical sorting (5) Aesthetic nuisance can be prevented while improving landfill stability.

Moreover, Figure 4 represents the general approach in dealing the MSW stream for MBP. Nevertheless, figure 5 illustrates the operational sequence of MBP of waste. Generally, the waste is subjected to mechanical conditioning operations followed by biological treatment for waste degradation under aerobic/anaerobic processes. The treated stabilized waste can be potentially reused as cover material/disposed into landfill.

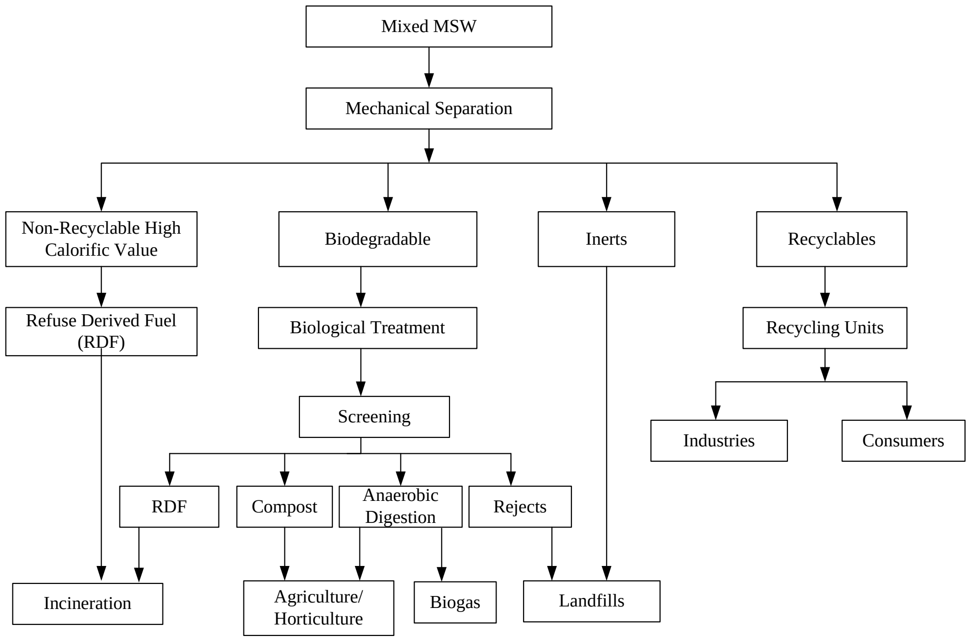

Figure 4: Approach for mechanical-biological pre-treatment process

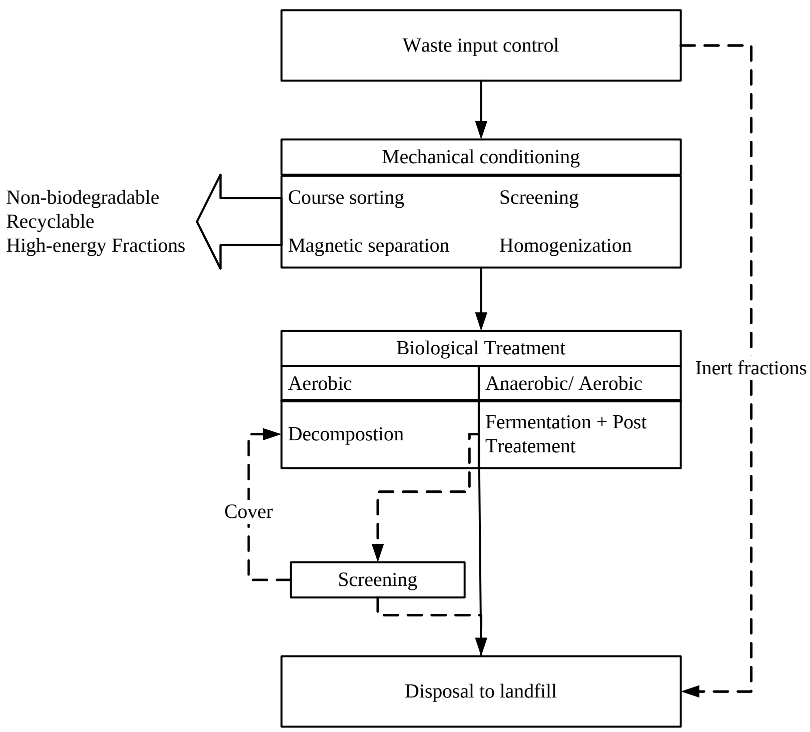

Figure 4: Operational sequence of mechanical biological waste treatment

LIMITATIONS OF MECHANICAL BIOLOGICAL PRE-TREATMENT UNDER ASIAN CONTEXT

Climatic Conditions

The design aspect of the waste management activities and landfill operations such as pre-treatment and disposal method require much attention on the climatic features of the particular country. Most of the Asian countries fall under the tropical boundaries which have a unique feature of climatic and weather conditions that are totally different from the other parts of the world. Local weather is of paramount concern and is best described as an alternation of an arid season (no rain up to 5 months) and a humid season with extreme rainfall events (Tränkler et al., 2001). The influence of the climate on landfill performance is complex: in relatively warm climates, for example, the increase leachate production after precipitation is generally quite rapid (Lema et al., 1988). Thus, it is important to understand the effect of landfill operations due to the local climatic variations.

Waste Composition

The solid waste composition in Asia and pacific region is almost similar. It constitutes high biodegradable portion of more than 50% (Table 1) composed of food waste, yard waste and mixed paper (ARRPET, 2004) with high moisture content. This waste is not suitable for incineration which requires high-energy input to bring to the ignition level. The attractive solution for solid waste disposal is pre-treatment prior to landfill. After mechanical pre-treatment of waste, aerobic/anaerobic processes can be employed. Aerobic composting was commonly used to convert the waste into humus-like material known as compost. However, this process is economically unwise due to low compost quality and requires high energy input.

Furthermore, anaerobic digestion is the most cost-effective process which overcomes the high moisture content and organic portion of waste with valuable resources recovery (biogas and fertilizer). Moreover, Vogt et al. (2002) reported that anaerobic digestion of waste was the preferred approach and reliable technology for the provision of energy and reduction of greenhouse gas emissions when compared to combustion/incineration, aerobic composting, pyrolysis, and landfilling/landfill gas recovery.

Table 1: Typical average waste characteristics in urban settings

Waste Categories (average percentage of wet weight)							
City	Bio-degradable	Paper	Plastic	Glass	Metal	Textiles & Leather	Inerts (ash, earth) & others
Indonesia	74	10	8	2	2	2	2
Dhaka	70	4.3	4.7	0.3	0.1	4.6	16
Kathmandu	68.1	8.8	11.4	1.6	0.9	3.9	5.3
Bangkok	53	9	19	3	1	7	8
Hanoi	50.1	4.2	5.5	-	2.5	-	37.7
Manila	49	19	17	-	6	-	9
India	42	6	4	2	2	4	40
Karachi	39	10	7	2	1	9	32

Zurbrügg (2002)

LANDFILL OPERATION AND PERFORMANCE

The integration of MBP prior to landfill in MSW management makes the operation, maintenance, design, and economics of the landfill feasible. In addition, the aftercare period require a simple operation for emission/effluent control in order to reduce the pollution load to the receiving water bodies as well as the gaseous emissions.

Landfill lysimeter simulations conducted by Kuruparan et al. (2003) showed that the pre-treated landfill (composted waste) had the minimum COD concentration (8 fold) and minimum TKN concentration (4 fold) and minimum COD loads (25 fold) and minimum TKN loads (5 fold) compared to the municipal solid waste landfills. The pre-treated lysimeter has shown a minimum of both COD and TKN concentration. Leikam and Stegmann (1999) also observed a similar trend in mechanically and biologically pre-treated waste in pilot scale lysimeters in Germany in 14 months of operation. They found a 10 fold reduction in BOD concentration and lower COD concentration and a 5-fold reduction in TKN between non-treated wastes and pretreated waste (1000 to 200 mg/L). Pretreatment could minimize nitrogen concentration to a large extent in future landfilling activities. Also it would ease and reduce leachate variations (young and old) difficulties in terms of treatment and handling, especially in long-term landfill management. Similarly, the methane gas emission potential would significantly reduced by the pre-treatment.

Mass Balance

In view of the potential emissions from landfills, a mass balance study which considers the fate of substances entering and leaving in the landfill system is considered as a useful tool to study the landfill emissions in long period. With this model it is possible to determine the effects of different alternatives for waste and landfill management, on the reductions of the emissions (Cossu et al., 2004).

A parameter model for mass balance is illustrated in equation 1. It is based on the assumption that the concentration of a given substance in volume V of landfill is always uniformly distributed in the space. The said author established the total balance for the system and is represented in equation 2.

Accumulation = input – output ± reaction (1)

$$x_L q_{Ld} + x_G q_{Gd} = \sum_i x_{Si} Q_i - x_L q_{Lr} - x_G q_{Gr} - dm/dt_{fix} - dm/dt_{mob} - rV \quad (2)$$

x_G – concentration of contaminant in the gas
x_L – concentration of contaminant in leachate
q_{Lr} & q_{Gr} – fraction of leachate and biogas that are collected
q_{Ld} & q_{Gd} – fraction of leachate and biogas migrated through landfill barrier system
Q_i – mass waste components
X_{Si} – solid phase concentration
dm/dt_{fix} – mass of compounds in deposited waste transformed into stable non-extractable compound
dm/dt_{mob} – mass of compounds in deposited waste mobilized into liquid phase by means of natural lixiviation
r.V- reaction

Table 2 exhibits the influence of several treatment processes in the minimization of the amount of waste material in the landfill, and maximization of biogas and leachate extraction through mobilization of extractable compounds and fixation of non-extractable compounds, and the reaction rate of degradable compounds. Among them, the pre-treatment which is very attractive especially in Asian context is the biological pretreatment (anaerobic digestion). An optimized digestion method could further more positive effect in terms of waste emission minimization while generating valuable resources prior to landfilling.

Table 2: Influence of treatment options on the reductions of emissions

Option	X_{si}	Q_i	X_L	q_L	X_G	q_G	dm/dt_{fix}	dm/dt_{mob}	rV
Mechanical Pretreatment			+		+		+		+
Biological Pretreatment	+		+		+				+
Thermal Pretreatment	++	++							
Waste Minimization		+							
Leachate Recirculation			+						
Open landfill /Flushing				++					+
In situ Aeration						+	++		++
Anaerobic Landfill			+		+		+		+
Anaerobic digestion	+		+	+	++	+	+	+	+

CONCLUSIONS

Here the significance of mechanical-biological pre-treatment of solid waste prior to landfill, which is attractive in the Asian context due to potential waste generation and characteristics is higligted. Pre-treatment of waste transformed and stabilized waste components to the extent that potential leachate and landfill gas emissions is reduced while saving land resources due to considerable waste volume and mass reduction. The limitations associated with MBP should be considered critically with the aim of implementing sustainable landfilling system. Since the primary aim of MBP is the optimum reduction of landfill leachate and gaseous emissions. However, it does not completely eliminate total emissions; in this regard the principle of mass balance can be used to understand the fate of the remaining waste components. A mechanical pre-treatment prior to biological anaerobic digestion process enhances the process and offer benefits that support the concept of sustainability.

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Mechanical Biological Pre-treatment of Solid Waste Prior to Landfill

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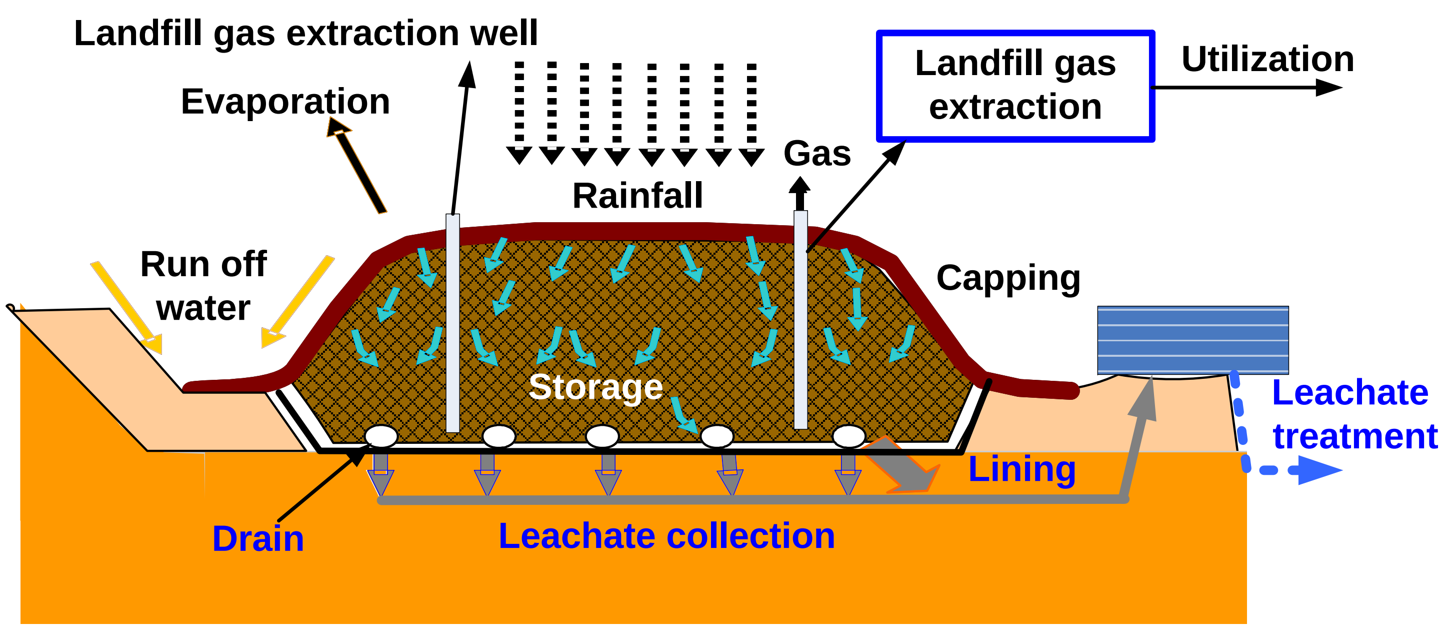
Controlled landfilling and sanitary landfills in Asia

- Control waste tipping
- Compaction of waste
- Daily cover and final cover
- Liner system for the landfill
- Leachate collection and gas vent or collection pipes
- Controlled waste picking
- Leachate treatment facilities



Open Dumpsites in Asia

Gohagoda dump site (Sri Lanka)

Chennai dumpsite (India)

Shanghai dumpsite (P.R. China)

Dump site (Thailand)

Landfilling in Asia

Dry season: Soil cracks in Landfills

Rainy season: Low compaction - high leachate generation, stagnant water

Return of the mummy

Organic body ---

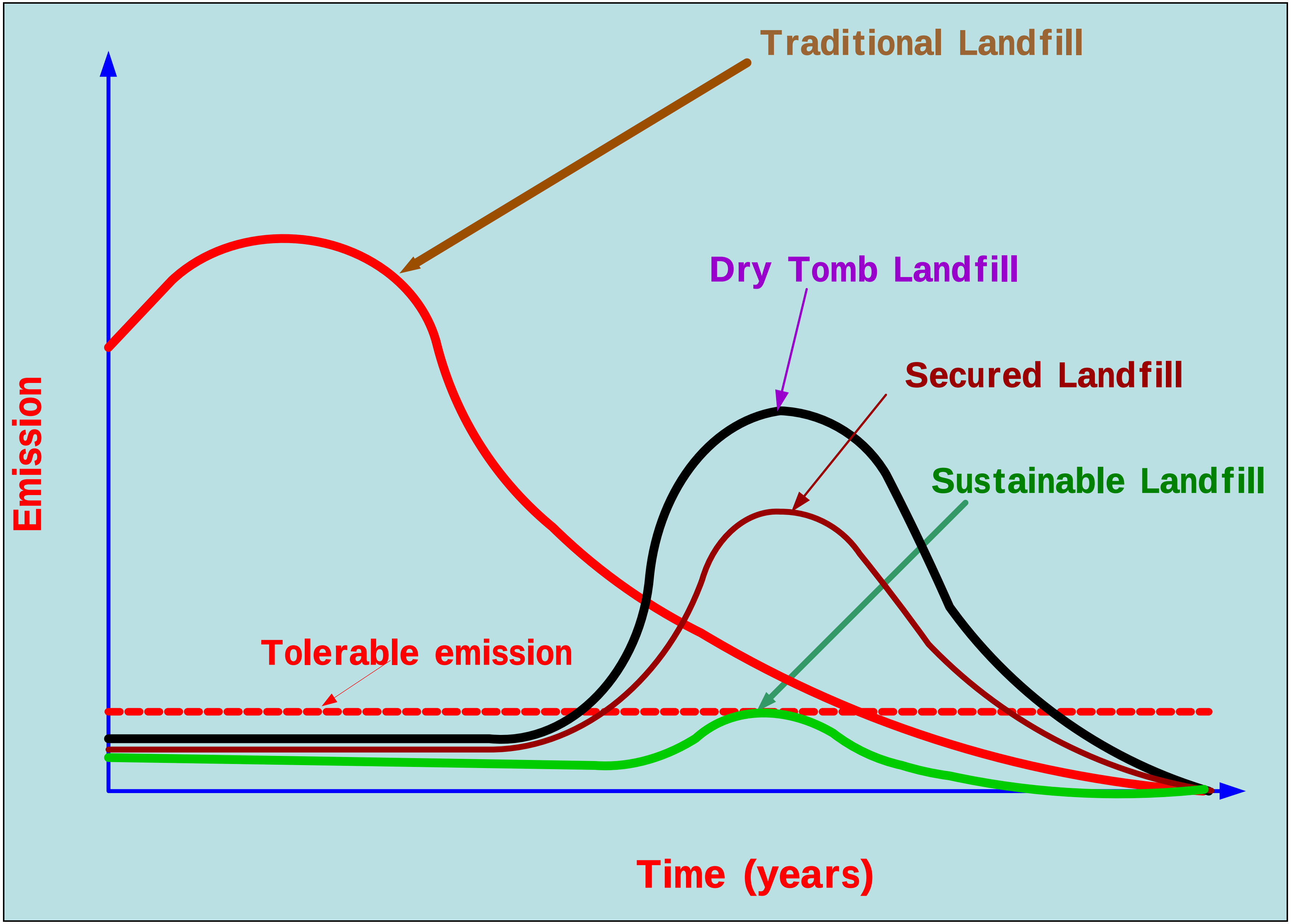
Stop degradation or retard it

toxic chemicals to kill bacteria,

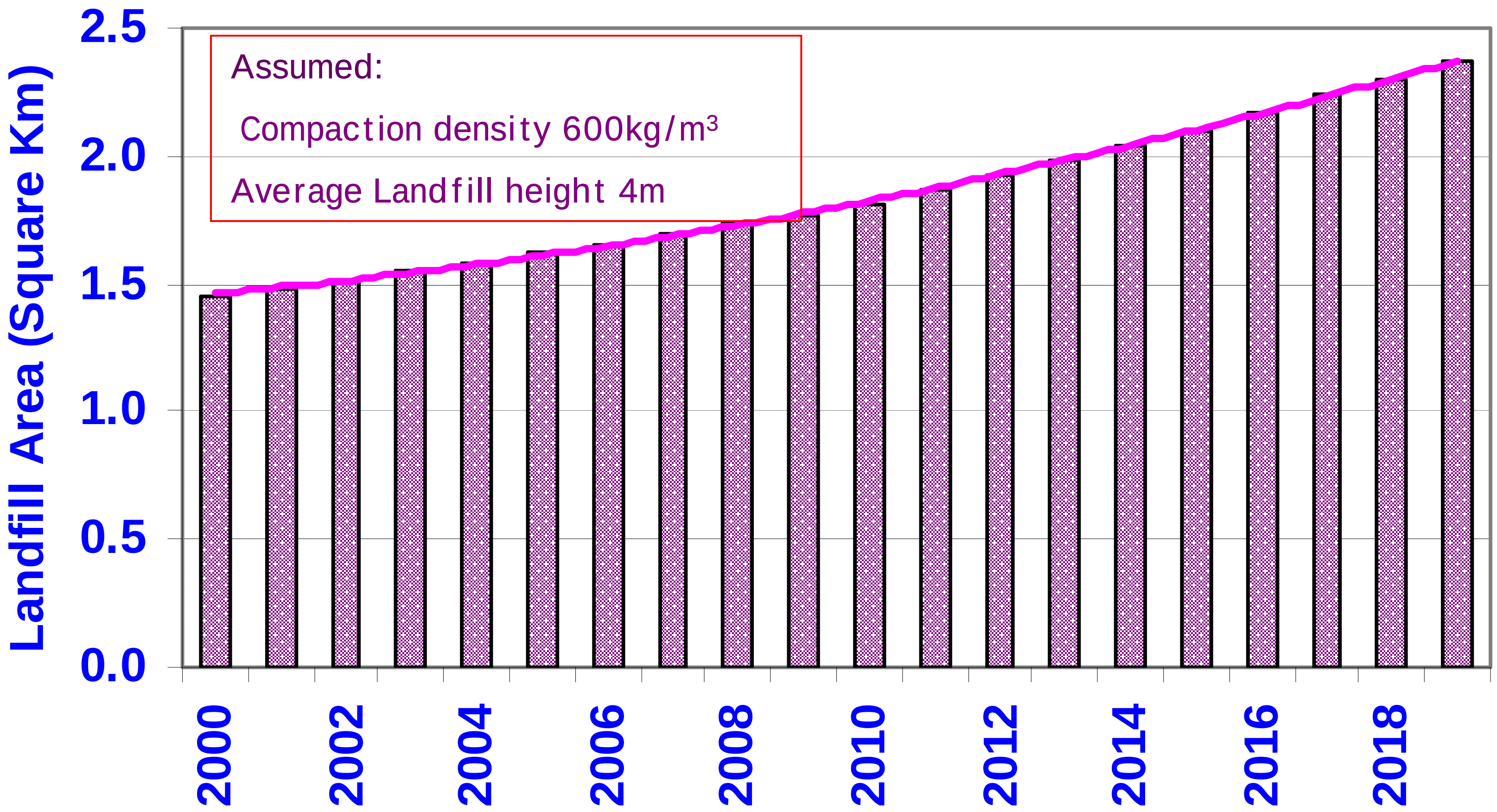
cover to avoid oxygen contact

Is that what happens in a landfill?

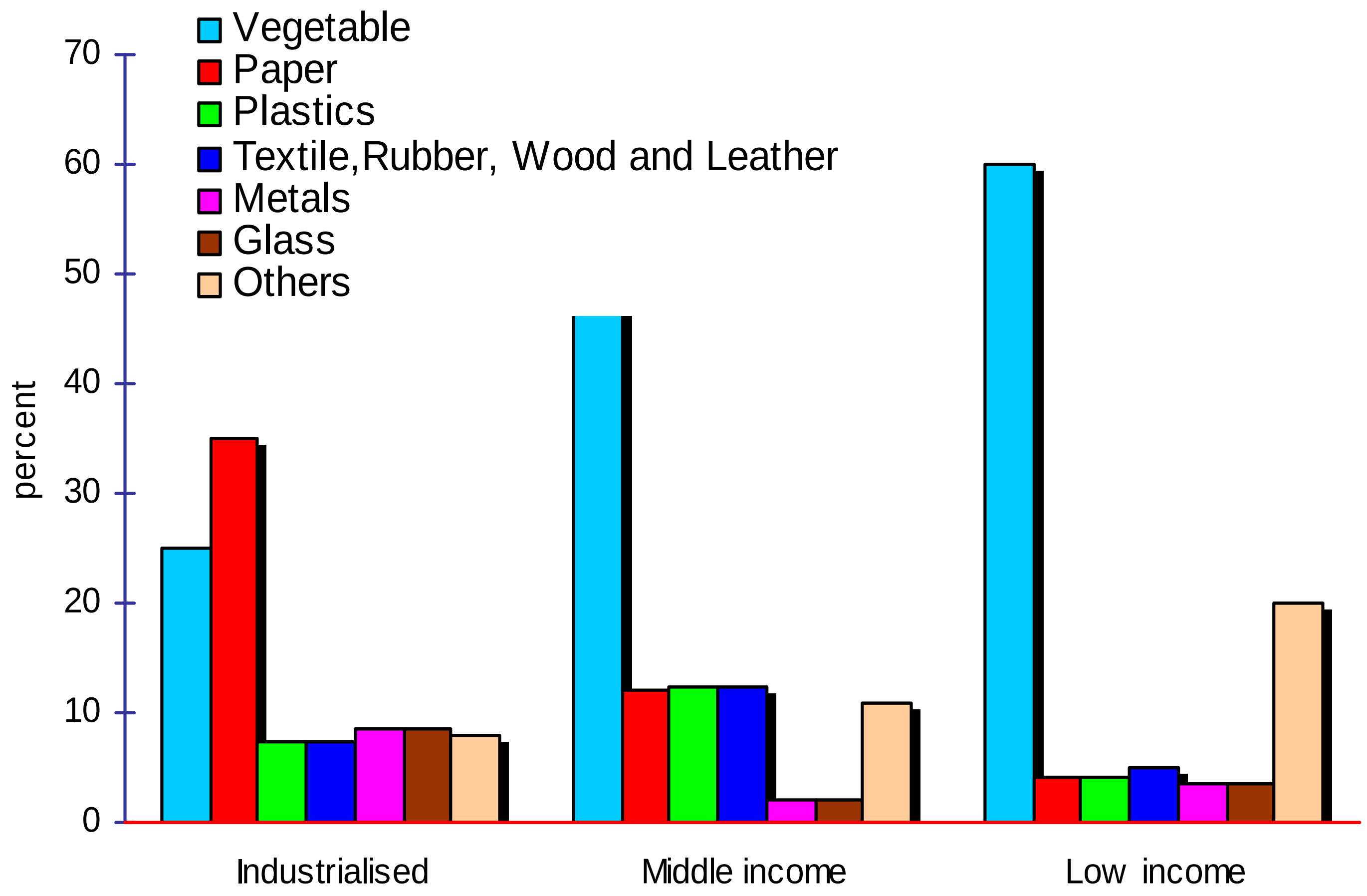
Possible emission from different types landfills



Forecast of land requirement for disposal: BMA

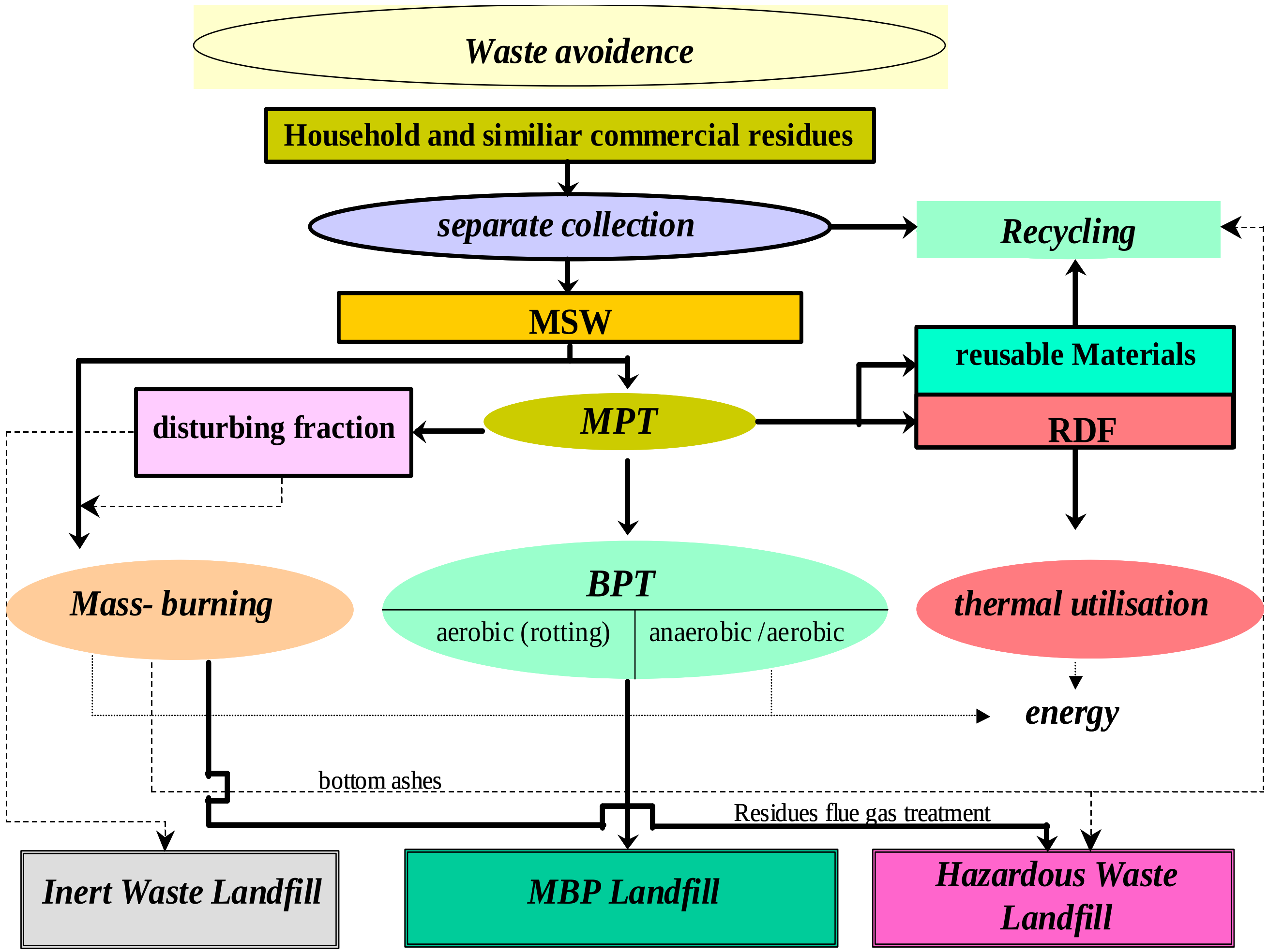


Waste Characterization and Composition



Comparison of organic and inorganic components in the MSW from high, middle and low-income countries

General Concept of MSW Management



Objectives of the Mechanical Pretreatment Process

- Separation of the waste mixture into e.g. reusable, inorganic, organic, light and heavy fractions (RDF)
- Provision of optimum waste characteristics for the biological pre-treatment
- Shredding of waste to improve the landfill characteristics (option)

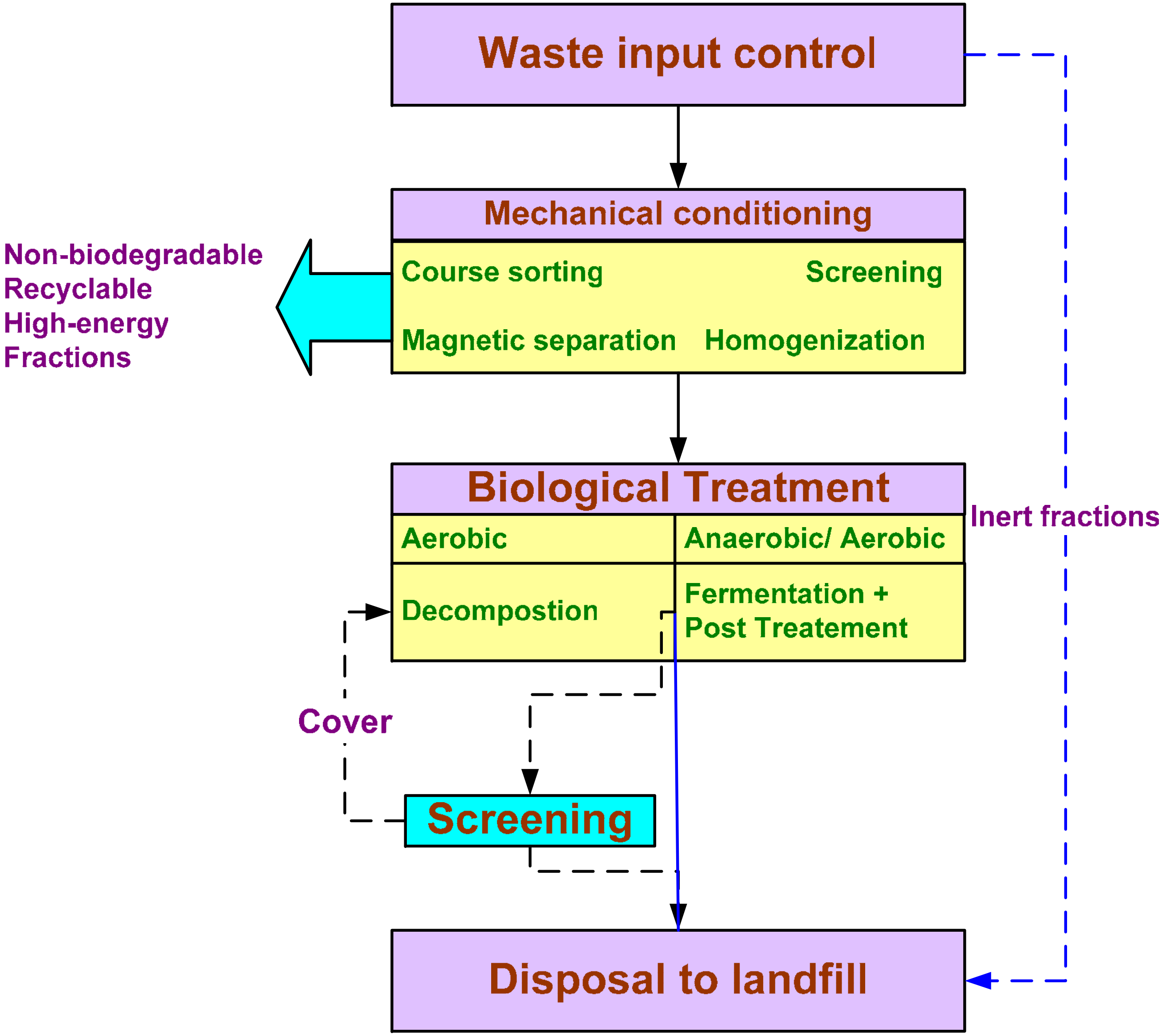
Objectives of the Biological Pretreatment Process

- Degradation of organic matter to reduce the emission and the emission potential
- Minor settlings
- Production of a biologically stable waste

Aims of the Pre-treatment of Residual Waste

- Biological (or thermal) *stabilisation* before landfilling
  - Reduction of the landfill *emissions* (biogas, leachate) by an accelerated biological degradation (or thermal destruction) of organic substances
  - Saving of landfill *capacity*
  - Minor *settlements* because of biological degradation
- Improvement of the *landfill installation* by more homogenous waste (material distribution, particle size, water content)
- Improvement of *landfill operation* by reduced dust and paper flow as well as odour-emissions

Operational Sequence of Mechanical-Biological Waste Treatment



Mechanical shredding

Hand Sorting

Magnetic Separation

Homogenization

Composting of MSW

Anaerobic Digestion of MSW

Mass Balance Approach for Sustainable Landfilling

Accumulation = input – output ± reaction (1)

$$\frac{dm}{dt} = dm/dt_{fix} + dm/dt_{mob} \quad (2)$$

$$\frac{\Delta m}{\Delta t} = \sum x_{S_i} \cdot Q_i - X_L \cdot q_{Ld} - x_L \cdot q_{L_r} - x_G \cdot q_{G_r} - x_G \cdot q_{Gr} - rV \quad (3)$$

$$X_L q_{Ld} + X_G q_{Gd} = \sum_i X_{Si} Q_i - X_L q_{Lr} - X_G q_{Gr} - dm/dt_{fix} - dm/dt_{mob} - rV \quad (4)$$

m- increase of mass in the landfill system

T- time

m_{fix} - transformed in to non extractable compound

M_{mob} – either mobilized or transferred into liquid phase by means of natural lixiviation

Q_i – mass of “n” streams of “i” waste components

X_{si} – Concentration in the solid phase

q_g – mass leaving the landfill through gas

q_l – mass leaving the landfill through leachate

x_g – concentration of containment in the gas

x_l – concentration of containment in the leachate

q_{lr} & q_{gr} – fraction of leachate and biogas that are collected

q_{ld} & q_{gd} – fraction of leachate and biogas that are migrated uncontrolled ways through the landfill barrier

For Sustainable Landfilling, uncontrolled emission have to be minimized { $X_L q_{Ld} + X_G q_{Gd}$ }

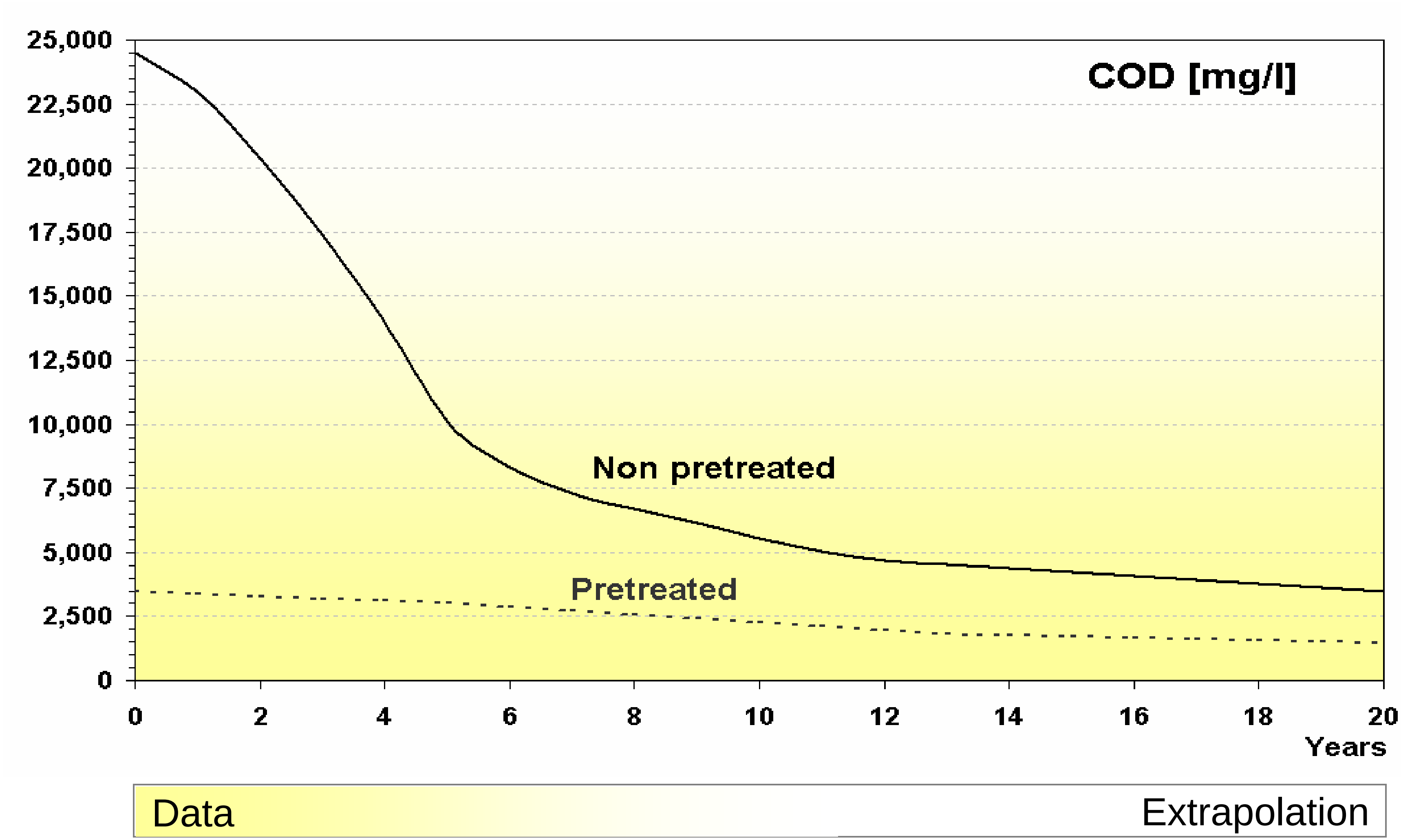
- Waste minimization
- Pretreatment prior to landfill
  - Mechanical pretreatment (shredding: size reduction followed by accelerated biochemical process
  - Biological pretreatment (reduces the readily available organics and enhances waste degradation process)
- Minimization of hazardous chemical introduced in the landfill { $\sum_i X_{Si} Q_i$ }
- Maximization of:
  - Biogas and leachate extraction
  - Mobilization of extractable compounds and elements and fixation of what is not extracted
  - The rate of reaction of degradable compound

Influence of options on the main parameter in the mass balance

Option	X_{Si}	Q_i	X_L	q_{L_r}	x_G	q_{G_r}	dm/dt_{fix}	dm/dt_{mob}	rV
Mechanical Pretreatment			+		+		+		+
Biological Pretreatment	+								
Thermal Pretreatment	+ +	+ +							
Waste Minimization		+							
Leachate Recirculation			+						+
Open landfill /Flushing				+ +					+
In situ Aeration						+	+ +		+ +
Anaerobic Landfill			+		+		+		+

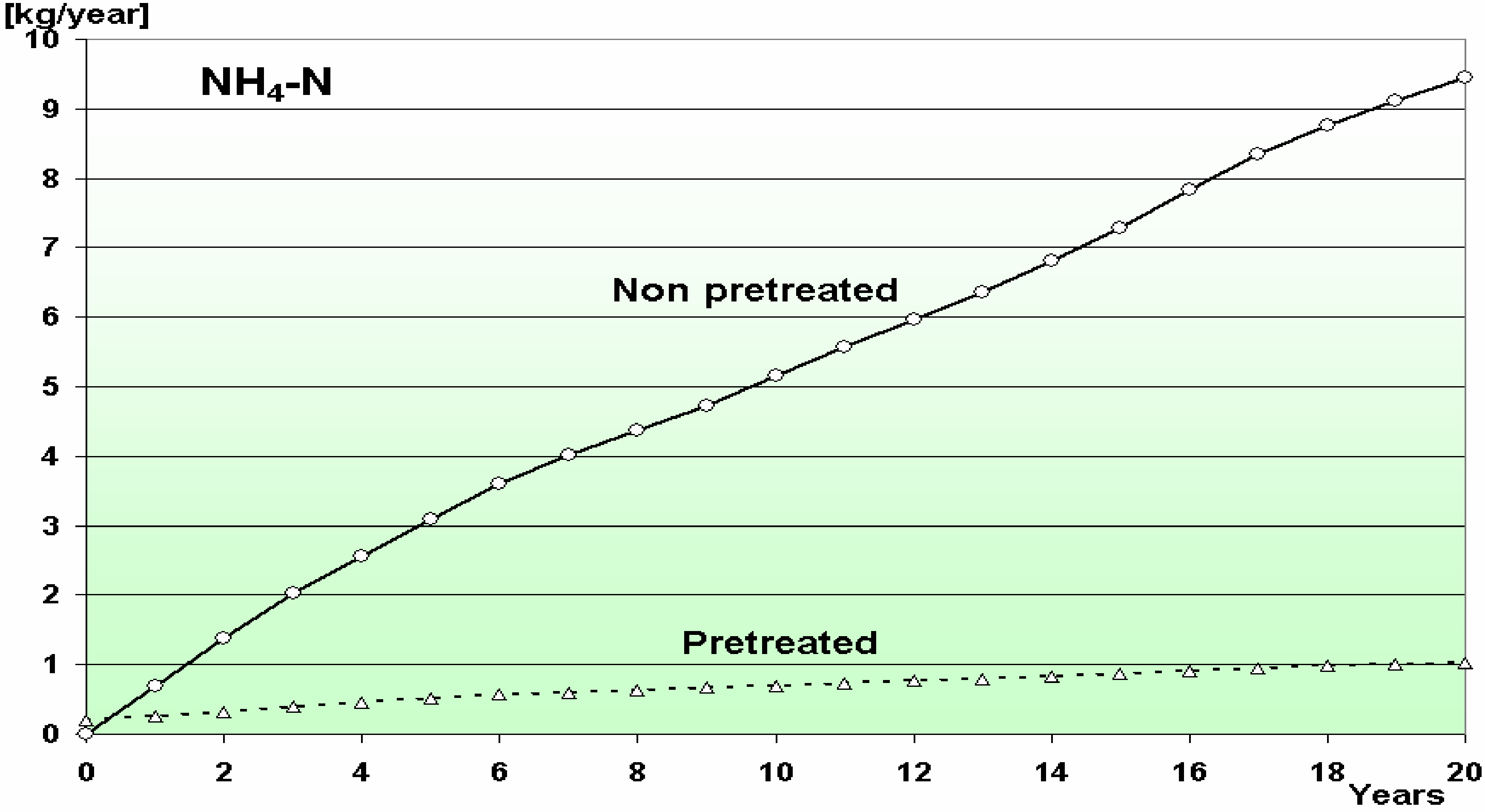
\+ Indicating a positive effect

Variation of COD concentrations for non- pretreated and pretreated MSW



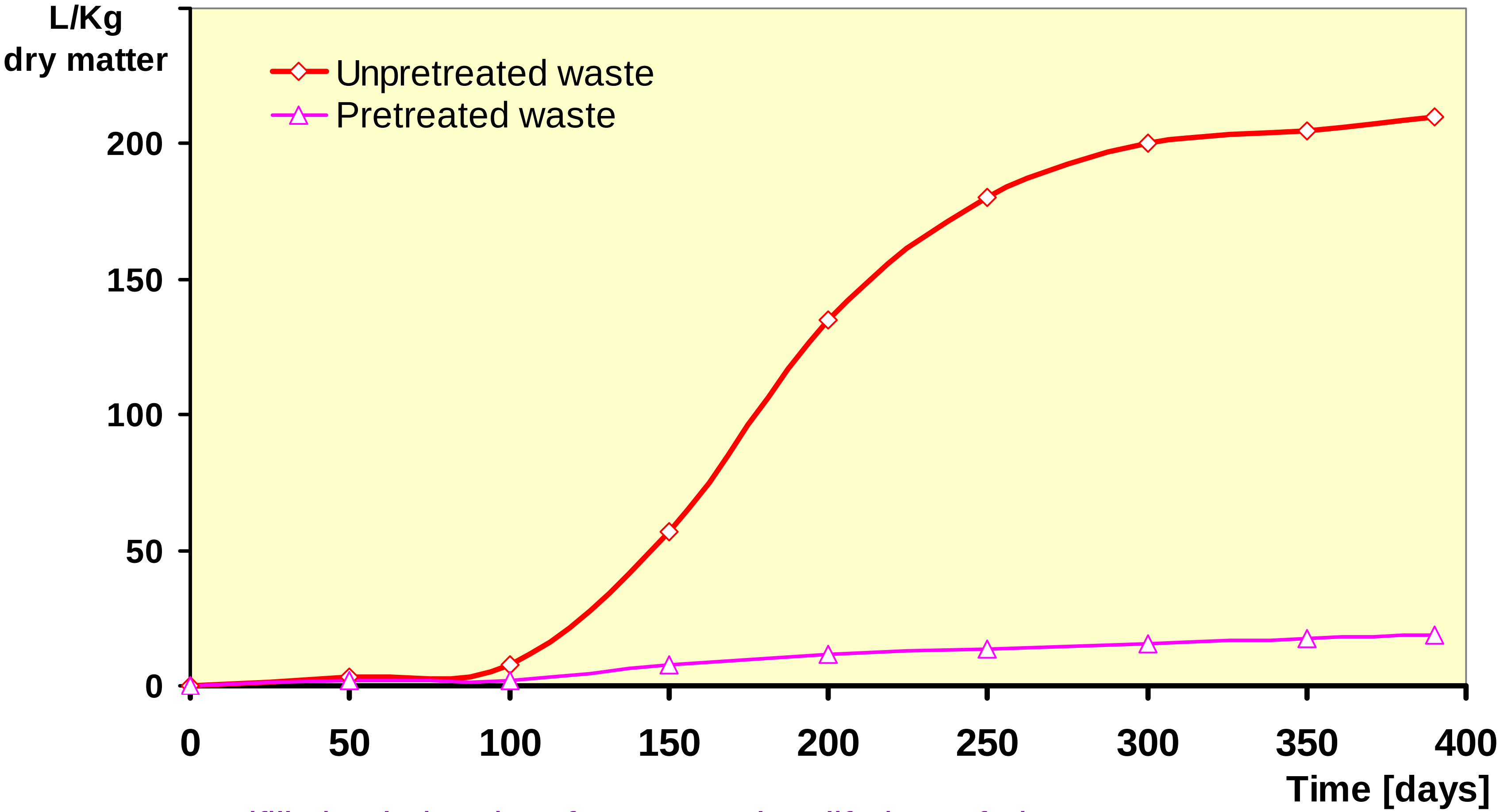
Mechanical biological pre-treatment

Comparison of the cumulative NH_4-N load over a period of 20 years



Predicted reduction : ~ 85 %

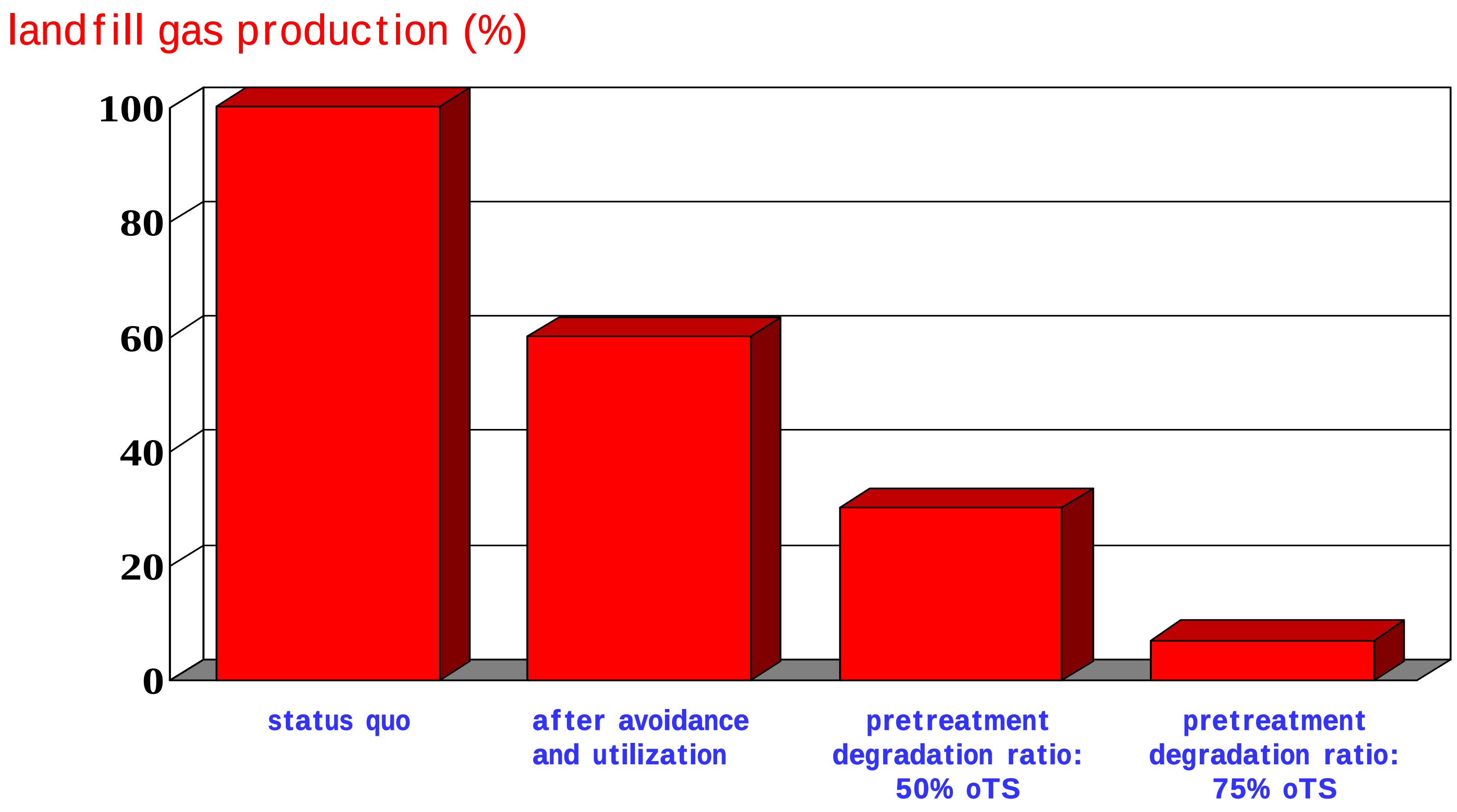
Biogas production of pretreated waste



Landfill simulation time frame equals a lifetime of about 50 years

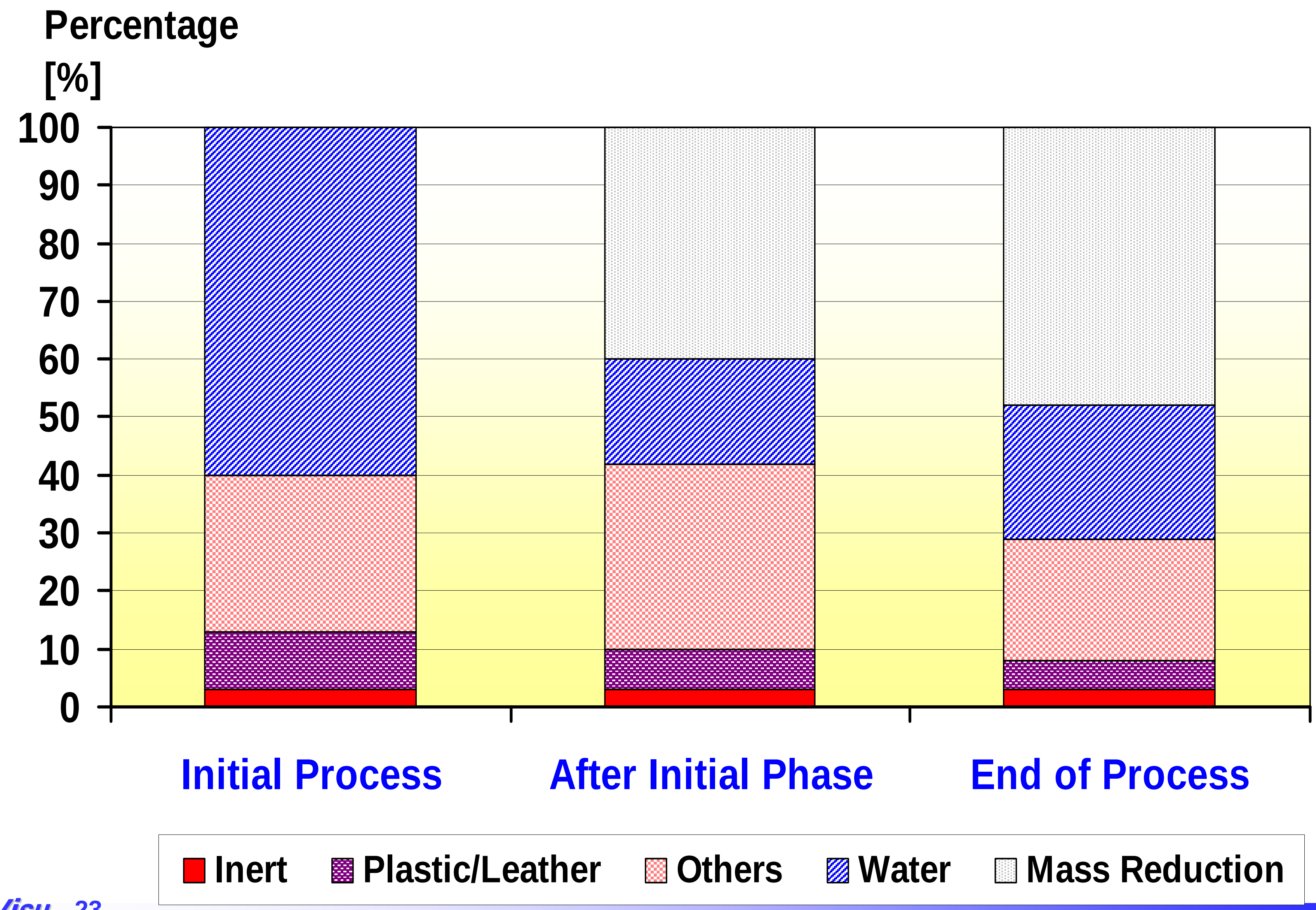
Pretreated waste generates 5 - 10% biogas compared to non-processed waste.

Predictions for landfill gas production



Mechanical biological pre-treatment

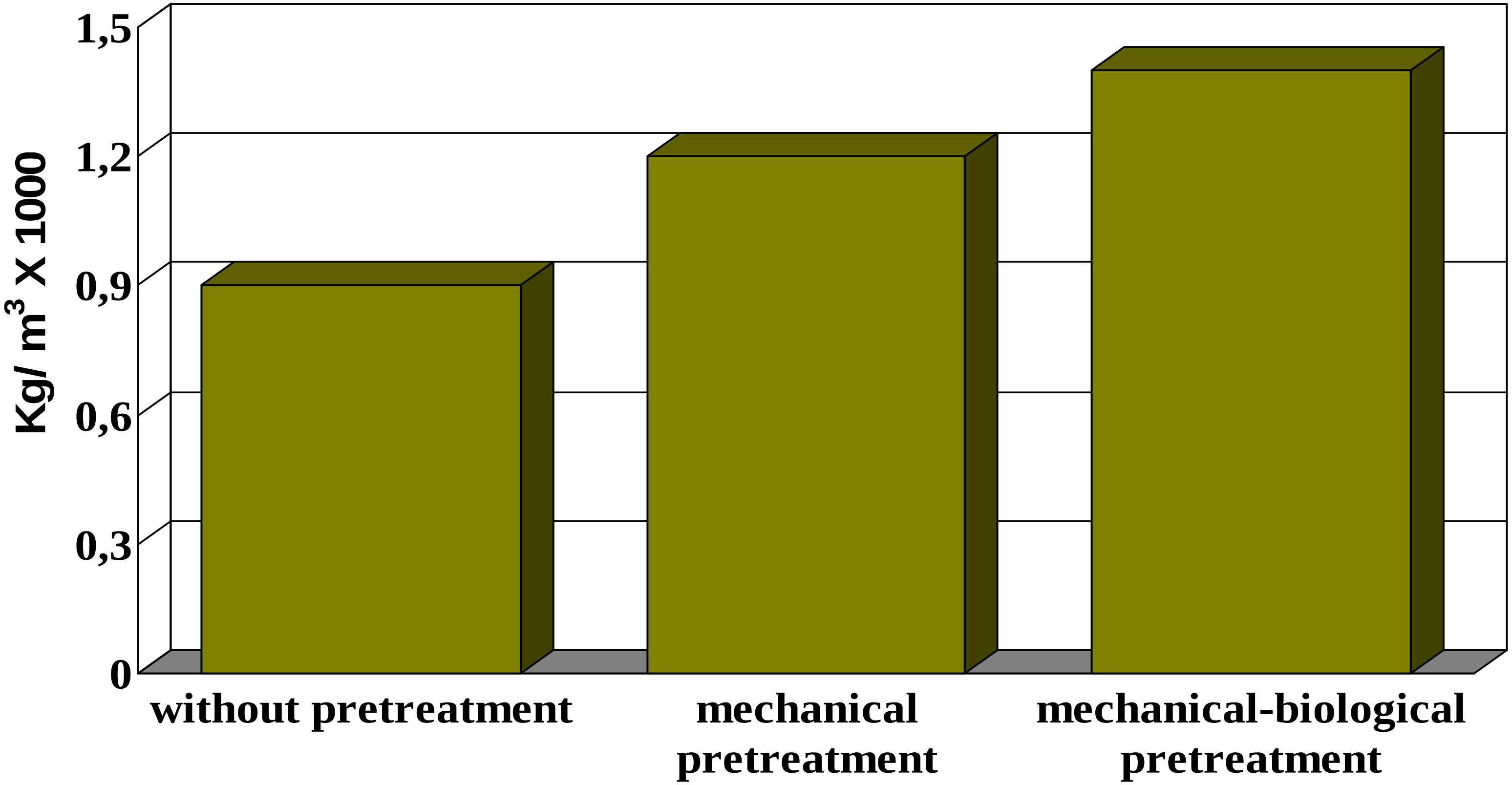
Assumed volume reduction - MBPT



Mechanical biological pre-treatment

Increase in waste compaction

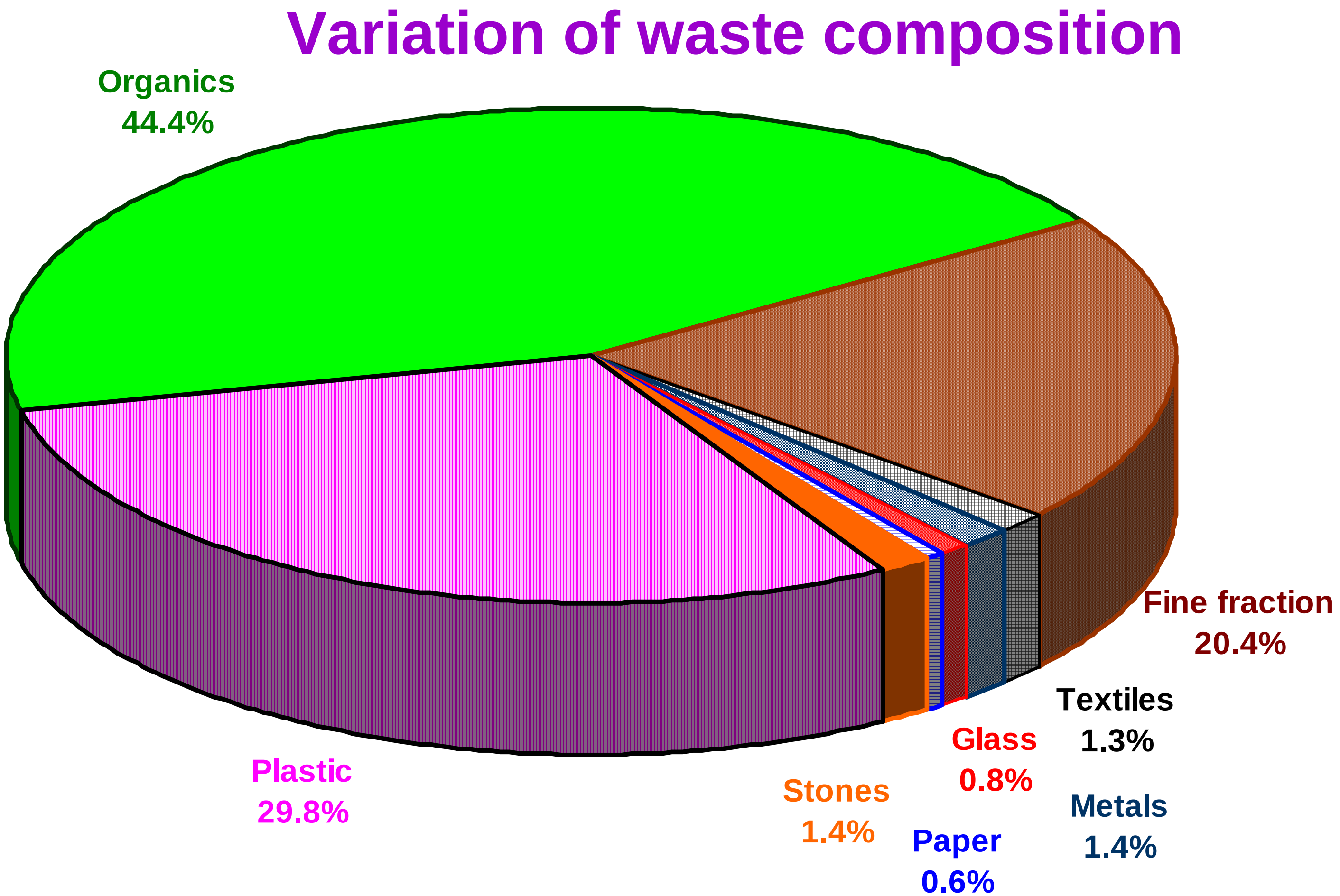
Waste compaction



MBPT - Ttreatment Plant - Example -

MBPT-Plant and Landfill, Bassum (Germany)

Full Scale MBPT Phitsanulok

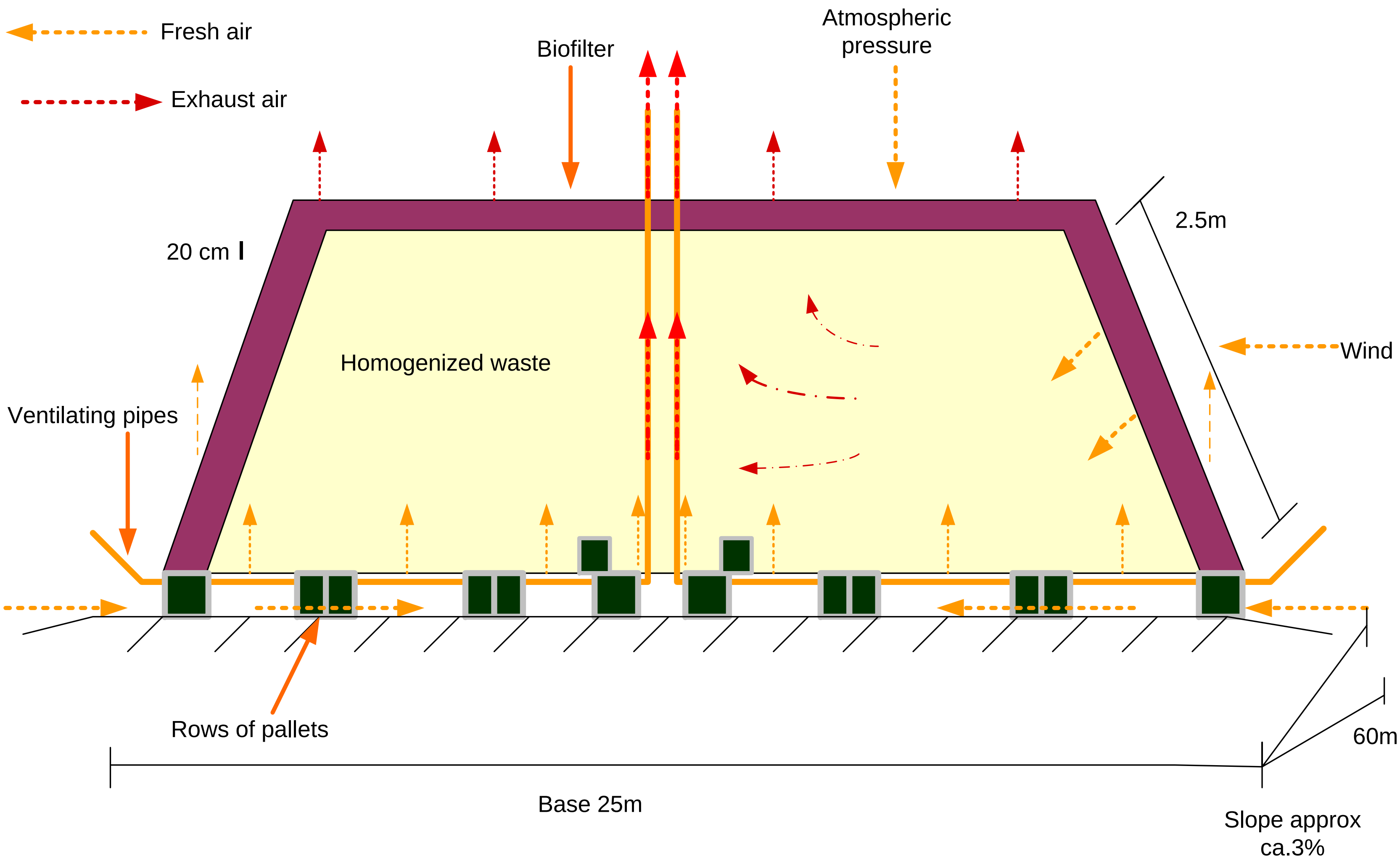


Incoming MSW composition:

Moisture content: 60 -65%

- Plastic content: Avg.: 39% dry wt.
  Range: 26-55% dry wt.

Natural-draft (convection) Biotreatment windrow - extensive aerobic decomposition



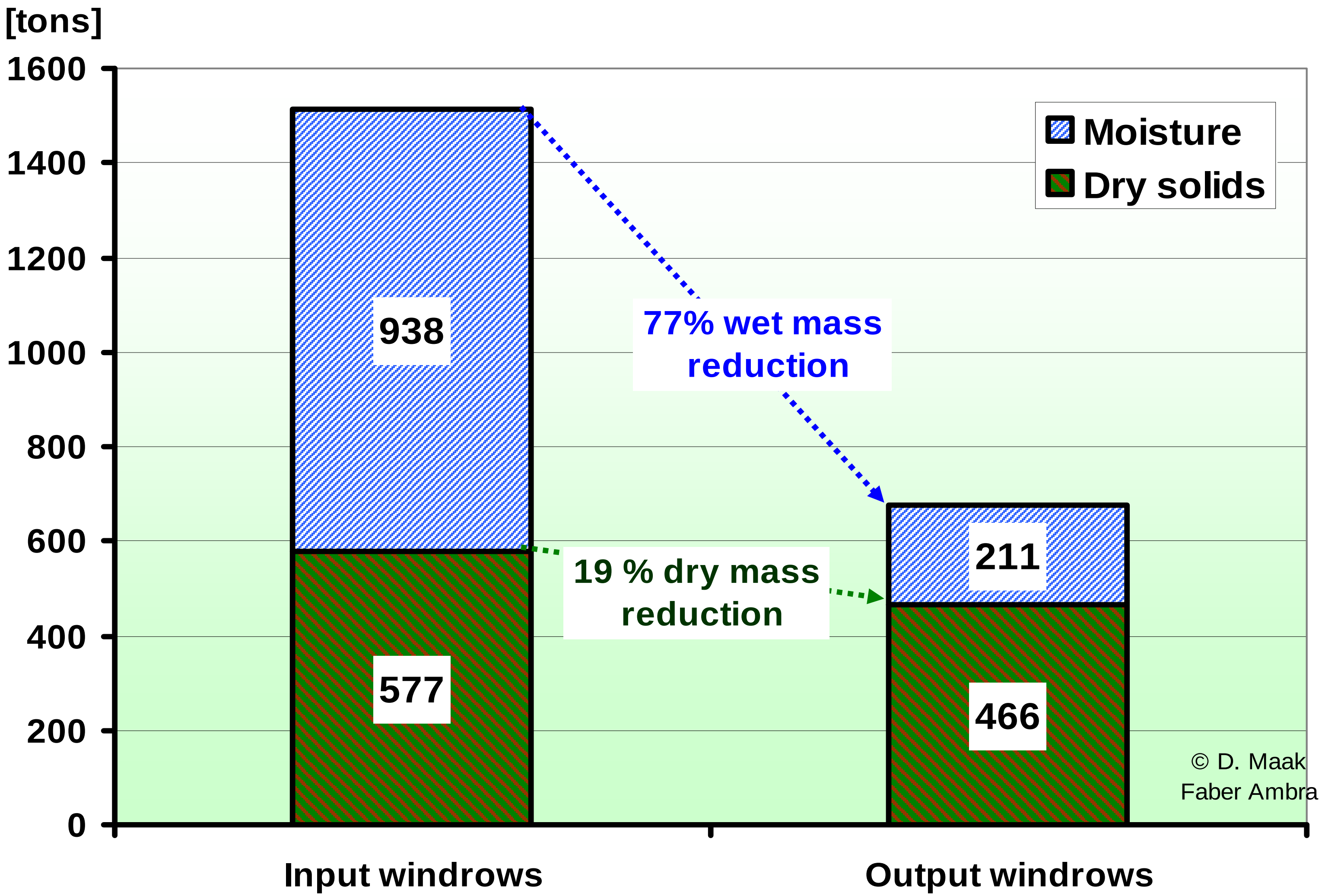
Homogenizing drum at work in Phitsanulok

Waste from Phitsanulok
before and after homogenization

Coconut-shell biofilter at the Phitsanulok MBPT facility

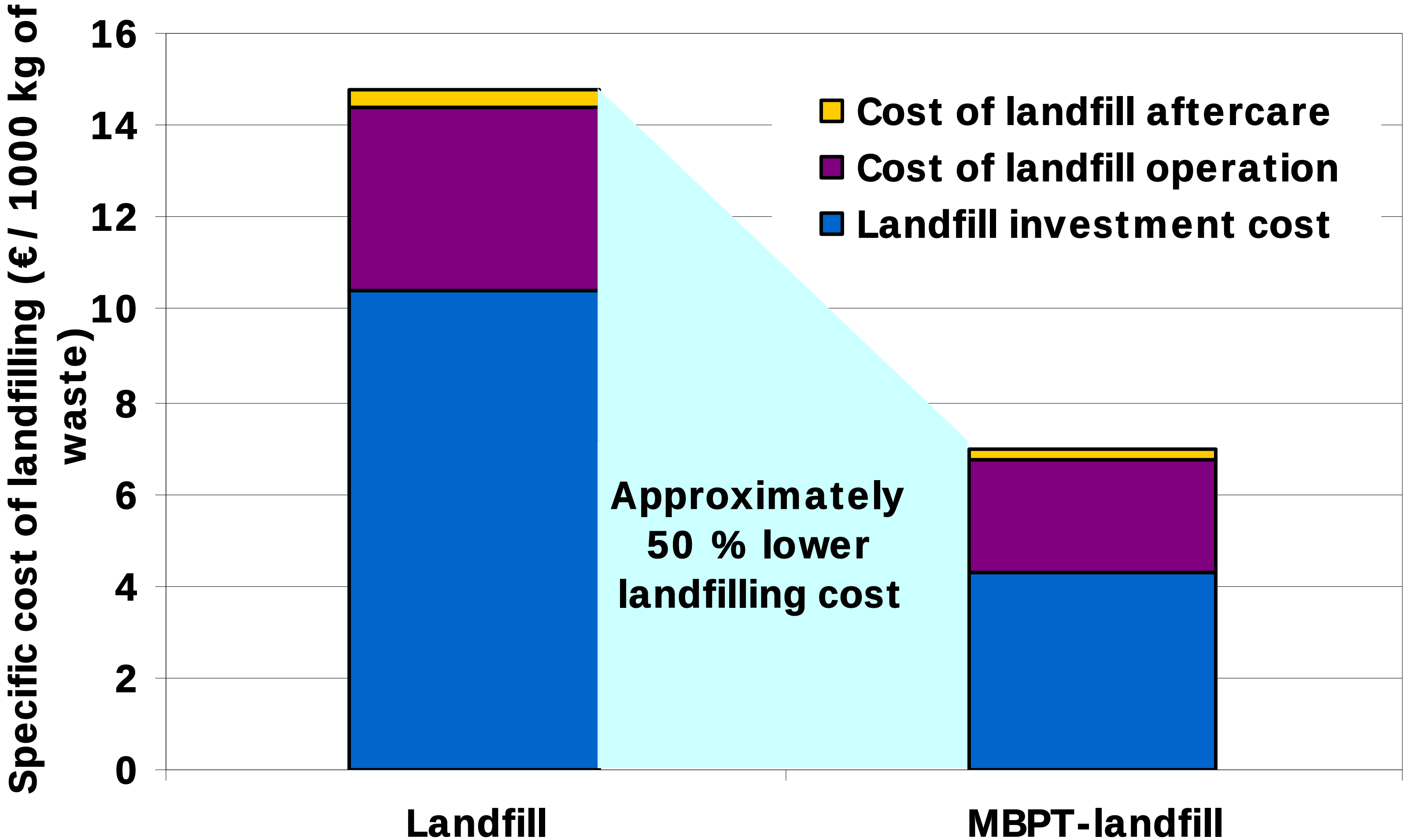
Static Pile Windrow Composting

Mass Reduction by Composting



Economies of MBPT

pretreatment reduces the specific landfilling costs by some 50 %.



Comparison of specific landfilling costs in Phitsanulok with and without MBWT (specific costs in €/1000 kg of waste)

CONCLUSIONS

- Need for mechanical material recovery <u>minimum</u> in developing countries due extensive source segregation
- Mechanical process to enhance biological treatment only

- Operation to reduced high organic content most important
- Risk to run into anaerobic conditions high
  - High organic content of waste
  - Low “bulky” waste content
  - High plastic content (bags) cause high compaction and impermeable “cells”
  - Torrential rainfalls aggravate the above mentioned
- Adjustment of operational conditions as well as windrow modifications improve the performance:

- Anaerobic Digestion could be another attractive Alternative

Do Birds need raincoat….. ???
Next time think before you throw your plastic bags….

Thanks for listing…. But now it is time to act……

Visu