Mechanical-biological pre-treatment of municipal solid waste in Asia

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Abstract

The potential of mechanical-biological pre-treatment (MBP) technology was recognized in Asian countries. The processes involves concur with the needed treatment for the waste quality and environmental conditions in developing economies. The high organic fraction and moisture content of solid waste were potential for MBP. This technology extensively enhanced waste stabilization and provides various advantages. Tropical weather with alternation of an arid and humid/rainy season may affect the biological treatment systems particularly the open pit-windrow composting. However, improved optimization measures may overcome such limitations. Nevertheless, anaerobic digestion is another treatment option that can be considered. The significant results from the MBP process in the presented case studies seemed to be stimulating towards sustainability because of significant pollutant load reduction while recycling/converting the waste into resources. Mechanical treatment processes conditions the waste for the subsequent biological treatment. Aerobic composting and anaerobic digestion were among the biological pre-treatment processes. Thus, MBP system conserves and preserves both the resources and environment; it will be the prevailing system in the near future in Asia.

Keywords

Municipal solid waste, pre-treatment, anaerobic digestion, composting

1 Introduction

In most Asian countries, the rapid shift of living habits in concurrence with the accelerated development in industrialization and population growth, significantly influence the quantity and quality of solid waste generation. This issue was aggravating due to limited public awareness, inadequate technology and waste management grasp, and lack of financial support. The uncontrolled generation of municipal solid waste (MSW) constitutes a serious dilemma in urban areas of most developing countries in Asia. The open dump approach, a prevalent disposal system, creates considerable environmental, health, and safety hazards. The most economical and widely practiced alternative for the elimination of MSW is sanitary landfilling. However, leachate and biogas are produced due to uncontrolled degradation of bio-fraction contained in the waste.

Generally, MSW stream in most Asian countries is highly biodegradable. Direct landfilling of waste without prior treatment is not environmentally-friendly approach. Various potential risk and hazards associated with landfills in connection with uncontrolled decomposition of waste causes the emergence of harmful pollutants that may agglomerate and affect the state of the environment. Such impacts include emissions of landfill gas that contributes global warming effect; generation of leachate that constitute toxic effects on water environment; depleting land resources; aesthetic and health nuisance; and the risk associated with landfill stability. These issues established the need for solid waste treatment system prior to landfill disposal. The MBP can play a part for the extraction of recyclable waste materials e.g. recovery of plastics that are not accessible prior to the composting process and can be thereafter used to generate RDF. In this view, the waste can be handled and managed in sustainable approach; similarly, the environment and potential resources are conserved most. The objective of this paper is to illustrate the potential of MBP as a MSW treatment technology under Asian settings. Similarly, the success in pilot scale MBP are presented in case studies further signifies the suitability of this treatment in Asia.

2 Potential factors for mechanical-biological pre-treatment in Asia

2.1 Waste composition

The solid waste composition in Asia and Pacific region is almost comparable. Mostly, it constitutes high biodegradable fraction of more than 50% (Table 1). Moreover, VISVANATHAN ET AL. (2004) described that the MSW stream in most Asian countries is dominated by organic portion composed of food wastes, yard wastes, and mixed paper. The biodegradable portion of the waste mainly remained in the waste stream. Table 2 represents the moisture content of solid waste from selected cities in Thailand and India. The average moisture content is relatively high, that is greater than or equal to 50%. In this regard, waste is not suitable for incineration because it requires high-energy input to bring the waste to its ignition level. Nevertheless, landfilling of such waste creates nuisance owing to the generation of highly concentrated leachate, methane gas emission, and quick settlement of waste due to decomposition that eventually affects the stability of landfill. The best disposal solution for this type of waste is the mechanical-biological pre-treatment system. Mechanical treatment enhances and conditions waste characteristics for biological processes. Waste materials potential for recuperation includes mainly paper products, and different types of plastics, little glass, and metals can be recovered through mechanical processes. However, mechanical processing isn't the main objective, moreover simple aerobic composting and anaerobic digestion is the biological treatment options to overcome the high organic fraction and moisture content of waste.

Table 1: Typical average waste characteristics in selected urban settings in Asia

Waste Categories (average percentage 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)

Table 2: Typical average moisture content of municipal solid waste

Municipality	**Moisture (%)**
In Thailand	
Hat Yai	57
Chonburi	59
Pathumthani	49
Samutprakarn	65
Pattaya	70
In India	
Kolkata	40-45

2.2 Depleting land resources, landfill operation, and performance

Landfilling is considered to be the most cost-effective method of solid waste disposal in developing countries if adequate sites are available. Significant problem with landfills is simply due to their large numbers, the expanse of valuable area they occupy, and the landfill criteria which are mounting with the urban population growth and increased waste generation. The existing landfill sites are nearly exhausted and new landfill sites are hardly available because of shortage of utilizable land.

The MBP or simple composting (not for the production of quality compost) has been suggested as a feasible option for improving the landfill performance in the tropical region (TRANKLER ET AL., 2004). The effect of mechanical-biological pre-treated waste in the landfill behavior can be illustrated by the result of experiments in the landfill simulation reactors (lysimeter). Landfill lysimeter simulations conducted by KURUPARAN ET AL. (2003) showed that the pre-treated landfill (composted waste) had a minimum COD and TKN loads of 25-fold and 5-fold respectively, compared to the untreated MSW in landfills. LEIKAM and STEGMANN (1999) also observed a similar trend in mechanical-biologically pre-treated waste in pilot scale lysimeters. They found a 10-fold reduction in BOD concentration and 5-fold reduction in TKN between the non-treated and pre-treated waste. Also, MBP 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 would significantly reduce.

2.3 Climatic conditions

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 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 (TRANKLER ET AL., 2001). The influence of warm climate on landfill performance is complex which is leading to the increase of leachate production after precipitation and is generally quite rapid (LEMA ET AL., 1998). However, if the waste is subjected to pre-treatment process; such potential emissions are avoidable, since the MBP-waste is a stabilized waste residue of which polluting materials have been reduced significantly. Thus, the effect of local climatic variations in landfill performance has been recognized and this fact resulted to consider the value of mechanical-biological treatment of MSW prior to landfill disposal.

3. Mechanical-biological pre-treatment technology

The objective of mechanical pre-treatment is to condition the waste to provide optimum waste characteristics for biological pre-treatment. According to SOYEZ and PLICKERT (2002), the biological pre-treatment step includes aerobic rotting, anaerobic fermentation or combined processes. Aerobic systems are in widespread use which includes windrows with or without aeration, containers or boxes, drums, or tunnels; biological processes promote waste stabilization with significant mass and volume reduction that conserves landfill space. The integration of MBP and landfilling of MSW makes the operation, maintenance, design, and economics of the landfill feasible and will be a useful technology especially for the Asian regional setting. In addition, the aftercare period require a simple operation for emission/effluent monitoring and control.

Figure 1 represents the general approach in dealing the MSW stream in Asia for MBP. Generally, after mechanical treatment operation, the waste is subject to biological process for waste treatment and resources recovery. MBP provides various important advantages, it includes: significant landfill volume/area reduction up to 40%, conserving land resources, and reducing the cost of landfilling; biodegradability of waste is reduced and stability of waste is increased, thereby reducing significant emissions from landfills; potential hazardous waste contaminants in the waste stream will not reach municipal landfill sites due to extensive waste sorting stage prior to treatment; recycling, reusing and recovering of waste materials will be maximized due to mechanical sorting; and other related nuisances can be prevented while improving landfill stability.

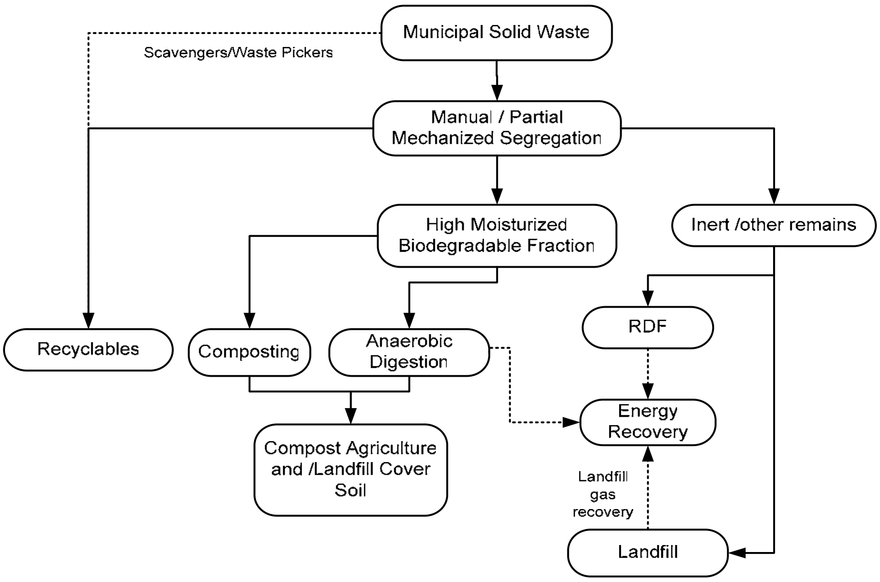

Figure 1: General approach for mechanical-biological pre-treatment process

Mechanical treatment which includes waste sorting, homogenization combined with crushing and followed by a biological treatment of windrow composting under full-scale trials and dry weather conditions were determined by GTZ (2003). The wet weight and LOI of both input and output waste were determined to evaluate the treatment performance in terms of organic matter reduction. The result indicates a significant wet and dry mass reduction of 53% and 19%, respectively (Fig. 2). Nevertheless, the waste compaction offered by windrows alone after degradation is already above the commonly achieved density values and a further mechanical compaction improved more the wet density by almost 50% of that windrow alone (Fig. 3).

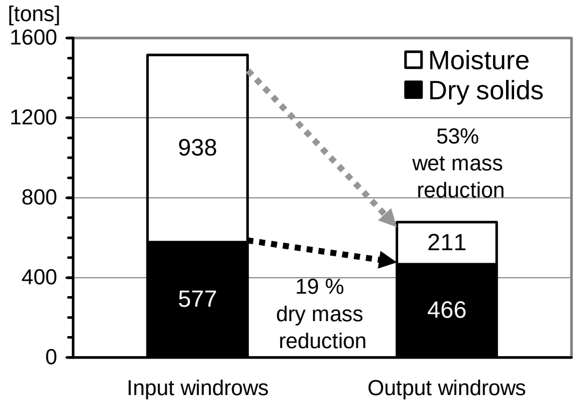

Figure 2: Wet and dry mass reduction (GTZ)

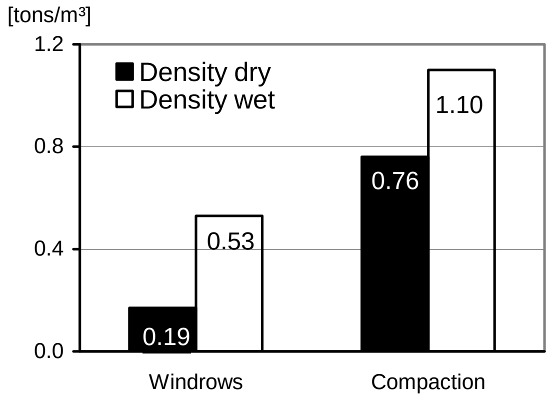

Figure 3: Improved compaction (GTZ)

4. Mechanical-biological pre-treatment pilot projects: Asian case studies

4.1 MBP in Phitsanulok, Thailand

The suitability of mechanical-biological waste treatment under FABER-AMBRA® process in Phitsanulok Municipal Landfill was commenced in 2001. The purpose of this experiment was to demonstrate the applicability of the said process to treat solid waste of high moisture content and high organic fraction that contain large amounts of plastics. Moreover, the technology intends to clarify the extent of high rates of precipitation during the rainy season that would cause problems with the open-air decomposing heaps. This project was conducted in cooperation with the City of Phitsanulok with the support of the Technical Cooperation project (Thai-German Solid Waste Management Programme for Phitsanulok).

The incoming MSW composition is mainly consist of organic fraction (44%) and plastics (29.8%) with high moisture content (62%) (TRANKLER ET AL., 2002). The waste is subjected to the process that involves coarse sorting, homogenization, followed by windrow composting. Given the composition of the waste and the climatic conditions, the first few windrows were found to be suffering a lack of oxygen supply. This was attributed to inadequate reinforcement and profiling of the bio-treatment areas, coupled with insufficient load-carrying capacity of the base course pallets. This gave rise to numerous optimizing measures designed to improve the supply of oxygen to the heaps. The results of subsequent tests confirmed that the decomposition process is proceeding satisfactorily (GTZ, 2003). The process adaptation is being monitored by an extensive temperature profiling and gas composition measurements. Since the project is still in its pilot phase, no ultimate throughput targets are being achieved yet. However, TRANKLER ET AL. (2002) who conducted a comparative case study for emission potential model for a period of 20 years was based on available on-site data. Figure 4 and 5 illustrates the variation of COD and NH_4-N between the pre-treated and non-processed MSW. During the first year of operation, the leachate's pollution load can most likely be diminished by 85% and 70% for COD and nitrogen compounds, respectively. Pre-treatment could minimize carbon and nitrogen loads to a large extent in future landfilling activities.

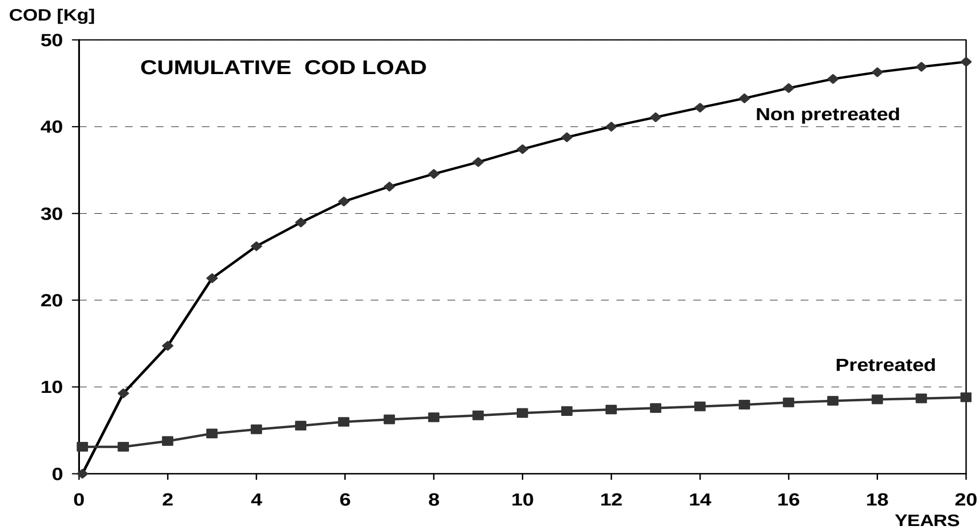

Figure 4: Cumulative COD load between the non- and pre-treated wastes

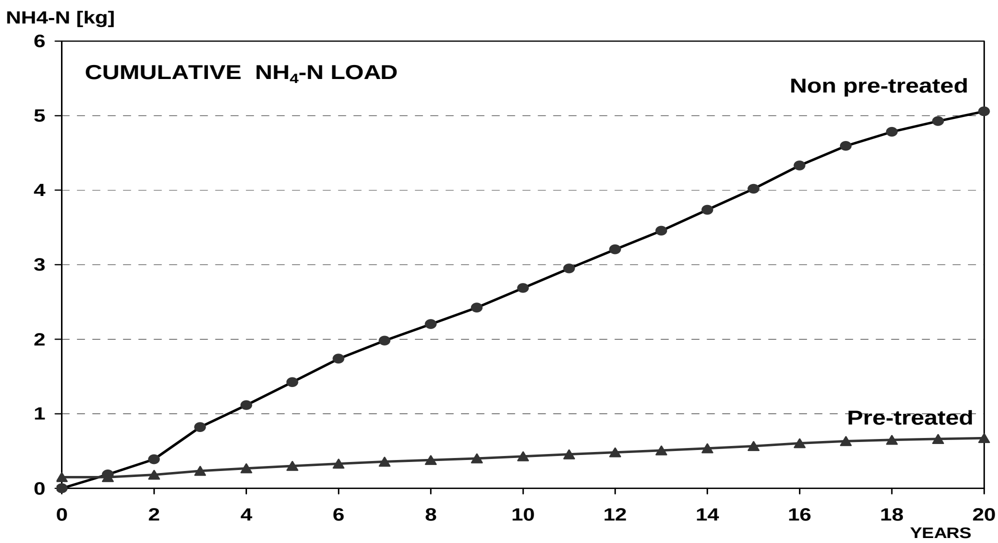

Figure 5: Cumulative NH_4-N load between the non- and pre-treated wastes

4.2 Rayong waste to energy and fertilizer project, Thailand

The increasing problem in solid waste management in Rayong municipality, Thailand end to a successful project that integrates waste management approach: recycling, reusing, anaerobic fermenting, generating fertilizer and energy. The Rayong waste to energy and fertilizer plant uses MSW, food-vegetable and fruit waste (FVFW), and night soil waste (NSW) as waste materials. The plant operation consists of Front-end treatment (FET) process, anaerobic digestion process, and Back-end Treatment (Figure 6). The collected MSW are weighed and unloaded on FET plant and conveyed to subsequent mechanical equipments such as the bag opener, drum screen, and magnetic separator. The collected FVFW directly loaded into the feed hopper after weighing. The delivered NSW is pumped into the feed preparation tank. The feed substrate is kept homogenous with the agitator and is semi-continuous pumped into the bioreactor. The anaerobic bioreactor is designed as a wet-continuous and completely mixed single-stage digestion process under mesophilic condition. The waste solid content is adjusted to about 15% prior feeding into the bioreactor. The minimum retention time of the substrate is 18 days in the bioreactor to ensure the conversion of organic material to biogas. Biogas yields at full designed load is around 2,207,392 m^3/year with 65% methane content that produce electricity and heat of about 5,062 and 3,172 MWh/year (at efficiency of 38.6 and 22.7 %), respectively. The digestate is led to the buffer storage tank then it is dewatered by a mechanical dryer. The rejected water from dewatering is led into the process water tank. The mechanically dewatered humus mass is transferred to the thermal dryer chamber for pathogen kill. The dried humus is conveyed to the fertilizer handling and packing area. The success of this project is achieved through the community willingness along with the support and cooperation from NGOs and government agencies.

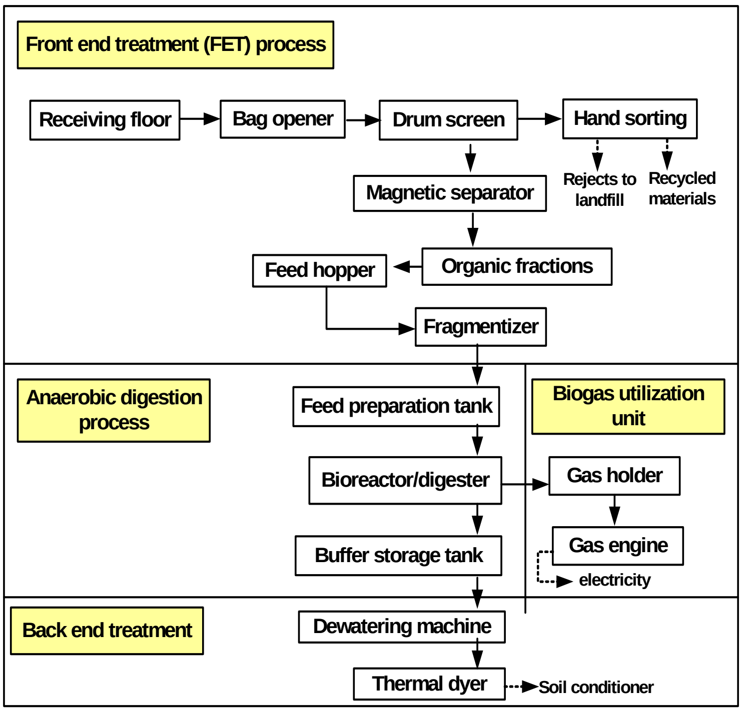

Figure 6: Process facilities

4.3 AIT pilot project: Dry anaerobic digestion of organic fraction of MSW

The Asian Institute of Technology (AIT) in Thailand is an international postgraduate institution that engaged with various research studies towards the betterment of environmental conditions for many years. MBP project that consist of waste sorting and size reduction prior to biological anaerobic digestion method was regarded as an attractive method for waste stabilization as a treatment technology prior to landfill. The process involves optimizing anaerobic digestion which aims to maximize the organic waste conversion into biogas at short digestion period. This pilot scale treatment performed a thermophilic dry-batch anaerobic digestion technology in two concepts: (1) combined anaerobic digestion which involves enhanced pre-stage leaching with microaeration and incoculum seeding during methane phase and (2) sequential staging concept (first cycle) that involves leachate cross-recirculation between the mature and new reactor.

The results showed that the combined anaerobic digestion after pre-stage operation removes 40% of organic carbon matter from the substrates into the flushed leachate. After 50 days of operation, the organic degradation process efficiency of 70% was achieved with 66% and 44% of mass and volume reduction, respectively. Nevertheless, leachate cross-recirculation between the old and new reactors directly without conducting pre-stage operation further optimizes the overall digestion process. The results showed that the sequential staging concept offers an improved process over the combined anaerobic digestion. Figure 7 and 8 represent waste stabilization in which an improved mass and volume reduction was achieved. Nevertheless, higher methane yield of 334 L CH_4/kg VS with 86% VS reduction which is equivalent to 84% process efficiency was obtained (JUANGA, 2005).

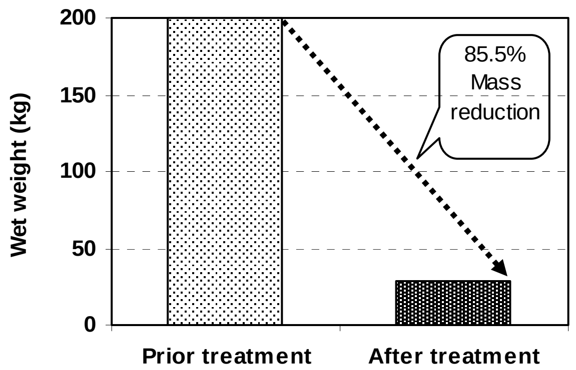

Figure 7: Mass reduction after MBP: anaerobic digestion (sequential staging)

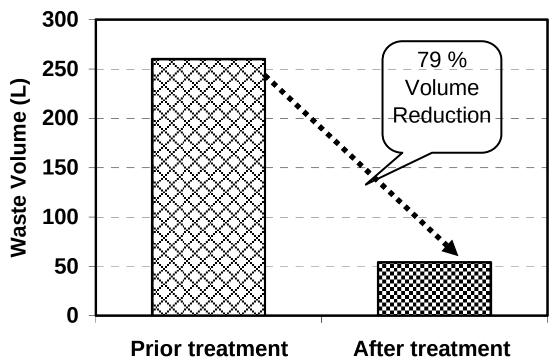

Figure 8: Volume reduction after MBP: anaerobic digestion (sequential staging)

5. Conclusion

The Mechanical-biological pre-treatment is an established technology for the treatment of municipal solid waste prior to landfill disposal. The extensive waste segregation during mechanical treatment recovered the utilizable materials. The subsequent biological process recycles the organic portion of waste into compost, fertilizer, or landfill soil cover, and biogas production for energy generation. This is an appropriate pre-treatment process in Asian countries because of its waste composition and characteristics. The primary aim of mechanical-biological pre-treatment is the optimum waste stabilization with the reduction of landfill leachate and gaseous emissions while generating valuable by-products. Therefore, a mechanical treatment prior to biological process enhances the overall operation and offer benefits that support the concept of sustainability. Aerobic composting and anaerobic digestion were the recognized biological treatment systems. An open-pit windrow composting was found some feedback limitations in tropical countries during rainy season. However, with significant optimization process, such limitations can be successfully overcome. Anaerobic digestion was seemed to be more attractive in treating the waste in which a significant mass and volume reduction of 85.5% and 79% respectively was achieved under anaerobic treatment. Detailed analysis and evaluation between these two systems could be beneficial towards the MBP improvement. Continued investigations to further improve the pre-treatment performance and to minimize the remaining environmental impacts should be considered.

6. Acknowledgement

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Mechanical Biological Pre-treatment of Municipal Solid Waste in Asia

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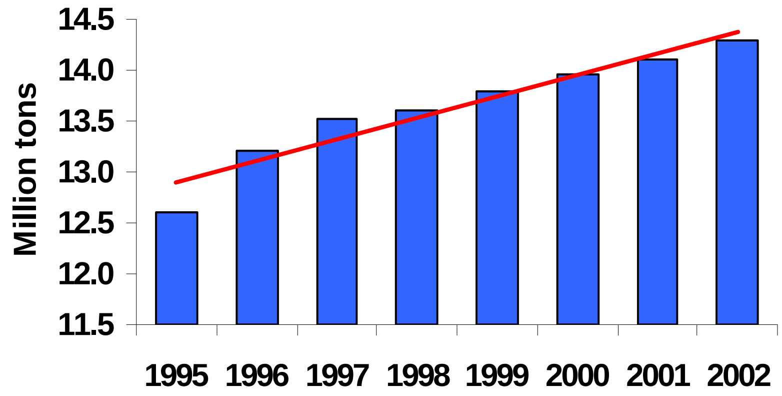
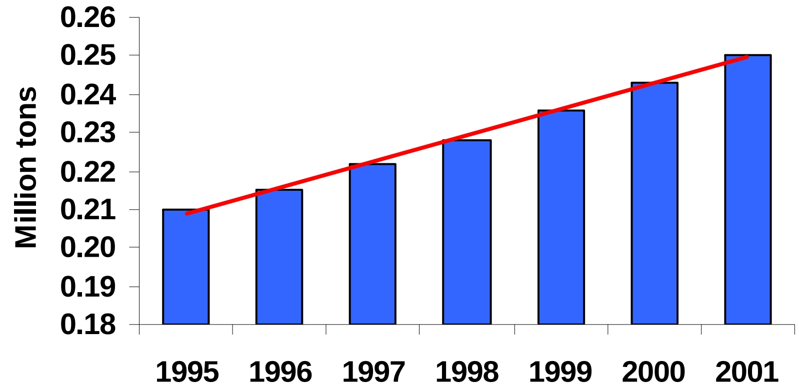
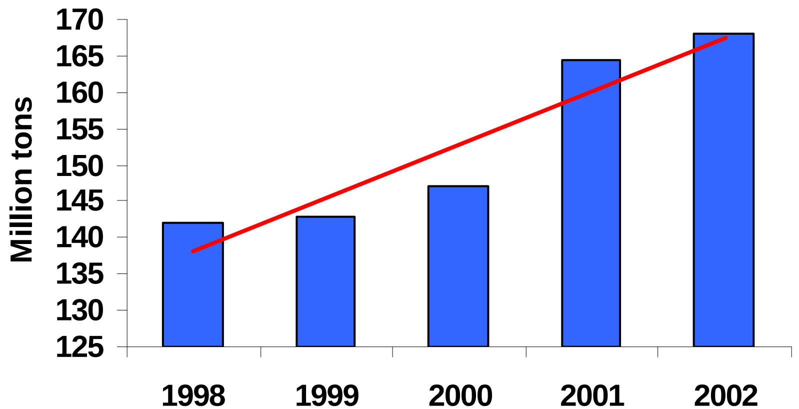
MSW generation in Asia



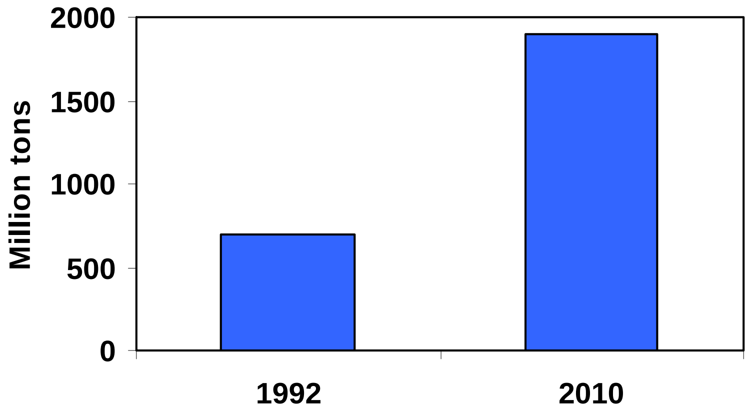
MSW generation in Thailand



MSW generation in Colombo, Sri Lanka

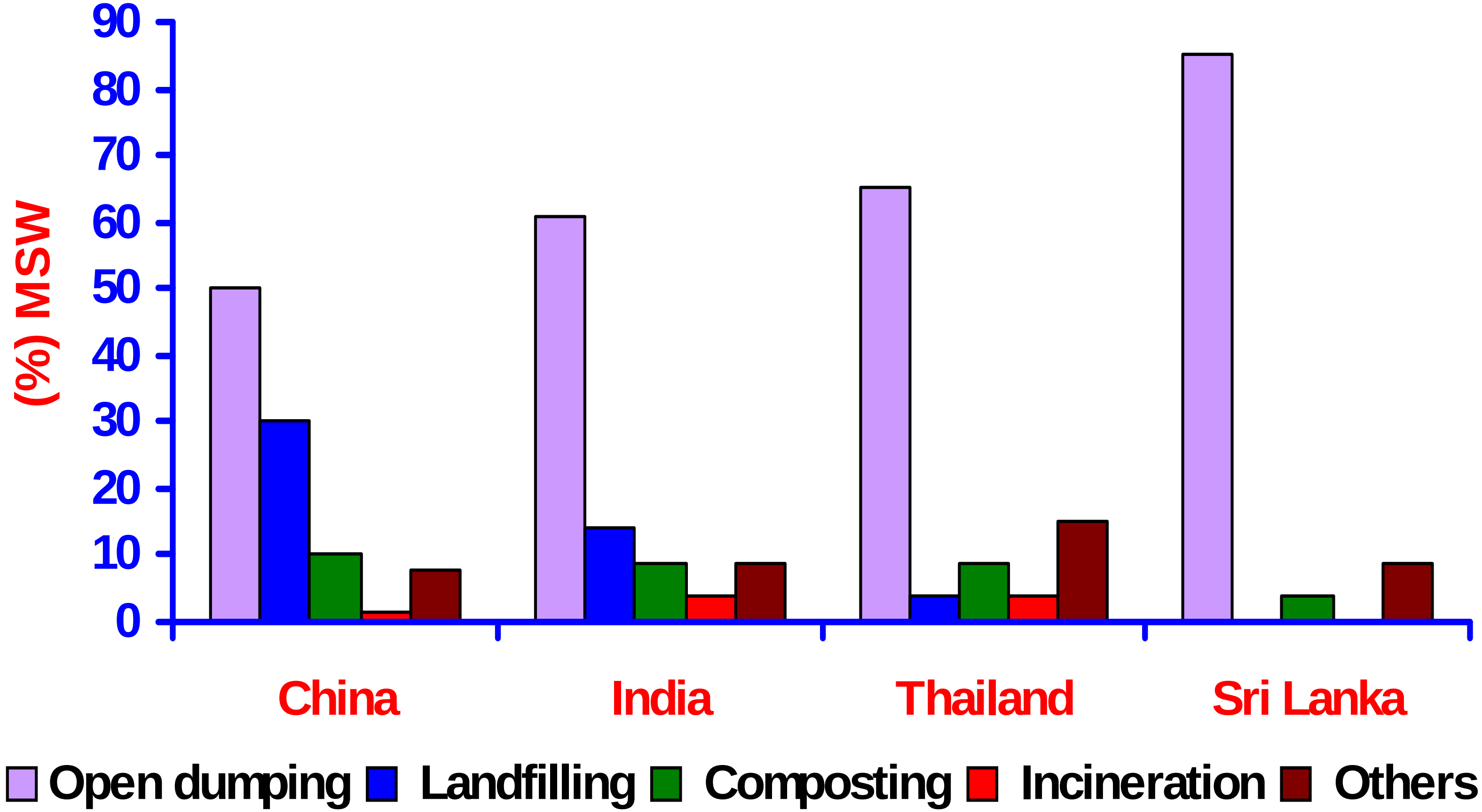


MSW generation in China



Municipal solid waste in Asia (ESCAP 1995)

MSW disposal methods practiced in some Asian countries



Open dumpsites in Asia


Gohagoda dump site (Sri Lanka)


Chennai dumpsite (India)


Shanghai dumpsite (P.R. China)


Dump site (Thailand)

Characteristics of open dumps in Asia

Unplanned heaps and uncovered waste

Uncontrolled leachate generation

Susceptible to burning

Animals infestations

Waste pickers/scavengers

Potential factors towards sustainable landfilling

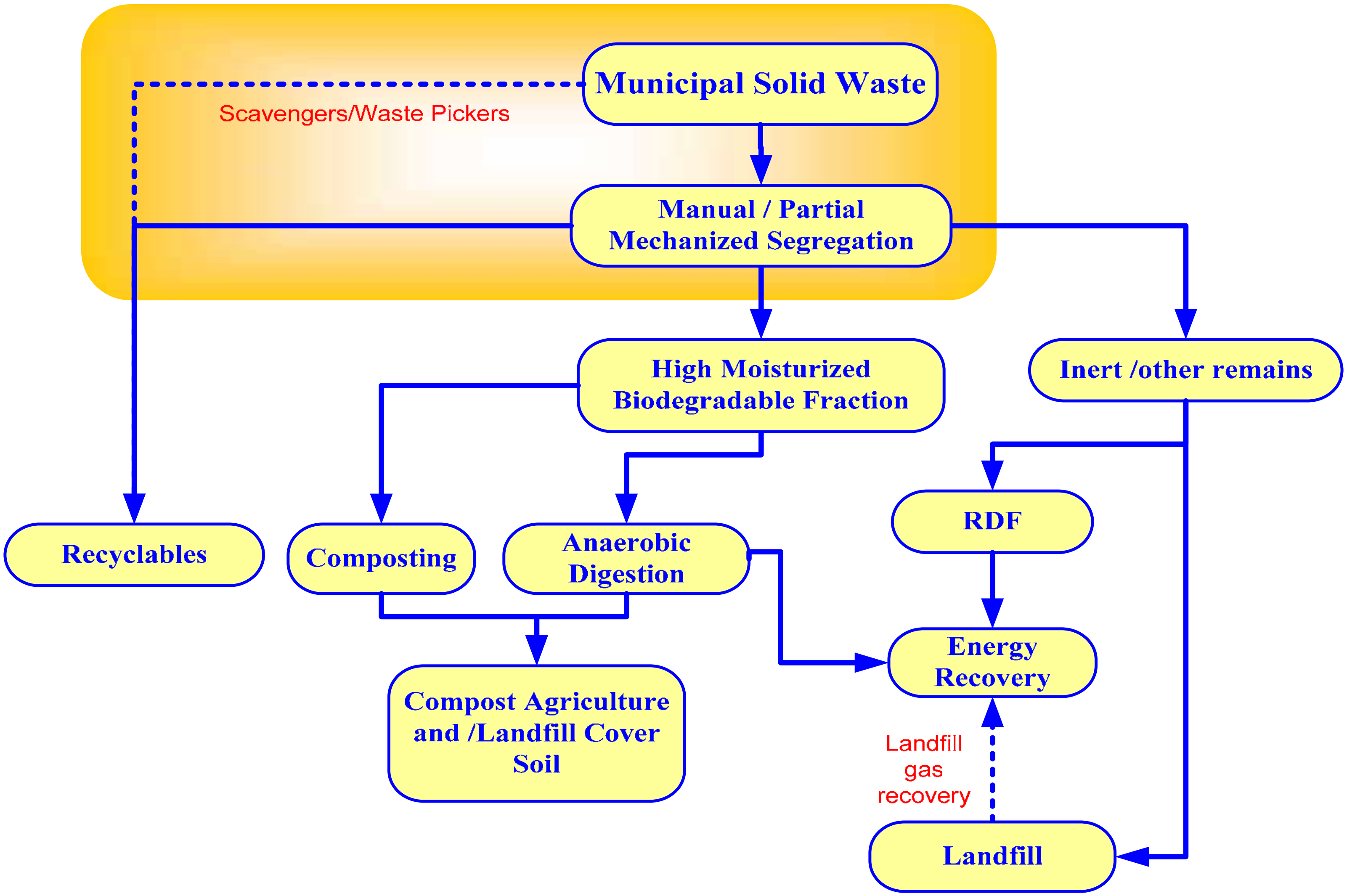
- Open dumpsites is gradually phased out in many Asian countries and replaced by sanitary landfills due to recognized negative impacts, however....
- Climatic condition. Alternation of an arid and humid seasons affects landfill performance
- Landfill sites are nearly exhausted and new areas are hardly available for landfilling because of shortage of utilizable land
- MSW in Asia is highly biodegradable with high moisture content

Mechanical biological treatment of MSW prior to landfill is an appropriate technology in Asia

Significance of MBP technology

- Mechanical pre-treatment conditions the waste to provide optimum waste characteristics for biological pre-treatment
- Biological processes promote waste stabilization with significant mass and volume reduction, conserves landfill space, reduce greenhouse gas, and reduce leachate pollutant load and generation
- Integration of MBP and landfilling of MSW makes the operation, maintenance, design, and economics of the landfill feasible
- Aftercare period require a simple operation for emission/effluent monitoring and control

General approach of MBP in Asia



Mechanical-biological pre-treatment pilot projects: Asian case studies

I. MBP in Phitsanulok, Thailand

Project objective: to demonstrate the applicability of FABER-AMBRA® process to treat solid waste with high moisture content, high organic fraction, and contain large amounts of plastics.

This project was conducted in cooperation with the City of Phitsanulok with the support of the Technical Cooperation project (Thai-German Solid Waste Management Programme for Phitsanulok).

Phitsanulok (experimental) landfill site

MBP in Phitsanulok, Thailand

Incoming MSW → **Coarse sorting** → **Homogenization**

44% Organic fraction

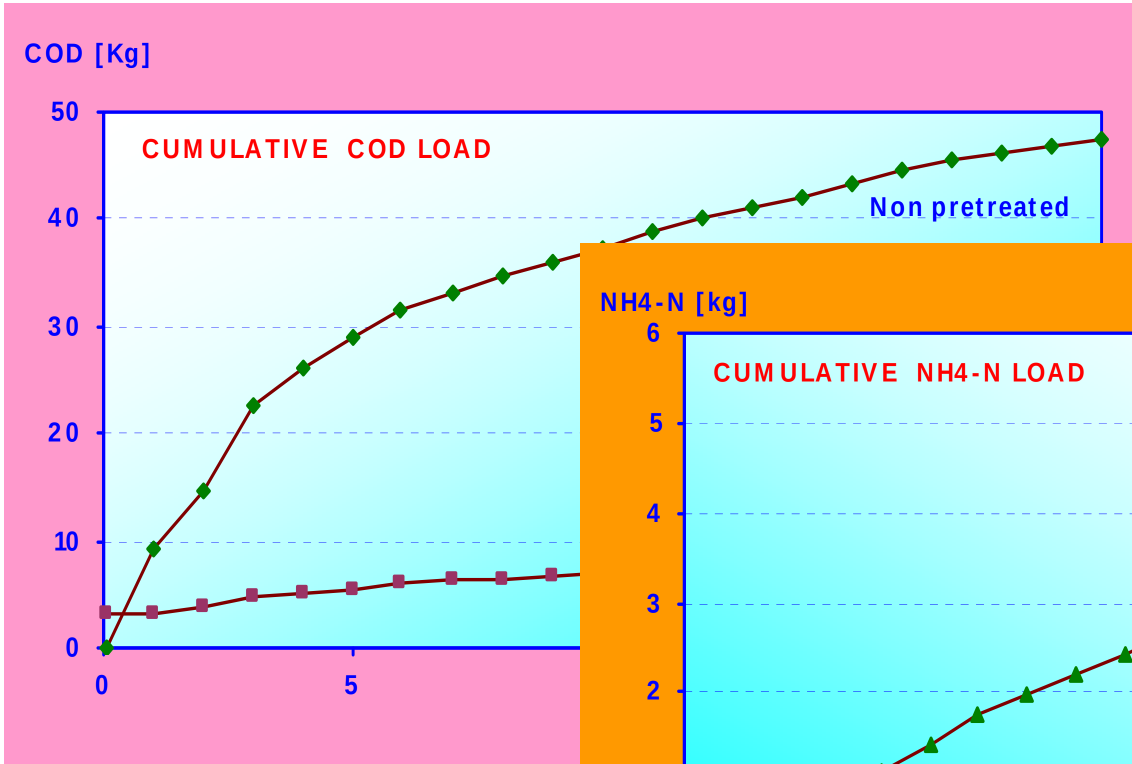
29.8% Plastics

62% Moisture content

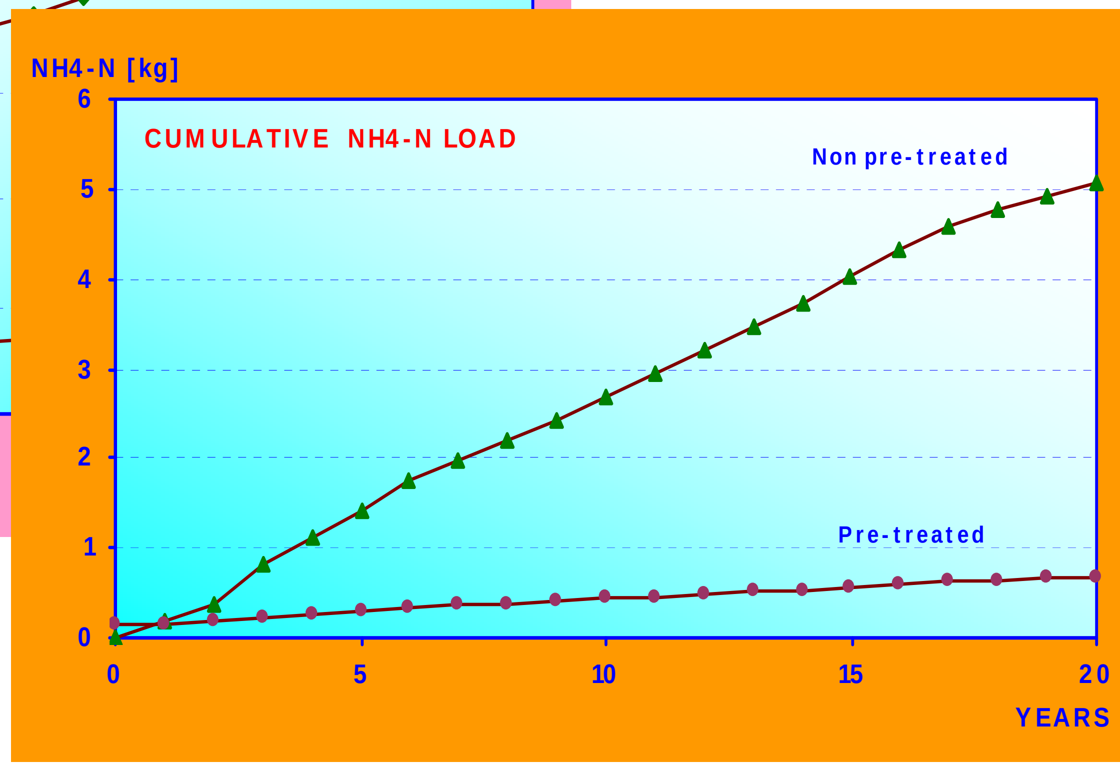
→ **Windrow Composting**

Emplacement trial for pretreated waste at the Phitsanulok landfill

Forecasted NH_4-N load in leachate between non- and pre-treated waste



Predicted reduction
~ 70 %



Predicted reduction
~ 85 %

II. Waste to energy and fertilizer project (Rayong, Thailand)

Project objective: production of electricity while the by-product (digestate) is to be used as soil conditioner or fertilizer.

Plant capacity: 25,500 tons of biowaste annually and may produce 5,800 tons of soil conditioner and 3,826 MWh surplus of electricity.

Waste to energy and fertilizer project (Rayong, Thailand)

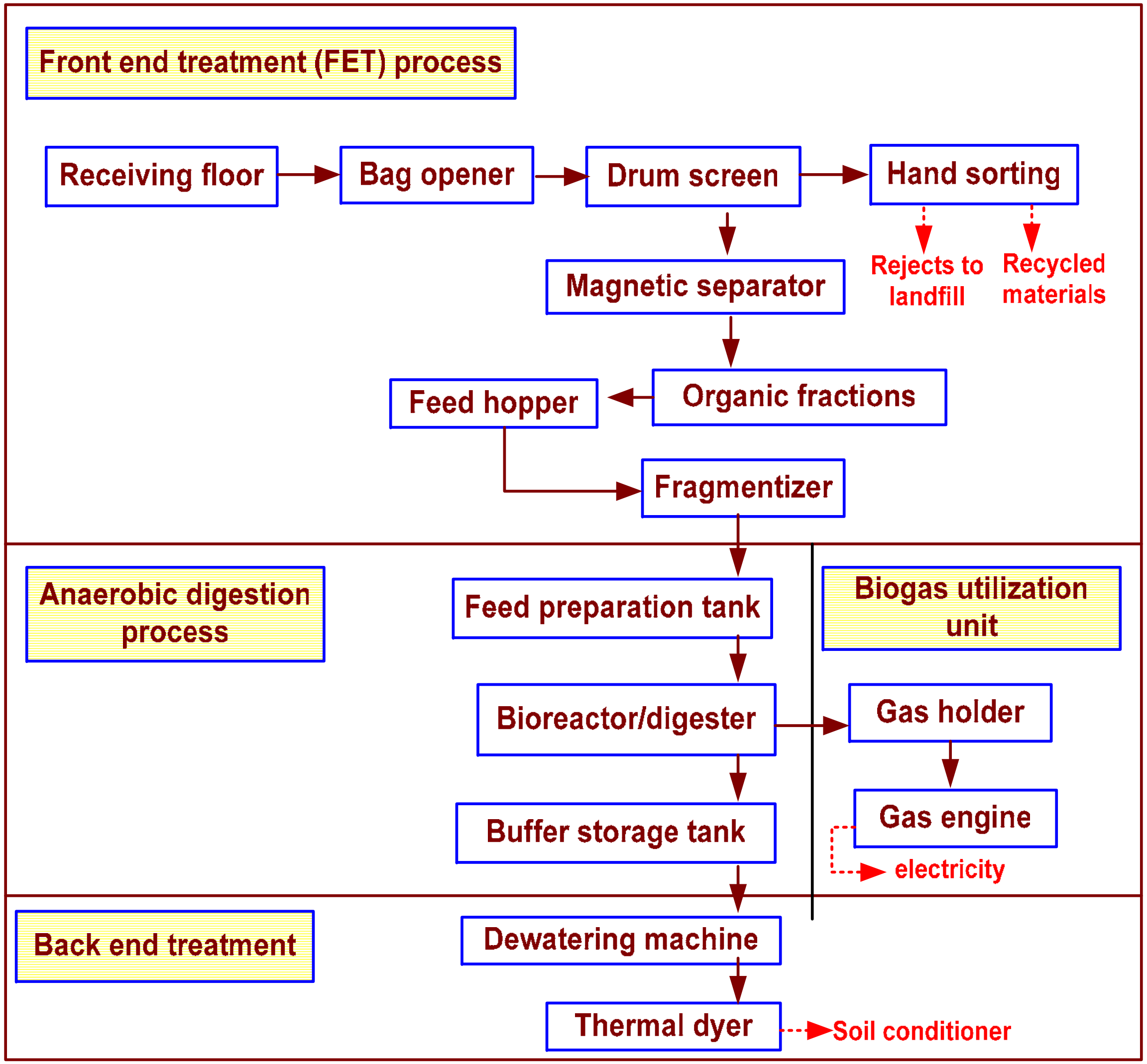
Waste Materials: MSW, fruit vegetable & fruit waste (FVFW), & night soil waste (NSW)

AD design & capacity: 74 tons/day (60 tons of sorted MSW & FVFW, & 14 tons of NSW

AD process: wet continuous, single-stage, completely-mixed digestion

Reaction temperature: mesophilic

Feed substrate: slurry form (15% TS)



Waste to energy and fertilizer project (Rayong, Thailand)

Front-end treatment area

Anaerobic digester

Gas holder

Gas engine

AIT pilot project: Dry anaerobic digestion organic fraction of MSW

Feedstock preparation


Segregated waste


Waste shredding


Weighing waste


Waste and bamboo cutlets


Reactor's loading

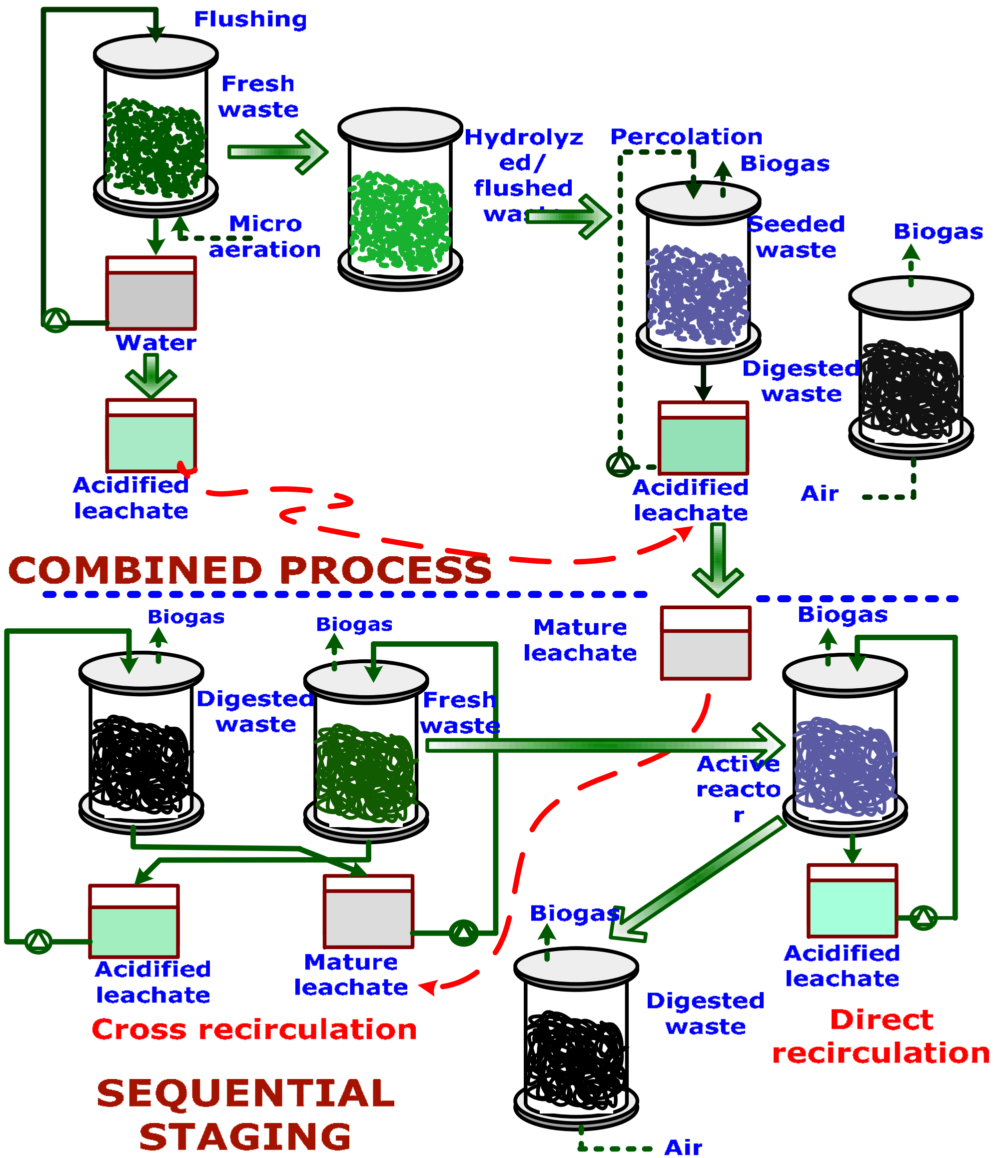
Anaerobic digestion system

Temperature controller

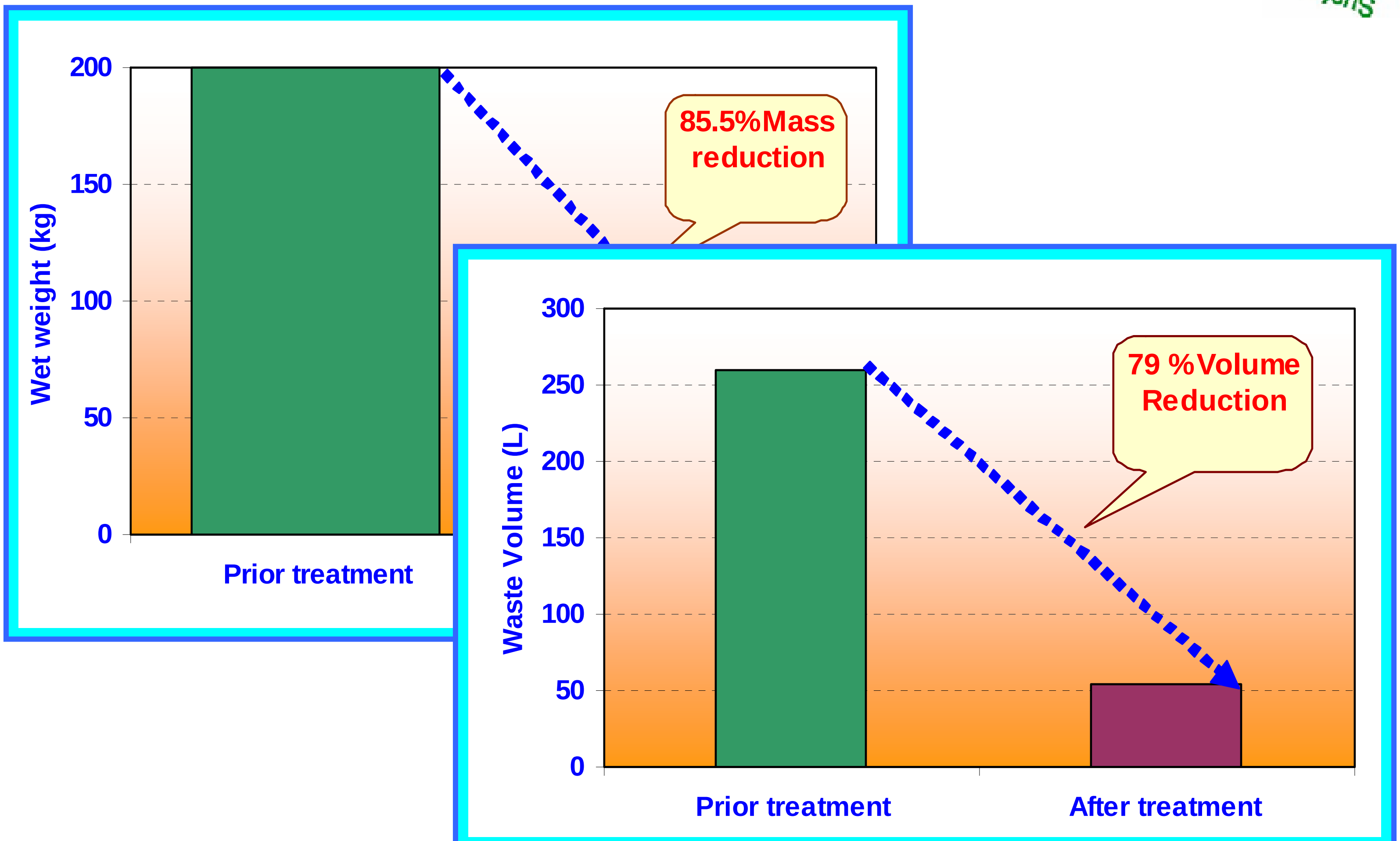
Peristaltic pump & Drum type gas meter

Air flow meter

Anaerobic digestion process



Waste stabilization efficiency in sequential staging anaerobic digestion process



Methane yield of 334 L CH4/kg VS with 86% VS reduction which is equivalent to 84% process efficiency was obtained

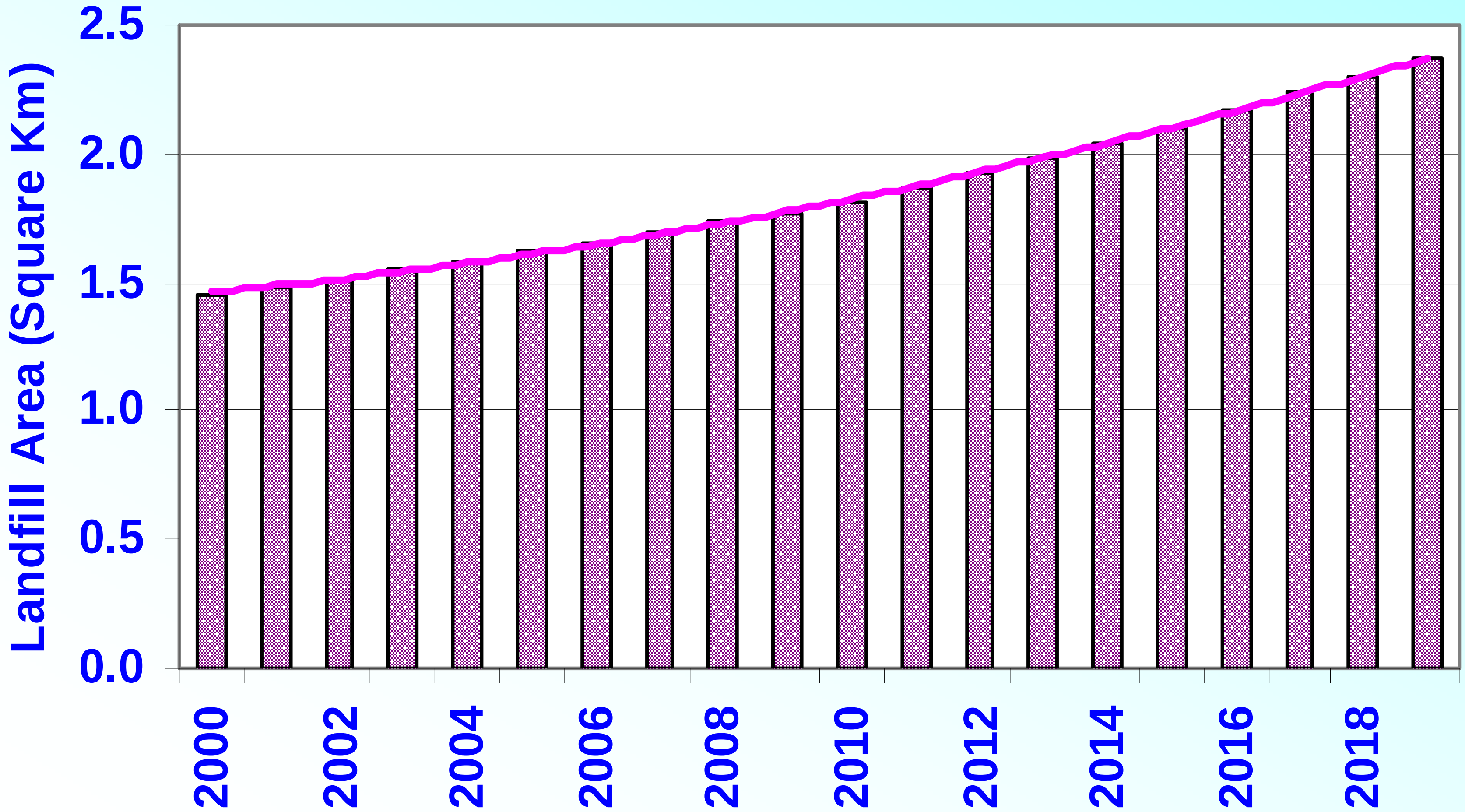
Conclusions

- The need for mechanical process is minimum in Asian developing countries due to extensive waste segregation (waste pickers/scavengers)
- Mechanical process conditions the waste and enhances biological treatment
- An open-pit windrow composting was found some feedback limitations in tropical countries during rainy season. However, with significant optimization process, such limitations can be successfully overcome
- High-solids anaerobic digestion in sequential staging batch process was found as attractive method in treating the waste with optimum waste stabilization
- Continued investigations to further improve the pre-treatment performance and to minimize the remaining environmental impacts should be considered

Sanitary landfill? Engineered landfill? In Thailand

Climatic influence to landfills in Asia

Forecast of land requirement for disposal: BMA



Waste characteristics in selected urban settings in Asia

Waste Categories (average percentage wet weight)							
City	Bio-degradables	Paper	Plastic	Glass	Metals	Textiles & leather	Inerts
Indonesia	**74**	10	8	2	2	2	2
Dhaka	**70**	4.3	4.7	0.3	0.1	4.6	16
Kathmandu	**68**	8.8	11.4	1.6	0.9	3.9	5.3
Bangkok	**53**	9	19	3	1	7	8
Hanoi	**50**	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

Municipality	Moisture (%)
In Thailand	
Hat Yai	57
Chonburi	59
Samutprakarn	65
Pattaya	70
In India	
Kolkata	40-45